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THE SECOND WORLD WAR

1939–1945

ROYAL AIR FORCE

SIGNALS

VOLUME IV

RADAR IN RAID REPORTING

ISSUED BY THE AIR MINISTRY (A.H.B.)

1950

A.P.
[redacted] 1063

THE SECOND WORLD WAR
1939–1945
ROYAL AIR FORCE

SIGNALS

VOLUME IV

RADAR IN RAID REPORTING

Promulgated for the information and guidance of all concerned.

By Command of the Air Council,

J. H. Barnes.

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ISSUED BY THE AIR MINISTRY (A.H.B.)
1950

Preface

THE 1939–45 War was the first in which a scientific and co-ordinated raid reporting and fighter control organisation was employed in air battles. The essential requirements of this air defence scheme were the provision of some method of detection whereby early warning of hostile raids could be obtained, a communications system over which the early warning reports were passed to suitable centres from which intercepting aircraft could be controlled, a means of distinguishing friendly from enemy aircraft, and the use of suitable devices carried in the aircraft whereby interception was aided. The foundations of this Royal Air Force system were based on Signals facilities, being dependent on radar devices and on ground and air telecommunications. A comprehensive narrative of Signals in air defence during the Second World War is too extensive to be included within the confines of one book. This Volume is therefore concerned only with the first of the essential air defence requirements, namely, the method of detection by means of which efficient raid reporting was possible.

The method of detection employed was known as " Radar "[1], a system which was to revolutionise the art of raid reporting during the War. The secret research in radar before hostilities broke out made a most important contribution to the preparedness of this country to face aggression—thanks to the foresight of scientists and Royal Air Force officers who had developed this radiolocation system. This narrative, therefore, begins at a time (1935) when the whole question of air defence was being reviewed and the first proposal for radio detection was made. After describing the scientific background, the introductory chapters continue the story to the point where a practical radio warning system was emerging and Royal Air Force Signals personnel were beginning to take over radar duties from research scientists. From that point onwards, the field of application of raid reporting radar in the Service expanded rapidly and became world-wide as the War progressed.

The story has been written in some detail, since radio detection was a novel principle in the military field and played a great and ever-increasing role throughout the War. From the original demonstration of the radar principle in the United Kingdom on 26 February 1935, a lead was established so that Britain, and later her Allies, maintained a supremacy over the enemy in the radar field. The importance of this cannot be emphasised too fully, as radar, more than any other single development since the aeroplane, changed the face of warfare by blunting the edge of one of the greatest weapons in war, namely, surprise.

Although radar was developed originally as the basis for defence against air attack and it is that aspect which is discussed in this volume, ultimately defending fighter aircraft were controlled directly from special radar stations.

[1] The detection system was originally known as " R.D.F." It was renamed " Radar " in September 1943 to conform with United States terminology and thus avoid technical and administrative difficulties between the Allies. Throughout the Royal Air Force Signals War Historical Monographs the name current at the time under consideration has been adhered to as far as possible. A further term introduced for general use was " Radiolocation " —when the existence of R.D.F. was disclosed to the public on 18 June 1941 by a statement in the House of Commons.

The growth of fighter control radar stations is dealt with elsewhere.[1] Nevertheless, eventually many radar stations, particularly in overseas theatres of war, had a dual function, being responsible for both early warning and fighter control. As a consequence, the fighter control aspect of these stations after 1942 is discussed in this volume as well as their raid reporting functions.

Finally, the metamorphosis of ground search radar operational technique, from a network of dispersed ground stations (reporting to an operational control centre) to a master control radar station which combined all the functions of early warning and fighter control in a centralised form, is dealt with in the closing chapters of this volume. Perhaps it is at this stage that the most valuable lessons are to be learned for the future employment of the radar " eyes " of our land, sea and air forces.

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[1] Volume V, " Fighter Control and Interception."

RADAR IN RAID REPORTING

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CHAPTER 1

THE CONCEPTION OF R.D.F. RAID REPORTING, 1935

In 1934, before experiments into radio detection of aircraft were authorised by the Air Staff, little work was being done on technical devices to assist in air defence. The only development in hand was Sound Location (Acoustic Mirrors), which seemed to have reached a stage where further improvement in operation was problematical. Judged by modern standards, sources of air raid warning, communications, and Operations Rooms were all of a primitive nature. The period of warning from the Observer Corps and the accuracy of prediction of the movements of hostile aircraft were inadequate. The time-lag in raid reporting and the increasing speed of aircraft made it imperative that some means should be devised for providing earlier warning.

Formation of Committee for Scientific Survey of Air Defence (C.S.S.A.D.)

On 12 November 1934, the Director of Scientific Research (D.S.R.), Air Ministry (Mr. H. E. Wimperis), drew attention to the difficulties of defence against hostile aircraft in view of the higher speed of aircraft, higher ceilings, less noisy engines, and the ability to fly with automatic pilot in cloud and fog.[1] He suggested that a committee under the chairmanship of Mr. H. T. Tizard, the Chairman of the Aeronautical Research Committee, might be set up in order to intensify research into new defence measures, such as the development of a ray of energy capable of nullifying engine ignition or capable of detonating bombs ; also to determine the effect of this radiation on the human body, or on the metal fuselage or wings of aircraft. He advocated that scientific surveys in these and other means of defence at that time untried might open up some such visionary channels for exploration. Mr. Wimperis suggested that members of the committee should include Professor A. V. Hill, Professor of Biology at University College, London, and Professor P. M. S. Blackett.

The suggestion was made to the Air Member for Research and Development, (Air Marshal Sir Hugh Dowding), the Chief of Air Staff (Air Chief Marshal Sir Edward L. Ellington), and the Secretary of State for Air (The Marquess of Londonderry), who all approved the formation of such a committee with the widest terms of reference to cover all possible developments, namely :—

> "To consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defence against hostile aircraft."

The constitution of this Committee for Scientific Survey of Air Defence was as follows :—

Chairman	Mr. H. T. Tizard.
Members	Professor A. V. Hill.
	Professor P. M. S. Blackett.
	Mr. H. E. Wimperis.
Secretary	Mr. A. P. Rowe.

The Air Defence Sub-Committee of the Committee of Imperial Defence

At about this time, but independently of the proposals for the C.S.S.A.D., air defence was being discussed by Members of Parliament and it was decided to set up an Air Defence Sub-Committee of the Committee of Imperial Defence

[1] Air Ministry File S.34763, Minute 2.

under the chairmanship of Sir Philip Cunliffe-Lister (later Viscount Swinton) to co-ordinate all Air Defence development at an inter-Service and inter-Department level.[1] Mr. Tizard was a member of this committee, and his own committee (the C.S.S.A.D.) reported to the Committee of Imperial Defence (C.I.D.) through its Air Defence Sub-Committee.

Mr. R. A. Watson Watt's Original Proposal on Radio Detection

In January 1935 Mr. H. E. Wimperis consulted Mr. R. A. Watson Watt, then Superintendent of the Radio Department of the National Physical Laboratory, on the possibility of using electromagnetic radiation to damage aircraft or aircrew. As a result of this informal approach, within two weeks Mr. Watson Watt, with the collaboration of one of his colleagues, Mr. A. F. Wilkins, produced a note showing that the quantity of energy required was far too great to be provided by any known method. Having established the impracticability of radiation for destructive purposes, Mr. Watson Watt added a comment that certain researches on which he had been engaged might be of great assistance in the problem of the detection and location of aircraft by radio.

The researches to which he referred had been carried out to investigate the properties of the ionosphere—a conducting region in the upper atmosphere having great influence on the long-range propagation of radio waves. For some ten years before 1935, scientists had been carrying out investigations and much effort had been and was being devoted to methods of determining the height of this region. In one method a short pulse of radio waves was sent out from a transmitter and on reaching the ionosphere was reflected and picked up by a receiver. By measuring the time taken by the pulse to travel to and from the region, the latter's height could be determined, since the speed of radio waves was known. The time taken was a minute fraction of a second so that normal mechanical timing devices were entirely inadequate for its measurement. A cathode-ray oscillograph was therefore used. In this instrument a beam of electrons was made to produce a spot of light on a fluorescent screen. The spot was moved uniformly across the screen by electrical means and both the transmitted pulse and the pulse received after " reflection " were made to deflect the spot downwards. The distance between these two deflections was thus proportional to height of the ionosphere. In practice, a regular succession of pulses was sent out and the horizontal traverse of the spot was synchronised so that the beginning of the horizontal trace was simultaneous with the emission of the transmitted pulse. The whole process was repeated at such a speed that persistence of vision made the path of the spot appear as a horizontal straight line with a kink corresponding to the received pulse ; the distance of this kink from the beginning of the line gave a measure of the height of the conducting region.

It was in work of this nature—though not exclusively so—that Mr. Watson Watt had been engaged, and it occurred to him that the same method could be used for the detection of aircraft, the aircraft taking the place of the " reflecting " region and its distance being found in the same manner as the height of the ionosphere.

These views were put to the Committee for Scientific Survey of Air Defence at its first meeting on 28 January 1935. The committee was agreed that " the problem of defence was largely one of detection of the positions of enemy

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[1] Ministry of Aircraft Production, S.R.I. Folder.

aircraft" and asked Mr. Watson Watt to act on the ideas he had put forward.[1] An immediate recommendation was made to the Air Member for Research and Development by the C.S.S.A.D. that a suitable scientific staff from the National Physical Laboratory should be seconded to the Air Ministry for experiments to begin at once. The cost of the necessary apparatus was expected to be about £4,000 and it was proposed that Treasury authority should be requested for the National Physical Laboratory to assist with the experiments, at a cost not to exceed £10,000 for the first year. Air Marshal Sir Hugh Dowding, the Air Member for Research and Development, while appreciating the benefits of the system if it proved successful, was rather dubious at asking for immediate authority to spend £10,000 on a purely defensive project in case an offensive device should arise during the early course of the Committee's researches.[2]

First Practical Demonstration of the Radio Detection of an Aircraft

Mr. Watson Watt rapidly produced a plan which he hoped would successfully locate aircraft by a radio echo method, and submitted it as a memorandum to the C.S.S.A.D.[3] Acting on the advice of Air Marshal Sir Hugh Dowding, a demonstration with an aircraft was arranged to take place before Treasury approval was sought for N.P.L. research. This was held on 26 February 1935, primarily to determine whether sufficient electro-magnetic energy would be "reflected" from metal components of an aircraft structure for measurement purposes.[4] No attempt was made to determine the location of the aircraft. The source of continuous wave radiation was the 10 kilowatt Daventry Station beam operating on a frequency of 6,000 kilocycles per second (50 metres). The maximum strength of the beam was at an elevation of 10°, little energy being radiated at zero and at 20° to the horizontal. The beam was wider laterally, the radiation falling to half its maximum value at 30° on either side of the beam.

The receiving apparatus, which had not been specially designed for the test, was erected the night before by Mr. A. F. Wilkins (a Scientific Officer on the staff of the Slough Radio Research Station) at Weedon, Northants, about six miles from Daventry in the direction of the beam. The direct signal from Daventry was recorded as a linear oscillation on a cathode ray oscillograph, appearing as a single line. It was anticipated that reflection of the Daventry radiation from the moving metallic structure of an aircraft would cause phase interference with the direct signal resulting in a fluctuation of the length of the oscillograph line. The frequency of the fluctuations would depend on the position and ground speed of the aircraft and of the wavelength used.

It was arranged that a Heyford aircraft should fly at 6,000 feet to and fro between Daventry and a point 20 miles distant along the lateral centre of the beam. Four runs were made during the time available for the experiment but none of them was directly over the receiver on the ground as intended, although three passed very close. On the three runs easily detectable signals were obtained, the only disturbance being occasional "flicks" caused by atmospherics. On the fourth run, the aircraft was not "seen" and must have been well away from the beam. When the aircraft passed most nearly overhead, the oscillograph line fluctuated between lengths of one half and one and a quarter inches. The maximum range obtained was estimated as being about eight miles.

[1] Air Ministry File S.35290, Minute 2. [2] *Ibid.*, Minute 3.
[3] On account of its historical importance, this memorandum is reproduced in full at Appendix No. 1. [4] Air Ministry File S.35290, Encl. 4A.

The arrangements for the test were not ideal and it was reckoned that 30 times the amplitude could have been obtained with a properly designed fixed receiver instead of the one used. The height and spacing of the aerial had not been accurately designed and the transmitter power was only 10 kilowatts. To obtain good results the wavelength should have been controlled in accordance with the reflective properties of the aircraft, but for the demonstration the wavelength was not under control. Mr. Watson Watt considered that for much of the time during which signals were obtained, the position of the aircraft off its intended track was such that reflection was mainly from the fuselage, for which the wavelength used was unsuitable.

It will be realised that this trial was not a test of the method proposed by Mr. Watson Watt in his memorandum, since continuous wave and not pulse radiation was used; also no range measurements were possible. Rather it was a crude demonstration of the fact that an aircraft would reflect radiation to an observable extent, carried out with apparatus readily available but hurriedly prepared.

In his report the Air Ministry representative at the demonstration said, "It was demonstrated beyond doubt that electro-magnetic energy is reflected from the metal components of an aircraft's structure and that it can be detected. Whether aircraft can be accurately located remains to be shown. No one seeing the demonstration could fail to be hopeful of detecting the existence and approximate bearing of aircraft at ranges far in excess of those given by the 200 feet sound mirrors."[1] The success of the demonstration was reflected in the first report[2] of the Committee for Scientific Survey of Air Defence which stated, "In the circumstances the result was much beyond expectation."

Preliminary Investigation Authorised

In view of the success which attended this demonstration, the Director of Scientific Research advised the Air Member for Research and Development that it provided, in embryo, a new and potent means of detecting the approach of hostile aircraft, one which would be independent of mist, cloud, fog or nightfall, and at the same time be vastly more accurate than present methods in the information provided and in the distances covered.[3] He pictured the existence of a small number or network of transmitting stations which would between them fill the entire sky over the eastern and southern part of England, using a frequency of probably 6 megacycles per second (50 metres wavelength). This radiation would cause every aircraft then in the sky to act as a secondary oscillator (whether it wished to or not) and these secondary oscillations would be received by a number of local receiving stations (equipped with cathode ray oscillographs) dotted around the coast much as acoustical mirrors might have been under the older scheme. These receiving stations would thus obtain continuous records of bearing and altitude of any aircraft flying in the neighbourhood (including those still 50 miles out at sea) and would be able to deduce course and ground speed. He recommended that there was every justification in requesting Treasury authority for the preliminary investigation.

The Orfordness airfield was suggested as being ideally situated for the immediate enquiry. It was secluded, had unused buildings in good condition

[1] Air Ministry File S.35290, Encl. 4A.
[2] A summary of the relevant sections of this report is given at Appendix No. 2.
[3] Air Ministry File S.35290, Minute 9.

that with little expenditure could be utilised as a radio laboratory, and was within easy flying distance from the Aircraft and Armament Experimental Establishment (A. and A.E.E.), at Martlesham. The erection of four 75-feet wooden masts and an additional hut would be needed, and apart from local telephone lines and a suitable power supply, no further work would be necessary to enable Mr. Watson Watt and the National Physical Laboratory staff to commence their research. It was proposed that the programme of work should be carried out under the direction of the Director of Scientific Research, Air Ministry, in association with Mr. Watson Watt and the Air Defence Committee.

Treasury sanction to go ahead with the scheme up to an expenditure of £12,300 in the first year was obtained.[1] This excluded the cost of aircraft required for co-operation in the research programme as the necessary services were to be obtained from the aircraft at Martlesham and other Service stations in the vicinity, flying in the course of their normal duties. Permission was sought from the Committee of the Privy Council for Scientific and Industrial Research for Mr. Watson Watt, together with three Scientific Officers and six assistants, to be seconded to the Air Ministry for work at Orfordness. The Department of Scientific and Industrial Research agreed to arrange for the services of the National Physical Laboratory to be made available for the Air Council, and for members of the Laboratory to work at Orfordness, but they could not agree to seconding members of their staff. This modification was accepted by Air Ministry and arrangements were put in hand for the work to begin as soon as possible. The Chief of the Air Staff had been advised of the plan and wished to be kept informed of the progress made in the experiments.

Choice of Frequency

A frequency of 6 megacycles per second (50 metres) was chosen for the initial experiments, which assumed that the aircraft had a horizontal metal component of its structure of the length of the wing span, responsive to the horizontal component of the electric field.[2] A higher frequency, say 43 megacycles per second (7 metres), would have been an advantage, as for a given range of detection a smaller power would be required. On the other hand, the pulse technique had been more fully developed for a frequency of 6 megacycles per second (50 metres) and determination of azimuth angles was difficult and inaccurate for a frequency of 43 megacycles per second (7 metres). The use of 6 megacycles per second (50 metres) would also secure some degree of secrecy, as the signals radiated would be received in foreign countries, and their nature and place of origin determined. It was reasonable to anticipate that foreign powers would assume such signals were associated merely with ionospheric research, known to be carried out at the Radio Research Station, Slough, and elsewhere.

Development and First Trials of Equipment

While preparations at Orfordness were in progress, Mr. Watson Watt and his staff at the National Physical Laboratory utilised their time in planning a scheme of work, obtaining supplies for a laboratory and workshop, and building an experimental transmitter for a frequency of 6 megacycles per second (50 metres).[3] This transmitter used Naval type N.T. valves and gave a peak

[1] Air Ministry File S.35290, Encl. 34A. [2] C.S.S.A.D. Minute of 6th Meeting.
[3] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

output equivalent to a 20 kilowatt C.W. station. It sent out 50 pulses each second, *i.e.*, it had a pulse recurrence frequency or " p.r.f." of 50. An important factor in the design of the transmitter was the provision for specially brief pulses much shorter than the 100 to 300 microsecond pulses previously used in ionospheric research, the emitted pulse to be of any desired duration between 10 and 50 microseconds.[1] The transmitting aerial, consisting of a single half-wave dipole between the two transmitting towers, was not erected at Orfordness until 31 May, when aerial rigging commenced.

An ionosphere receiver was also installed and tried out, using batteries in the absence of a mains supply.[2] The first echo pulses from the ionosphere were received on 29 May, using temporary receiving aerials and power obtained from a temporary mains supply laid by the N.P.L. scientists themselves.[3] Later, a receiving aerial similar to the transmitting aerial was used. At this early stage, aerial arrangements for height-finding (*i.e.*, the measurement of angle of elevation) had not been provided.

Work to improve receiving gear was proceeding at the N.P.L. at Teddington. The first receiver was unsatisfactory in that it increased by some 100 microseconds the duration of the pulses injected. Two further receivers were therefore developed. Experimental work to reduce the effect of an excessively strong ground ray, and discussions on technique with computation and design work, occupied the greater part of their time after the N.P.L. staff had transferred to Orfordness.

A note on discussions with the staff at Orfordness on 29 and 30 May is of interest in its mention of the special difficulties which Mr. Watson Watt and his colleagues foresaw in obtaining long-range detection of " hedge-hopping " aircraft or of pilotless aircraft at, say, 2,000 feet, and their desire to go to shorter wavelengths to meet these difficulties. The note also contained an assurance that the matter of radio detection aids to anti-aircraft gunnery was being watched.

Results of Preliminary Trials to 31 July 1935

Promising results were obtained from the early practical demonstrations of the equipment. One of the first tests with an aircraft took place during the visit of the Sub-committee for the Scientific Survey of Air Defence on 15 June 1935, and was made under very unsatisfactory conditions. Not only was interference from other signals very heavy but there were thunderstorms in the neighbourhood which increased the receiver background noise considerably. In spite of this, however, it was possible to see echoes occasionally from the test aircraft, a Valencia aircraft flying at 15,000 feet in the most favourable direction for the aerials. A curve connecting range and time on the basis of the pilot's log was drawn at the conclusion of the test, and it was found that the few observed echoes were in good agreement with the log. A further test for the Committee was carried out early the following morning when it was thought that the interference would have subsided, but no better results were obtained.

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[1] Narrator's Interview with Mr. A. F. Wilkins, O.R.S., H.Q.F.C.

[2] The names of the N.P.L. party of scientists who arrived at Orfordness on 13 May 1935 to instal the technical apparatus and commence development of the technique were Messrs. Bainbridge-Bell and A. F. Wilkins, Dr. E. G. Bowen (Scientific Officers), Mr. J. E. Airey (Assistant II), Mr. G. A. Willis (Assistant III).

[3] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

On 16 July, a further demonstration was given to the Secretary of the Committee, who stated when summarising the results that it "would be difficult to exaggerate to the Committee the advance made in this short interval." During the demonstration a Bristol Type 120 aircraft was flown from Orfordness to Bircham Newton and back; the maximum height reached was 15,000 feet.[1] The frequency used was 12 megacycles per second (25 metres). On the outward run, to about 25 miles, the amplification was reduced to give a straight line datum, *i.e.*, there was no disturbance from interference or atmospherics. Up to this distance of 25 miles the aircraft response was obvious at a mere glance. The amplification was then increased and the datum line was disturbed; the aircraft response was, to the "untrained eye" of Mr. Rowe, quite definite until a range of 33 miles was reached. Mr. Watson Watt continued to record ranges up to 43 miles, at times which were subsequently confirmed by the dead reckoning record.

On the return run, Mr. Watson Watt detected the aircraft at 38 miles after it had been lost for about ten minutes; the response was obvious to Mr. Rowe at about 32 miles. Severe interference from morse signals was occasionally experienced, but at ranges less than 25 miles the aircraft response was obvious when the amplification was reduced to eliminate the morse signals. Accurate ranges were recorded to a minimum distance of 5 miles, below which ranges could then not be given with any accuracy. When the Bristol aircraft turned so that it presented its fuselage as a horizontal dipole, no response was observed.

In addition to the pre-arranged run with the Bristol aircraft, responses were observed from many other aircraft. On one occasion Mr. Watson Watt detected an unknown aircraft at 33 miles; the aircraft decreased its range from Orfordness and the characteristic aircraft response was obvious to Mr. Rowe at about 27 miles.

Performance Figures

In a report[2] on the work at Orfordness up to the end of July 1935, after only two months' research, the following performance figures were given as "obtained with a transmitter capable of some improvement, a receiver capable of considerable improvement, and an aerial system capable of very great improvement":—

(*a*) Maximum range to which a known aircraft has been followed	42 miles.
(*b*) Maximum range at which a known aircraft has been detected	39 miles.
(*c*) Maximum range at which an unknown aircraft has been detected	33 miles.
(*d*) Maximum range at which an unknown formation has been detected and diagnosed as a formation.. ..	25 miles.
(*e*) Maximum angle of elevation (neglecting curvature) to which a known aircraft has been followed	0° 40′.

Owing to interference from commercial radio signals, which was very heavy on the 6 megacycles per second frequency (50 metres) especially with the use of 75 feet masts, experiments were begun on about 11·5 megacycles per second (26 metres). It was found that this change in frequency also cured

[1] M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.   [2] Air Ministry File S.34763, Encl. 63A.

bad interference (Z-echoes), caused by reflection from the middle atmosphere, which had been causing signals on the oscillograph on 6 megacycles per second frequency; these spurious signals were usually negligible on the higher frequency. This interference was specially noticeable during 18 July when two thunderstorms separated by a few hours passed over Orfordness. During observations on 11·5 megacycles per second, Z-echoes appeared only while the thunderstorm was nearly overhead and disappeared when the storm passed away. A change to 6 megacycles per second during the storm showed exceptionally intense Z-echoes over the whole region 12 to 100 kilometres in height.

The main transmitter had been improved considerably and ran normally at 100 kilowatts rating on the new frequency of 11·5 megacycles per second. Design of a transmitter of twice this power was in hand and an experimental transmitter had been constructed and tested for a frequency of 37·5 megacycles per second. Receiver development was in hand under Mr. Bainbridge-Bell at the N.P.L., and two new wide-band receivers, one for use on 11·5 megacycles and one for 37·5 megacycles per second frequency, were nearing completion. The existing receiver had been modified for use on 37·5, 11·5 and 6 megacycles per second.

The following scientists were working the whole time at Orfordness: Mr. A. F. Wilkins, on transmitter and receiving aerial development and experiments on height measurement; and Dr. E. G. Bowen, on transmitter development.

Short Title for Radio Detection of Aircraft

The problem of a name for this system of detection of aircraft which would not immediately indicate the method of operation was solved by the initials "R.D.F.", a compression of the initials "R.D." for Radio Detection and "D/F".[1] This was intentionally misleading since, at the time, the problem of Direction Finding was receiving little attention.

Probable Service Applications of R.D.F.

From the research work carried out at Orfordness, the following five distinct uses for R.D.F. appeared probable:—[2]

(*a*) Long-range detection for the guidance of the R.A.F. interceptor fighter aircraft.

(*b*) Short-range detection and location, for the use of Army searchlights and anti-aircraft guns.

(*c*) Long-range detection apparatus for installation on board Naval vessels.

(*d*) Short-range detection for guidance of searchlights and anti-aircraft guns at Naval dockyards.

(*e*) Long-range detection of sea-going vessels for the information of the Navy.

Proposals for Improved Performance

Mr. Watson Watt, who had been spending some 50 per cent. of his time on radio detection development, mainly at Orfordness, stated that it was unlikely that any further substantial improvement could be effected on 11·5 megacycles

[1] Air Ministry File S.35982, Minute 4.

[2] *Ibid.*, Encl. 1A.

frequency (26 metres) until higher aerial towers of the order of 200 feet were available instead of the 75-foot masts employed.[1] It was thought that with no changes in the apparatus other than provision of mastheads 250 feet above sea-level on which convenient aerial arrays could be carried, an improvement of the order of two to one in range and the extension of operations to notably lower angles of elevation would be achieved. The vulnerability to interference by other radio signals, which was inherent in the 11·5 megacycles per second system (on 75-foot masts) could be very greatly reduced, without change of frequency, by the provision of the higher masts. Some of these improvements were dependent only on height above sea-level, so that high ground was advantageous ; some, on the other hand, were dependent on height above the ground at the mast-bases. A site for the erection of two 200-foot towers for the transmitter at Orfordness was agreed with the Officer Commanding, Aircraft and Armament Experimental Establishment, Martlesham Heath, with a conditional site for two more to be erected later if necessary, and it was recommended that sanction should be given for the erection of the first two towers.

It was also the view of Mr. Watson Watt that experience with two receiving stations at the ends of a moderate base-line was an urgent necessity before the planning of a chain of stations could be attempted, and it was thought that a great deal could be learnt by the use of the receiving station then operating at Orfordness, together with a separate receiving station some five to ten miles away. The need to develop a method whereby one range and one bearing could both be obtained from the same receiving site was also apparent.

There was no site at Orfordness for the suggested additional receiver development station but it was known that the coast at Bawdsey about ten miles south of Orfordness was 50 feet above sea-level. The acquisition of Bawdsey Manor at the mouth of the Deben River was suggested for a central radio laboratory.[2] The estate had some half-mile of 50-foot high coast-line and ample land and buildings for workshops, laboratories, and would provide living and messing facilities for the research staff.

First Proposals for an R.D.F. Chain

In a first forecast of the requirements of an R.D.F. network, Mr. Watson Watt had stated that it appeared probable that the ultimate network would be composed of equally spaced transmitters with receiving stations midway between transmitters. The receiving stations would have composite installations such that with one main long-range array and one direction-finder, two ranges and an azimuth would be visible on three dials side by side, without interconnection of stations by wire. Indication of angle of elevation would be provided on a fourth dial, so that each receiving station would be its own "control-room," capable of feeding complete data into the channels of communication without any linkage with other stations.

This forecast was followed by a memorandum by Mr. Watson Watt dated 9 September 1935, in which the state of development reached was set out.[3] This memorandum stated that development had led to the following of metal-framed aircraft of various wing spans to distances of 90 kilometres on a frequency of 11·5 megacycles per second and to detection at distances over

[1] Air Ministry File S.34763, Encl. 63A.
[2] *Ibid.*, Encl. 63B, 6 Aug. 1935.
[3] Given in Appendix No. 3, taken from M.A.P./S.R.I. C.S.S.A.D. Folder No. 11.

60 kilometres, measuring the distance of the craft from the observing station with an accuracy of the order of 1 kilometre. Tests had mainly been made on aircraft flying above 10,000 feet with a few trials at 7,000 and 5,000 feet and one at 1,000 feet. Comparable performances had been obtained on frequencies of 6, 10·71, 11·11, 11·54 and 12 megacycles per second although no success had been attained in a few trials on 37·5 megacycles per second. Experiments were being carried out on measuring the angles of elevation of the aircraft detected. The detection of low-flying aircraft might be obtained by additional mast height, and by selecting coastal sites well above sea-level. Research had shown that as a conservative estimate of average performance, with 75-foot masts, a detection range of 37 miles on aircraft flying at 13,000 feet could be expected.

The memorandum outlined a scheme for a chain of stations with transmitters every 20 miles along the coast to be defended, with receiving installations at each alternate station, *i.e.*, every 40 miles. Each set, transmitter and receiver, would require two masts, not under 200 feet high, situated on land not less than 50 feet above sea-level and not more than two miles from the coast. A range measurement by the station equipped with both transmitter and receiver would serve to fix the aircraft as lying on a certain circle surrounding the station. By measuring the time-interval between the pulse transmitted by one of the neighbouring stations (fitted only with a transmitter) and its reflection from the aircraft, the position of the aircraft could be tied down to a certain ellipse. Thus a transmitter-receiver station in conjunction with the transmitters flanking it could provide a fix on the aircraft. It was proposed not to introduce height-finding facilities to begin with, but the scheme was designed to allow the introduction of this and other improvements without substantial scrapping of equipment.

A chain of this character, it was stated, should be able to locate accurately all aircraft between the coast and the location frontiers, and count any reasonable number, say of the order of 30 per sector per five minutes. The frontiers were unlikely to lie at less than 83 miles for aircraft flying at 13,000 feet, 50 miles for 5,000 feet, 35 miles for 2,000 feet and 25 miles for 1,000 feet. These ranges could be increased with improved installations, but involving a substantial additional cost. The installation proposed could locate in plan position only, could not measure flying height, but included provision for minimising the effect of interference, especially of deliberate jamming.

The development of R.D.F. had so greatly exceeded the expectations of the Air Defence Sub-Committee of the Committee of Imperial Defence which had assumed that a range of detection of 50 miles would not be achieved for some five years, that at their fifth meeting it was recommended with the Air Council's agreement that a chain of radio detection stations covering the approaches to the coast from the Tyne to Southampton should now be established.[1] It was estimated that some twenty stations would be needed to provide detection and location of enemy aircraft at ranges between 65 and 5 miles from the coast. It was also recommended that Bawdsey Manor should be acquired and established as a centre for research work and headquarters for the organisation of a chain of stations.

[1] Air Ministry File S.35982, Encl. 40A and Minute 8 of 16 Sept. 1935.

First Air Staff Proposals

A conference was held on 24 October 1935,[1] with the Deputy Chief of the Air Staff in the chair, to discuss such matters as—

(*a*) the form in which the intelligence should reach the Fighter Group Operations Room ;

(*b*) manning ;

(*c*) technical organisation ;

(*d*) Service trials.

It was agreed that—

(*a*) Intelligence should comprise the position and number of the aircraft as a bearing and distance over the sea, with height to within 2,000 feet at extreme range, but with increasing accuracy to a limit of about 500 feet at the coast. Observations should be plotted at the R.D.F. station and telephoned at minute intervals to the appropriate Fighter Group Operations Room.

(*b*) Manning of the transmitter stations was to be undertaken by Wireless personnel from the nearest R.A.F. Station, the maintenance of the R.D.F. transmitter being regarded as part of the responsibility of the Station W/T personnel as a whole. Each receiving station would require four Oscillograph Operators plus one for relief for leave and sickness. These men would have to be specially trained, which would take initially a minimum of three months, with a further thirty days training annually, the operators being provided as the stations were constructed.

(*c*) The Service control of the R.D.F. organisation should be under the Signals Staff at Fighter Command Headquarters, and it was considered unnecessary to have officers in command of R.D.F. stations or groups of stations. It was thought that no advantage would be gained by linking the Observer Corps with the R.D.F. system.

(*d*) A scheme to cover the coast approximately between Southwold and the South Foreland should be worked out as early as possible to provide for training facilities and for Service trials to be carried out.

In November 1935, an ambitious programme was proposed by the Air Staff for seven stations to be available for operations with the Service in August 1936, and for the first three stations to be in operation by June 1936.[2] To achieve this programme, it was necessary that the Air Ministry should ensure within nine months, the selection of sites, the erection of 250-foot masts at each of the receiving and transmitter stations, the design and erection of suitable buildings to house the transmitter and receiving sets, and the supply of power from the grid system. The Department of Scientific and Industrial Research was to provide the radio apparatus on repayment, and the G.P.O. was to take the necessary action for providing line communications between the stations and a headquarters from which the Air Intelligence would be supplied to Fighter Command Operations Rooms. It was proposed that

[1] Air Ministry File S.35982, Encl. 27A.
[2] *Ibid.*, Encl. 33A and Minute 33, 15 Nov. 1935.

civilian personnel would operate the stations for the exercises which were to be held in August 1936, but that, if possible, Service personnel should commence training before that date.

The seven stations required by the Air Staff were to be in the neighbourhood of Dunwich, Bawdsey, Clacton-on-Sea, Shoeburyness, Birchington, South Foreland, and Dungeness, but due to the heavy works service involved it was decided to concentrate on five stations only, omitting Dunwich and Dungeness.[1] The Air Council were so impressed with the scheme that in their letter to the Treasury asking for financial approval, they stated that they had suspended construction of the Acoustic Mirrors for Sound Location. By the end of 1935, Treasury sanction had been received.[2]

[1] Air Ministry File S.35982, Encl. 33A and Minute 37 of November 1935.
[2] *Ibid.*, Encl. 42A and Minute 46.

CHAPTER 2

EARLY RESEARCH ON R.D.F., 1936-1937

The result of the recommendation of the Air Defence Research Sub-Committee of the Committee of Imperial Defence to acquire Bawdsey Manor as a centre for research work and headquarters for the organisation of a chain of R.D.F. stations, was that Air Ministry obtained Treasury sanction for the purchase of the estate.[1] The necessary buildings for research work were approved, together with accommodation and masts to establish Bawdsey as one of the chain of R.D.F. Stations.[2] Provision was made in the 1936 Air Estimates for the establishment of a scientific staff at Bawdsey comprising ten Scientific Officers and some twenty-six assistants, and arrangements were made between Air Ministry and the Department of Scientific and Industrial Research for staff of the National Physical Laboratory to be transferred to the Bawdsey Establishment.[3] Among the Scientific Officers were Mr. A. F. Wilkins and Dr. E. G. Bowen.

Admiralty and War Office Liaison at Bawdsey

The Admiralty appointed a scientific officer, Dr. A. B. Wood, for liaison duties with H.M. Signals School, Portsmouth, and it was agreed that the staff of the Bawdsey Establishment should act in an advisory capacity in connection with research at the Signals School.[4] In February 1936, the War Office asked permission for Dr. E. T. Paris of the Air Defence Experimental Establishment, Biggin Hill, to visit Bawdsey to investigate the development in short-range location of aircraft suitable for use with searchlights and guns, with a view to the Army Council nominating a small staff of scientific officers to work in conjunction with the Air Ministry staff and under the supervision of Mr. Watson Watt on this line of research.[5] This request was readily agreed, and eventually staff from the War Department were appointed to Bawdsey under Dr. Paris.

Transfer of Mr. Watson Watt from the Department of Scientific and Industrial Research to Air Ministry (1 August 1936)

The second interim report of the Committee for the Scientific Survey of Air Defence recommended the transfer to the Air Ministry of Mr. Watson Watt from the Department of Scientific and Industrial Research, where he had served since 1921 and, since 1933 as Superintendent of the Radio Department of the National Physical Laboratory.[6] The Chief of the Air Staff considered Mr. Watson Watt should be employed as Superintendent of Bawdsey Research Station as a whole-time Air Ministry official. A meeting was arranged between Mr. Watson Watt and a Principal Assistant Secretary of the Air Ministry (Mr. J. A. Webster) at which the proposed conditions of Mr. Watson Watt's employment were explained :—

> " To be in charge as Superintendent of radio detection work at Bawdsey Manor ; to advise the Air Staff on detection and location work (including the transmission of the results) in connection with all schemes of defence ; and to conduct research and technical development thereon as may be required."[7]

[1] Air Ministry File S.35982, Encl. 40A.
[2] Air Ministry File S.361120, Encl. 57A.
[3] Air Ministry File S.36728, Encl. 25A.
[4] Air Ministry File S.37506, Encl. 1A.
[5] Air Ministry File S.37518, Encl. 1A.
[6] Air Ministry File S.37745, Encl. 1A.
[7] *Ibid.*, Minute 8.

His position in the Air Ministry organisation was to be :—

> " In all matters of research and technical development he would be under the Directorate of Scientific Research and Technical Development ; and that, in so far as detection and location work in connection with Air Force defence schemes were concerned, his position would be that of an Adviser of the Air Staff and Signals on these matters."

Mr. Watson Watt thought the proposed organisation took too restricted a view of the magnitude and importance of the work and its urgency which, he felt, indicated the desirability of setting up a separate research system under a Director independent of the present joint directorate, for which he suggested the title of Director of Investigations on Communications,[1] with the following duties :—

(*a*) The special study of the whole of the problems involved in :

(i) the detection and location of approaching enemy aircraft ;

(ii) the most rapid determination of positional data for such craft ;

(iii) communication of data to Fighter Command and other units as required ;

(iv) expeditious plotting by automatic or semi-automatic means ;

(v) communication to fighters and other aircraft and provision in such aircraft of means for direct detection at short range to facilitate interceptions without intervention of a ground organisation.

(*b*) The inception, direction and direct conduct of research, technical development, and initial production and installation work required for the attainment of the ends indicated under (*a*) above.

(*c*) Initial arrangements for the training organisation to be developed.

(*d*) Maintenance of the special contacts required with other defence and civil departments.

(*e*) Duties of principal adviser to the Air Staff on all problems concerning this branch of home defence.

The Bawdsey Research Station he regarded as only incidental to these functions, and the tenure of its superintendentship by the Director as only incidental and temporary.

The Secretary of State for Air held the view that Mr. Watson Watt had made a most ingenious and valuable discovery which could be of the greatest possible value in enabling interceptor aircraft to deal effectively with enemy attack, and that Mr. Watson Watt should devote himself to this vital work by pursuing this discovery continuously and energetically.[2] He thought that although Mr. Watson Watt should have the closest liaison with the communications authorities at the Air Ministry and Post Office and, to a less degree, with the War Office in regard to their air defence duties, his primary place of duty should be at Bawdsey rather than in the Air Ministry. Following a discussion between the Secretary of State for Air, the Air Member for Research and Development, the Director of Scientific and Industrial Research, Mr. Tizard and Mr. Watson Watt, it was agreed that the latter should be transferred to the Air Ministry and take up an appointment on the staff of the Directorate of Scientific Research as

[1] Air Ministry File S.37745, Encl. 14A.

[2] *Ibid.*, Minute 17.

Superintendent of Bawdsey Research Station, and to advise Air Staff on detection and location, including the transmission of R.D.F. information. The appointment took effect on 1 August 1936.

Plans for the First Five-Station Chain (1936)

It will be recalled that the ultimate needs of any scheme for locating aircraft approaching the coast are the continuous measurements of range, bearing, height and number of aircraft over the greatest practicable range of approach. As investigations and experiments progressed, it grew clear that the maximum range of location was largely governed by mast height ; that height could be obtained by using a special aerial system, as outlined in the original proposals, that the bearing of an aircraft could probably be measured by a suitable aerial system and that some idea of number could be obtained. It also became evident that interference from ground radio stations could largely be eliminated by employing special aerial arrays. A particularly attractive forecast of ultimate performance was that range, bearing and height could be obtained from one locating station, provided that aircraft were within the zone of detection.

The first three stations planned to be erected by June 1936 were a transmitting station at Orfordness (using the research equipment already installed, but with the addition of two 250-foot guyed masts, erection of which was in progress), a transmitting–receiving station at Bawdsey Research Station, and a transmitting station at Great Bromley. The five stations envisaged for the service trials in August were Bawdsey, Canewdon, and Dover as transmitting and receiving stations (each requiring one 240-foot tower for the transmitting aerial, and two such towers spaced by 500 feet for carrying the receiving aerials and height measuring systems), and Great Bromley and Dunkirk as transmitting stations only (needing one tower each).[1] The Canewdon site was approximately four miles north-east of Southend-on-Sea Municipal Airfield. The site at Dover was approximately half a mile north of Swingate Airfield and stood 400 feet above sea level. The Dunkirk site was midway between Faversham and Canterbury. These stations would work on one frequency only, 11·54 megacycles per second (26 metres) and report information to the headquarters where the reports would be sifted and the mean aircraft plot communicated to Headquarters, Air Defence of Great Britain, by landline. Each station would require technical buildings to house the apparatus, the transmitter hut being situated as near the transmitting tower as possible and the receiver hut midway between the two receiver aerial towers. The huts were to be separated by 500 feet.

It was expected that the erection of the 250-foot towers would be completed by May, ready for the aerial arrays to be installed, but by the middle of May it was seen that the contract dates could not be met.[2] The contractors were therefore instructed to concentrate on the transmitter and receiver towers at Bawdsey, Canewdon and Dover, and defer work on Great Bromley and Dunkirk until after the annual Royal Air Force air exercises had taken place. In July, only the first Bawdsey tower was in a state to permit of aerial installation. For those at Canewdon and Dover, it was now felt that they could not be finished before the end of September. On receiving this information, the Air Staff decided that the air exercises with the Royal Air Force to take place in September should be planned utilising only the one transmitting tower together with the 250-foot mast at Bawdsey. This respite allowed the scientific staff at

[1] Air Ministry File S.37186, Encl. 27A and Minute 6. [2] *Ibid.*, Minute 40.

Bawdsey to introduce modifications in the construction of the towers still to be completed. (It was essential to reduce backward radiation so that the plotting of aircraft over the sea should not be confused by responses from aircraft flying behind the station.) Owing to the need for a higher degree in accuracy of spacing of the reflector curtain from the energised curtain in the transmitter array it was found necessary to provide means for setting the spacing to any value between 20 and 23 feet so as to minimise the echoes from backwards radiation. It was suggested that the simplest method of meeting this requirement was to carry each aerial on a cradle which would run on horizontal extension arms at the appropriate levels, subject to the strength of the towers being adequate for this added loading.[1] The actual rigging, and setting in place of aerials and cradles was to be undertaken by the Bawdsey Research Staff, the supports being fixed by the contractors.

Research during 1936

Both Bawdsey and Orfordness were being used for research purposes until 1937. Two hundred and fifty foot guyed masts were erected at each place with the anticipated increase in range. Measurements of bearing and of height were made, but little progress could be made with height-finding until additional towers were available. Tests were made with formations of up to six aircraft, and it was found possible to deduce that one, two, three or more than three aircraft were being observed. This " counting " of the numbers of aircraft in a formation from the nature of the response seen on the cathode ray tube was a most important practical discovery. It ultimately enabled Controllers at the Operations Room during the War to decide on the size of the defending fighter force which had to be dispatched to meet an incoming hostile attack.

Direction Finding

The question of Direction Finding and the method of overcoming this problem has been described by Mr. A. F. Wilkins :—

> " However bold might now seem to be the decision to start work on this chain at a stage when ambiguity in pin-pointing was inevitable,[2] the anticipated troubles never had to be faced, as revolutionary development occurred towards the end of 1935. The need for some system of direction-finding had been obvious right from the beginning, and provision had, in fact, been made at Orfordness for a hut (known as " Y " Hut) in which research was to be performed. I cannot remember any proposals other than nebulous ones as to how D/F was to be done, until on arriving at Orfordness for one of his regular week-end visits, Mr. Watson Watt announced his proposals for the use of crossed horizontal halfwave aerials as the solution of the D/F problem. He had thought of this scheme on the way to Orford that day."

Investigation into the accuracy of Direction Finding was conducted at Bawdsey, using a single pair of crossed dipoles at 250 feet with the Orfordness transmitter.[3] A design for a full D/F array system was completed, the accuracy of which was found to be adequate. The whole aerial array required at a

[1] Air Ministry File S.37186, Encl. 65A.

[2] This ambiguity in establishing the location of an aircraft from a knowledge of its ranges from two or more stations was caused by the fact that the range position lines intersected at two points at least, only one of which was the true position of the aircraft.

[3] Bawdsey Research Station File B.R.S. 4/4, Encl. 21A, Dec. 1936.

receiving station to give bearing, range and height of an aircraft, could be carried on two wooden towers not less than 240 feet high, the transmitting station having one similar tower. After the initial difficulties of direction-finding were overcome, the original proposal for obtaining fixes by using the re-radiated impulses from the adjacent transmitters at the receiving station was dispensed with, and each station became both a transmitter and receiver. Accordingly, Great Bromley and Dunkirk (transmitting stations) required two extra masts. With the extra masts, each individual station in the chain would be independently capable of locating aircraft in height, bearing and range.[1] This would thereby increase the effective concentration of stations along the East coast, with better results in locating and following low-flying raids, owing to the smaller spacing between stations and the faster determination of the plan position of the aircraft by the observers.

Research and development continued rapidly. The number of frequencies used was increased and new apparatus designed. Work was proceeding on frequencies between 75 and 11·5 megacycles per second (4–26 metres wavelength). It was anticipated that mobile gear would be needed for the Service, and work was put in hand on the higher frequencies. A requirement for short-range location in aircraft had arisen and experiments were continued on the 75 megacycles frequency-band.[2] Little success was achieved using this frequency for detection from the ground, although Mr. Dewhurst made a long distance detection record by being the first to record a range of over 63 miles using this frequency. He was, however, unable to repeat the performance. It was felt that the ultimate need for a set which could be installed in Service aircraft would require a frequency of 300 megacycles per second (1 metre wavelength) and Dr. E. G. Bowen was put in charge of this research. Improvement of range was looked for in a better utilisation of energy in the transmitter, and in a reduction of receiver noise background by a re-design of the receiver on a frequency of 11·5 megacycles per second (26 metres) and an increase in gain of the 75 megacycles frequency-band receiver. The need for automatically communicating the information obtained from R.D.F. stations with no unavoidable delay to the Fighter Headquarters produced a " polar co-ordinate " repeater for use over telephone lines. This repeater utilised a screen on a cathode ray oscillograph tube, on which a spot appeared showing plan position of a formation on a grid.

First R.D.F. Air Exercise, 1936

The original plan for the 1936 exercises comprised a preliminary test in May, and then full-scale exercises with the Royal Air Force from 31 August to 11 September.[3] These trials were to be the responsibility of Headquarters, Air Defence of Great Britain (which was re-formed as Headquarters, Fighter Command, at Bentley Priory, Stanmore, on 14 July 1936, under the command of Sir Hugh Dowding). Aircraft capable of operating 100 miles from the coast were to be loaned from Coastal Command. Single aircraft and formations of up to nine aircraft were to carry out a series of approaches at different heights over the East Anglian coast. However, owing to delays, mainly in the erection of the 240-foot towers, the date of the exercises was postponed to October and then November. Only a small-scale test was

[1] Air Ministry File S.35982, Minute 66.
[2] Air Ministry File S.37929, Encls. 7A and 13B.
[3] Air Ministry File S.37364 gives all details of the first R.D.F. Air Exercise.

actually carried out in September, with aircraft supplied by Coastal Command –Anson aircraft from Manston and flying boats from Felixstowe. The R.D.F. apparatus at Bawdsey Research Station had one 250-foot mast and later one unfinished 240-foot tower for transmission, with the receiving aerials on the completed 240-foot tower. Range and bearing but not height measurements could be made. An Operations Room was improvised at Headquarters, Coastal Command, on the lines of the No. 11 Fighter Group Operations Room at Uxbridge, and by means of direct tie lines from Uxbridge the plots reported by Bawdsey were simultaneously reproduced in each Operations Room.

Seven flights were planned, six by day and one by night, and involved six to sixteen aircraft operating singly or in formations at a true air speed of 95 knots. The first flight serial, consisting of a formation of nine flying-boats flying at 10,000 feet and followed ten minutes later by a single Anson aircraft to make good the same track at the same height, took place on the morning of 17 September 1936. The reports from Bawdsey were irregular and not forthcoming until the aircraft were within 30 miles of the English coast. The positions given were very inaccurate and did not include bearing. On 18 September, two further flights were carried out consisting of a formation of six flying-boats, a formation of three Anson aircraft and one Anson flying at 10,000 feet. The reports from Bawdsey were very few and far between and the information was vague and for the most part inaccurate. Flight serial No. 3 in the afternoon of 18 September, consisted of four flying-boats and six Anson aircraft acting independently. The flying-boats flew at heights varying between 5,000 and 7,000 feet and the Ansons between 7,500 and 10,000 feet. A considerable amount of low cloud upset the flying programme, causing some of the aircraft to return without completing their runs. The information received from Bawdsey was almost negligible, and useless from an operational point of view.

The Air Officer Commanding-in-Chief, Coastal Command, decided to visit Bawdsey on 21 September, and further flights were postponed until after this visit was made. As a result it was decided to cancel further flight serials and substitute three simple flights by approximately six flying-boats flying in formation at a height of not less than 5,000 feet. Advantage of the flying on 22 September was taken by the Bawdsey staff for recalibrating their apparatus, and positions of aircraft were not reported by them. On 23 September a formation of five flying-boats flew on a track Felixstowe–North Hinder Light Vessel–Felixstowe at a height of 8,000 feet. The quality and frequency of the information supplied by Bawdsey showed a marked improvement on the previous results. Ninety reports were made in 90 minutes and the information supplied was far more comprehensive, the flight being followed with reasonable accuracy during the outward journey. However, on the homeward journey the ranges given in the reports indicated that Bawdsey had become confused between the two returning flights of aircraft.

On 24 September, a formation of five flying-boats was ordered to fly Felixstowe–Kentish Knock Light Vessel–West Hinder Light Vessel–Felixstowe at a height of 8,000 feet. During the outward flight the information given by Bawdsey was accurate to 3–6 degrees in bearing and 5 miles in range : aircraft on the outward tracks were followed up to a range of 45 miles, beyond which distance the errors increased rapidly. On the inward track the formation was picked up at an extreme range of 40 miles and followed homeward to a distance of 12 miles, when the errors in bearing increased from plus 5 degrees north to plus 16 degrees north. The information received in the reports varied from one to more than four aircraft. The range was always given but the bearings were sometimes missed.

The First Air Exercises Summarised

The tests were summarised by Headquarters, Coastal Command, who pointed out that it was not until after Bawdsey had recalibrated their apparatus on 22 September, that even reasonably accurate results were forthcoming.[1] The progress made after the recalibration could be gauged by a comparison between the number of reports received on 18 and 24 September. On 24 September, 124 reports were given in 115 minutes as opposed to nine reports in 60 minutes on the 18th. There was a tendency for " loose " bearings and ranges to be given. It was suggested that the increased accuracy of the plot received at No. 11 Fighter Group Operations Room may have been due to Bawdsey passing the bearing and distances by direct speech instead of using the more elaborate and somewhat untried cathode ray tube method. The report concluded: " While the results achieved are somewhat disappointing it is understood that unexpected difficulties were encountered with certain new equipment at Bawdsey. The Air Officer Commanding-in-Chief, Coastal Command, is very anxious that a further exercise of a similar nature should be held as soon as the new equipment is functioning properly. Until this exercise is held he considered that no attempt should be made to carry out the more ambitious programme originally envisaged for November." The Deputy Chief of the Air Staff, commenting on the trials, stated that their object was to enable the Air Staff to satisfy themselves that the system was sufficiently sound to justify its adoption on a more extensive scale. It had soon become obvious that the programme of flights originally devised was much too ambitious. One of the difficulties was apparently that the programme of construction of the R.D.F. stations concerned was very late and that there had been insufficient time for proper calibration. He did not think that the analysis of the results of the exercises should be regarded as representative of what the system could achieve. The Air Staff were proposing to repeat the trials as soon as the apparatus was ready and it was hoped that the results would then be more satisfactory. In the meantime, they were not yet in a position to say that the system had proved itself in practice.

With this conclusion the Chief of the Air Staff disagreed, expressing the view that the R.D.F. system was already proved.[2] He realised from a visit to Bawdsey in October that the apparatus and the personnel were not really ready for the experiment in September. The apparatus used included a new transmitter of a design which had not been thoroughly tried before the commencement of the trials, also one of earlier design. Further, it was found necessary to stop transmission from the 150-foot mast and instal hurriedly erected aerials on an unfinished 240-foot tower. At one time men were found working on the towers while the apparatus was being operated.

Measures following the First Air Exercise

As a result of a general discussion during a visit to Bawdsey by Professor E. V. Appleton after the September trials, it was decided by the Committee

[1] Air Ministry File S.37364, Encl. 86B. [2] *Ibid.*, Minute 94.

that work should be concentrated at that Establishment for the purpose of obtaining consistently satisfactory results, including height measurement on a frequency of 11·5 megacycles per second, with the three self-supporting towers.[1] This involved the postponement of trials using Bawdsey, Canewdon and Dover, until the Spring of 1937. It was considered that insufficient attention had been paid to the engineering aspect up to that time, and Colonel A. G. Lee, Engineer-in-Chief of the G.P.O., visited Bawdsey to investigate what facilities the Post Office could offer. A G.P.O. Engineer, Mr. E. J. C. Dixon, was seconded to Bawdsey to co-operate with the scientific staff. It was agreed that in future experiments in the presentation of R.D.F. information by a cathode ray tube, data should not be relayed to Uxbridge, but that records should be transmitted to a point some 30 miles distant and back again in order that errors in the system could be examined before its introduction to Service users and until actual Air Staff requirements were known.

The revival of an early suggestion that a form of " Radio Searchlight "[2] might possibly be used to follow aircraft at relatively close ranges (after location at longer range by the Chain stations) had prompted research using a frequency of 75 megacycles per second (4 metres wavelength), employing a mechanically-swung beam. The G.P.O. Engineering Department now undertook to assist with the design of the mechanical equipment. (In the earlier discussions, Mr. Watson Watt had said in October that " he was loath to substitute the operational difficulties of radio beam technique for the simplicity afforded by floodlighting." He suggested that the situation should be reviewed when a " floodlighting " scheme had been provided for the Service.)[3]

Attachment of Service Personnel for R.D.F. Duties

The progress made with radio detection caused the Director of Signals to send a minute to the Air Member for Personnel with proposals for the training of Service personnel and the attachment of a Royal Air Force officer as Commandant of R.D.F. training.[4] Squadron Leader R. G. Hart, attached for Signals duties to Headquarters, No. 11 Group, was selected, and his duties in addition to training, included liaison with the Royal Air Force for administration and operation of R.D.F. Stations. This latter responsibility involved the development of the operational system for the applied use of R.D.F. in Home Defence. It was planned to train initially thirty airmen and thirty civilians at a school to be formed at the Dover R.D.F. Station. It was estimated that the course would last three to four months, after which time it would be possible to man stations as they were erected, and thus obtain experience of R.D.F. plotting without recourse to scientific staff at Bawdsey or the utilisation of Bawdsey Research Station. It had been found that Service trials and demonstrations had on occasions seriously held up development work.

Squadron Leader Hart visited the existing five station sites in December 1936, for the purpose of choosing the most suitable for the Training Centre, and a recommendation was made that buildings should be made available

[1] Minutes of C.S.S.A.D. 21st Meeting, Minute 137.

[2] It is convenient to use in a radio sense terms normally applied to visible light such as illumination, floodlighting, searchlight, telescope, etc. ; this will be done without comment except where ambiguity is possible.

[3] Narrator's interview with Mr. R. A. Watson Watt.

[4] Air Ministry File S.39100, Encl. 1A.

at Bawdsey for accommodation, training, and messing of personnel.[1] Grounds for this decision were that more " casual " flying would be proceeding in the Bawdsey district, and closer co-operation obtained with the Research Establishment. In his memorandum, Squadron Leader Hart suggested the following establishment for a single watch :—

(*a*) One supervisor trained technically, of N.C.O. Wireless Operator Mechanic standard.

(*b*) One Mechanic of experienced L.A.C. Wireless Operator Mechanic standard to operate the transmitter.

(*c*) Two observers, of L.A.C. Wireless Operator standard to change duties every hour.

On the above basis the staff required for a 24-hour watch would be twelve (three N.C.O.s, W.O.M., three W.O.M.s and six Wireless Operators) all of whom would have to undergo special training in the use of R.D.F. apparatus. He suggested that supervisors and mechanics required the same course, but that observers could have a less extensive course and could complete their training at operational stations where they could obtain practice in observation on actual aircraft. On the assumption that four stations would be completed during 1937 this would necessitate the training of forty-eight airmen.

Bawdsey Research Programme for 1937

The Bawdsey research programme for 1937 contained the following items of first priority :—

Multiple waveband system for reduction of jamming.

Attainment of maximum radiated power in desired directions.

Improvement of accuracy in height determination at all ranges.

Improvement in accuracy of plan and height determination at ranges over 50 miles.

Synchronous working systems for a number of stations.

Communication systems to carry R.D.F. data to Fighter Headquarters.

Production of transportable ground installations for inland location by R.D.F. methods.

Less important items for research were :—

Mitigation of jamming by means other than wavelength change.

Improvement of accuracy in direction-finding in azimuth at short ranges.[2]

During 1936 development had been progressing at Bawdsey on the 23 megacycles frequency (13 metres wavelength), and after the September trials it was decided that the chain frequency should be established on 23 instead of 11·5 megacycles per second.[3] The advantages of the shorter wavelength of 13 metres were :—

(*a*) less interference from the ionosphere ;

(*b*) better coverage for a given mast height. (Heights were limited by mechanical and economic factors) ;

(*c*) less liability to jamming.

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[1] Air Ministry File S.39100, Encl. 25A.
[2] Bawdsey Research Station File B.R.S. 4/4, Encl. 22A.
[3] Air Ministry File S.37929, Encl. 13B.

Height Finding

At this stage the first really practical height-finding system was introduced. The method normally employed by the Radio Research Station, and which was suggested by Mr. Watson Watt in his original proposals, made use of two horizontal dipoles some distance apart. The angle of elevation (and hence height) was determined by comparing the phase of the received signals in the two aerials. This system was very sensitive to changes in the bearing of aircraft and as there was no accurate system for determining azimuth in the early stages, trials were confined to determining elevation on aircraft flying on a previously-known bearing. Mr. Dewhurst, who was conducting the research on 23 megacycles, then tried a well-established system in which the signals from two horizontal dipoles at different heights up a mast were compared. The comparison was one of amplitude and not phase, so that the height-finding was independent of bearing. In practice, owing to inequalities in the aerial and surrounding ground there was some slight dependence on bearing. Even at a later date when reasonably accurate bearings could be obtained, it was this second method of height-finding which was generally used. The problem of sense-finding was solved by Mr. A. F. Wilkins, who employed switched reflectors behind the dipole aerials. The satisfactory solution of the problems of height-finding and sense-finding mark a notable step forward in the progress of R.D.F.

Bawdsey Air Estimates 1937[1]

The Air Estimates for 1937 were considerably increased and covered extensions in the laboratory accommodation at Bawdsey, and an increase in the scientific staff, which Mr. Watson Watt estimated would total 81 by the end of the year. These additions could reinforce the existing groups, who would have additional work as a result of design and development activities, and permit the formation of new groups to include work on :—

Cathode-ray direction-finding.

A.A. gun and searchlight control (War Office).

Jamming methods (including means for the mitigation or avoidance of jamming).

Identification of friendly aircraft.

Homing devices for defensive aircraft.

The estimates for wireless and electrical equipment alone amounted to £59,000, of which £12,000 was in respect of equipment for completing the four R.D.F. stations already under construction, viz., Great Bromley, Canewdon, Dunkirk and Dover. In presenting the estimates, the Director of Scientific Research stated :—

> "The technical advances recently made and the preliminary results of the Service Exercises make it clear that the future application of this research work on a large scale is virtually certain, and although big strides have been made in recent months, there remain a great many directions in which the technique will have to be improved and applied to special purposes."

[1] These estimates are given in detail in Air Ministry File S.39070.

R.D.F. announced to Chief Signals Officers

On 19 May 1937, Mr. Watson Watt gave a lecture on R.D.F. to the Chief Signals Officers of Coastal, Bomber and Fighter Commands and No. 11 Fighter Group. This was the first official disclosure of the subject to personnel of the Royal Air Force outside Air Staff and those directly concerned with its development for Service use under Squadron Leader Hart.[1] By July 1937 it was agreed that the Directorate of Signals should have direct contact with members of the Bawdsey Research Station on the following matters concerning the installation of the R.D.F. scheme[2] :—

(*a*) R.D.F. Policy.
(*b*) Operational matters relating to R.D.F.
(*c*) Manning of R.D.F. Stations for use by the Service.
(*d*) Training of Service personnel.
(*e*) Communications as they affect the R.D.F. System.
(*f*) Administrative matters connected with Service Stations.

The 1937 Service Trials

Further air exercises were held from 19 to 30 April 1937, the organisation for the trials being similar to that for 1936. Their purpose was to determine the value to the Royal Air Force of R.D.F. in its present stage of development.[3] It was the view of the Director of Scientific Research that the apparatus should obtain plan position by reference to map squares, and height of raiding aircraft, with some indication of the number of raiders. The R.D.F. information was to be transmitted by telephone to Uxbridge and Headquarters, No. 16 Group, Lee-on-Solent, and would subsequently be compared with the position of aircraft obtained by dead reckoning and D.F. The Commands were asked to suggest in their reports " the direction in which efforts should be made to improve performance from the user's point of view." The Air Officer Commanding-in-Chief, Fighter Command, raised the question of identifying aircraft as hostile or friendly, and it was arranged this should be attempted by friendly aircraft making a code recognition signal at a fixed distance of 30 miles from the area. It was anticipated that the resulting increase of signals traffic would not interfere with the main purpose of the Exercise. The Air Officer Commanding-in-Chief, Coastal Command, asked for the prohibition from the observed area of aircraft not engaged in the trials, and all Units were advised of this restriction ; it was deemed neither practicable nor desirable to ban civil aircraft from the prohibited area.

Results of the 1937 R.D.F. Service Trials. Report by Air Officer Commanding, No. 16 Group, Coastal Command[4]

(*a*) *Range.*—Most of the aircraft operating in the Observed Area were reported by R.D.F. with good accuracy for ranges up to 80 miles (the maximum range tested), except when an aircraft was masked by a stronger echo from another aircraft about the same distance from Bawdsey. The reason that some of the flights were not reported at all by Bawdsey might be that the operator could not observe more than one group of aircraft at a time.

[1] Air Ministry File S.40493, Encl. 26A.
[2] Air Ministry File S.41234, Encl. 17A.
[3] Air Ministry File S.40260 has full details of the 1937 Trials.
[4] Air Ministry File S.40260, Encl. 39c.

(*b*) *Bearing.*—The R.D.F. accuracy for bearing was not so good as for range, but gave useful indication of aircraft positions.

(*c*) *Height.*—The accuracy with which height was reported by R.D.F. was good above 8,000 feet, deteriorated as the height decreased, and was unreliable at heights below 5,000 feet.

(*d*) *Composition.*—R.D.F. reports of the number of aircraft in a formation were unreliable. During the approach of a raid it was very difficult to form an accurate opinion, from the R.D.F. reports received, of the number and dispositions of the forces taking part. The R.D.F. plots received from Bawdsey after the end of the Exercise, did however indicate this information to some extent by joining the points attributed by them to one aircraft or groups of aircraft. This information was not available to the Operations Room during the time that flights were being made, and as will be seen from the results, was not always right.

R.D.F. Accuracy

An interesting incident from the detailed analysis supplied by Headquarters, No. 16 Group, instances R.D.F. accuracy provided by the record of the flight of a flying-boat on 27 April when it left Felixstowe at 1125 hours on a course Kentish Knock–Galloper and thence back to Felixstowe. Bawdsey came on watch, and reported the aircraft's track from 1115 until 1225 hours when the aircraft landed. Two officers of Headquarters, No. 16 (R) Group were present at Bawdsey. At 1144 hours the flying-boat informed Lee-on-Solent by W/T of its position (over the first turning point), and its estimated time of arrival over the second turning point. This information was passed immediately by telephone to the two Royal Air Force officers at Bawdsey. These officers confirmed that the Bawdsey records accurately indicated the flying-boat's estimated track as regards both time and position. It was later noticed at Lee-on-Solent that the R.D.F. plot was not following the pre-arranged track of the flying-boat. Instead of recording a line towards the second turning point, Bawdsey showed a number of observations around the first turning point. At the time of these observations, it was believed in the Operations Room (as a result of the last signal from the aircraft), that the flying-boat was well on its way to the second turning point. At about 1230 hours, after the flying-boat had landed at Felixstowe, the pilot was cross-examined from Lee-on-Solent by telephone. He stated that he had been unable at first to pick up the first turning point, but had had to circle several times before identifying it. This diversion from the programme had been correctly indicated on the Bawdsey plot.

Views of the Air Officer Commanding-in-Chief, Coastal Command, on the 1937 Air Exercises[1]

Air Marshal Joubert, Air Officer Commanding-in-Chief, Coastal Command, in a letter to the Air Ministry, dated 21 May 1937, said that he wished to place on record his opinion that sufficient experience had been obtained to justify the erection of a chain of R.D.F. Stations. He based this view on the fact that, although it was not yet possible to locate with absolute precision an aircraft or a formation of aircraft flying at more than 30 miles from the coast, yet sufficient indication of enemy aerial activity could be regularly obtained up to 80 miles

[1] Air Ministry File S.40260, Encl. 41A.

from the coast to facilitate very greatly the task of Fighter Command. He made this interim recommendation because he felt there was no time to be lost in carrying out further trials on a large scale, and with the additional facilities for correcting observations that the increased number of stations would provide.

Views of the Air Officer Commanding-in-Chief, Fighter Command, on the 1937 Air Exercises[1]

Air Chief Marshal H. C. T. Dowding, Air Officer Commanding-in-Chief, Fighter Command, in his report dated 7 June 1937, was more reserved. He regarded the existing achievements of the R.D.F. system as being of great value to the defence of this country in so far as they indicated generally the approach of aircraft towards our shores. This was but a fraction of the benefit which he hoped would eventually be obtained from this system, but he emphasized that it was all that had been attained up to the present. A general view of the charts accompanying the report showed that the *average* track as plotted by Bawdsey bore no recognisable relation to the track flown by the aircraft and, although there were a few exceptions, even these plots were not sufficiently accurate to enable interceptions to be attempted before the coast was reached. He thought the principal reason for this was the inaccuracies of the R.D.F. observations in azimuth, particularly when other aircraft were in the neighbourhood. The observations for height also were sometimes very erratic. It seemed to him that the most important objective for technical development in this connection, was to improve the azimuth reading by some form of cut, or combination of the observations of two or more stations. The D.F. system for the recognition of friendly aircraft was a complete failure. This he attributed largely to defective liaison ; he would expect no difficulty in obtaining satisfactory results if the whole system were under unified control ; but the matter was at present of minor importance, since, even if the D.F. system had been successful, there were no recognisable plots on the Operations table to which the identifications could have been applied. He recommended that if, and when, another exercise of this type were held, it was important to ensure that Coastal Command, Bawdsey, and Fighter Command, used the same scale charts for recording, owing to the difficulty of making comparisons when the scales of charts differed. He regretted that the results of the exercise did not yet enable him to put forward definite proposals for the transference of R.D.F. plots to the various Operations Rooms concerned.

Technical Views by Mr. Watson Watt on the 1937 Air Exercises

A detailed technical report on the 1937 R.D.F. Service trials was prepared by Mr. Watson Watt. In it, he recorded that the apparatus used in the R.D.F. observations for this exercise was wholly designed and constructed at Bawdsey. The working frequency was 22 megacycles per second (13·5 metres wavelength), the transmitter power was approximately 40 kilowatts. The stand-by transmitter was used on one afternoon to enable permanent improvements to be introduced in the main set. The total lost time, wholly at the transmitting end, was 19 minutes in 60 hours operation : of this, $7\frac{1}{2}$ minutes was due to an error of judgment as to starting time, and 4 minutes to experimental changes, unessential but thought worth trial in the midst of exercises. There were no failures in valves or components, either in transmitter or receiver. Aerials

[1] Air Ministry File S.40260, Encl. 43A.

and receivers were tested each day, but no changes in performance were detected nor was any repair or adjustment required. On no occasion during the exercise did interference by signals, atmospherics, or ignition systems produce troublesome interference. It was not found necessary to prohibit the running of internal combustion engines, save in the area of about 100 yards radius round the receiving aerials.

The direction of maximum sensitivity was designed to lie South-East, and the sensitivity was expected to fall substantially to zero along a line N.E. to S.W. through Bawdsey. The useful sector of operation was therefore expected to lie between East and South. The power radiated inland was reduced to about 1 per cent. of that radiated to seaward, and means for discriminating between craft inland and over sea were provided. No calibration corrections were introduced in the bearing and height determining gear, and no practice runs on formations of more than three aircraft had been made. The minimum objective to which design had been directed was a location range of 30 miles for a formation not below 5,000 feet. No provision was made for following raids into the zone of 8 miles radius surrounding Bawdsey. It was found during the exercise that effective locations could be made in the unfavourable sector West of South, nearly, in fact, to the South-West axis, but that the corresponding sector North of East was one of much lower relative sensitivity. This discrepancy was ascribed to distortion of the energy distribution from the transmitter by the stays of a temporary stayed mast, from which distortion of unforecastable amount had, in fact, been expected. It would appear that, after allowance for this extraneous distortion, the useful sector of the station is not less than 120°.

The time taken for the observation and transmission of positional data (plan position and height) varied between 12 and 22 seconds. Of this time, the observation occupied 8 to 14 seconds, both this and the reading and transmission time (forming the balance of the total) could be reduced by practice and the latter by the improvement of speech on the telephone lines, the poor quality of which involved frequent repetitions. It was clear during the exercise that the interpretation of the individual observations in terms of ground track and speed was notably easier in the Operations Room at Bawdsey itself than elsewhere. Preliminary experiments to facilitate a rudimentary raid identification system were made late in the exercise, and showed very considerable promise. They were being carried further. The charts available from Bawdsey contained only such interpretation as was effected during the period of observation, without improvement after the event, and were therefore representative of the material which could be made available at any R.D.F. filter centre. The need for such a centre had been clearly established in the exercise.

Mr. Watson Watt's Conclusions on Operational Performance

The performance of the system as it stood, in so far as it could be judged from an exercise carried out in weather conditions which, without affecting the observational conditions, were unfavourable for navigation on long tracks over sea, and employing comparatively small formations, is estimated in " Conclusions on Operational Performance " :—

" (a) Accurate plan location of close formations of six or more aircraft at heights of 10,000 or more feet can be effected at ranges of 100 or more miles from the coast, by co-operation of two or more R.D.F.

stations, in cases where the raid density in the 100-mile zone is not high and where observers can be provided to watch this zone without impairment of observations on nearer zones. (The height-reader and teller would normally be able to take this additional duty.)

(*b*) Plan location in similar circumstances can be effected by a single calibrated station with an accuracy in range better than 1 mile and an accuracy transverse to mean apparent track better than 5 miles in the 90-mile zone, 3 miles in the 70-mile zone, 1½ miles in the 50-mile zone, ½ mile in the 30-mile zone, and ⅛ mile in the 12-mile zone. At 20 miles the range is accurate to a quarter mile. (A zone is taken as approximately 20 miles with control on the range named.)

(*c*) Plan location for formation of three or more aircraft at heights between 5,000 and 10,000 feet can be effected with high accuracy, by two or more stations, at ranges of 60 or more miles from the coast.

(*d*) Plan location in the conditions of (*c*) above can be made by a single station with accuracy better than 1 mile and an accuracy transverse to mean apparent track better than 5 miles in the 50-mile zone. In other (nearer) zones the improvement is in approximately the ratios shown in (*b*) above.

(*e*) The range of location for a single craft flying at a height of 1,000 feet is normally better than 20 miles, the accuracy of a single station location is better than 1 mile in range at 20 miles, the accuracy transverse to mean apparent track is better than 1 mile at 20 miles.

(*f*) The flying height of a formation can be determined with a consistency of 7 per cent. for flying heights of the order of 15,000 feet, at ranges of 50 miles, 10 per cent. for 10,000 and 40 miles. Whether these consistencies can be regarded as applying to the true flying heights is a matter to be determined by calibrations which can be made against flying data of exercise and in later experiments.

(*g*) The number of aircraft in a close formation cannot be determined with certainty at present. This determination will depend on experience not yet sufficiently acquired by observers. The discrimination among single aircraft, formations of three to six, and large close formations, appears likely to be made with considerable certainty by sufficiently experienced observers. Special flying arrangements will, however, be required to give experience with large formations."

The Exercise clearly showed a vast improvement in operation using the 22 megacycles per second frequency in place of 11·5 megacycles per second, which had been used during the 1936 trials. The performance and standard of the whole equipment—transmitter, receiver and aerials—were better. Direction-finding and height-finding were both carried out by means of a goniometer ; in the case of height a series of conversion curves were used to convert the goniometer reading and range into height. The D/F errors were not more than 2 to 3 degrees and it was possible to average out the zigzag of individual plots : about five to ten numbers were required before the true track of an incoming raid could be determined.

* * *

The opinions of the Air Officers commanding Coastal Command and Fighter Command, and the impressions of the Air Ministry representatives at the 1937 Service trials of the R.D.F. equipment installed at Bawdsey were all, in the main, very favourable. Although it was agreed that there was not yet precision in the location of formations of aircraft flying at more than 30 miles from the coast, there was no doubt that the air exercises had verified that sufficient experience had been gained to justify proceeding with the erection of a coastal chain of R.D.F. Stations. The exercise therefore provided a valuable impetus to the need for accelerating the construction of the Home Chain.

CHAPTER 3

INCEPTION AND PROGRESS OF THE R.D.F. HOME CHAIN, AUGUST 1937—THE MUNICH CRISIS, SEPTEMBER, 1938

After receiving the reports on the 1937 Exercise, the Deputy Chief of the Air Staff suggested to the Chief of the Air Staff that the R.D.F. equipment had shown itself sufficiently satisfactory to go into production.[1] He pointed out the five stations sanctioned by the Treasury in November 1935 were designed to provide data as a first step towards the complete chain of twenty stations recommended by the Air Defence Research Committee on 16 September 1935. These five stations were to have been ready by August 1936, but so far, only Bawdsey was in operation, with the possibility that all five would be completed by the end of 1937. It had been estimated that the complete chain would take two years to build, so that if the necessary work were not commenced until after the completion of the five-station chain, it would not be finished before the Spring of 1940 at the earliest ; probably later, bearing in mind the example of the five-station chain where construction had already lagged by more than a year. He therefore considered that further delay in the construction of the Main Chain as originally proposed could not be accepted and that there were ample grounds on which to approach the Treasury for the necessary financial backing.

The Chief of the Air Staff agreed that the scheme for the Main Chain should be put in hand, and the matter was discussed at a meeting between the Deputy Chief of Air Staff, the Director of Scientific Research, Mr. Watson Watt and others on 30 June, where the Air Staff requirement was stated :—[2]

> " That, by means of R.D.F., we should get warning as accurately as possible of the position of enemy aircraft approaching the coast between St. Catherine's and Lowestoft at a minimum height of 3,000 feet and at a distance of 40 miles from the R.D.F. station at this height. From Lowestoft to St. Andrews a lesser degree of accuracy could generally be accepted, and the Air Staff would be satisfied to have warning of aircraft approaching at 5,000 feet at a distance of 35 miles from the coast, except in four coastal areas, the Forth, Tyne, Tees and Humber, which in view of their importance and exposed condition required the same standard of warning arrangements as proposed for the St. Catherines–Lowestoft sector."

Air Ministry Memorandum No. 133 was accordingly drawn up and submitted to the Treasury Inter-Service Committee, who gave the necessary sanction at their meeting on 12 August 1937.[3]

Co-operation of Commercial Firms in Production of R.D.F. Equipment (1937)

Even before Treasury sanction had been given, tentative discussions on the production of R.D.F. equipment by commercial firms had been taking place. In January 1937, it had been recommended that the system of R.D.F. should be disclosed to the Metropolitan-Vickers Electrical Company Limited and that

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[1] Air Ministry File S.35982, Minute 80 of 11 Jun. 1937.
[2] *Ibid.*, Minute 82 and Encl. 89A.
[3] *Ibid.*, Encl. 100A and Minutes 100/101.—This Memorandum is given in full at Appendix No. 4.

they be asked to carry out certain experimental and development work. However, as a result of a conference held on 22 January 1937 under the chairmanship of the Director of Scientific Research, it was decided that Metropolitan-Vickers should be informed only in respect of the transmission side of R.D.F. The receiving apparatus, it was decided, should be given to A.C. Cossor Limited for development. It was considered that there would be little risk as regards secrecy if the goniometer development were placed with another firm, and this was made the responsibility of the Radio Transmission Equipment Company Limited. It was recommended that the erection of aerial arrays should be the responsibility of the Bawdsey staff assisted possibly by G.P.O. workmen who might be made available.

After discussion between the Secretary of State for Air, the Chief of the Air Staff, and the Air Member for Research and Development, approval was given for the selected firms to be approached.[1] The staff of Metropolitan-Vickers were convinced that they would be able to design a satisfactory transmitter to meet the requirements (which called for hitherto unattained peak outputs), delivering the first experimental model, at a rough estimate, within nine months of the date of the contract, and thereafter at the rate of three transmitters every two months.[2] Arrangements were made for a member of the Company who would be in charge of the experimental work and design to visit Bawdsey to draft an outline working specification with the Bawdsey staff. Messrs. Cossor anticipated no difficulty in designing and producing the receivers provided adequate facilities were afforded to discuss technical details with the experimental officers concerned ; they were prepared to set aside certain special shops for experimental work and for the assembly of components made in the general shops. By limiting the assembly work to specially selected and trustworthy staff they were satisfied that secrecy could be ensured. They estimated that twenty receiving sets could be available in from twelve to eighteen months from the date the contract was placed.[3]

After Treasury authority had been granted for the Main Chain, the Directorate of Signals made a formal request to the Directorate of Equipment for the purchase from Metropolitan-Vickers of twenty sets of R.D.F. transmitting equipment to the specification B.R.S. 10001/B, each set comprising two complete transmitters ; and from Cossors twenty sets of receiving equipment to specification B.R.S. 10002/A.[4] Treasury authority allowed for the expenditure of £320,000 on the apparatus, the cost of transmitters and receivers being as follows :—

Transmitters ..	£21,000 for the first set (comprising two transmitters), £16,500 for the next four sets, and £14,500 for the remainder.
Receivers ..	£1,000 per set (comprising one Receiver).

On 28 October, Cossors were instructed to proceed with the manufacture of a further nineteen sets similar to the apparatus already being developed by them.[5] This contract was later increased to forty sets to cover one standby at each Station. On the 6 November, Metropolitan-Vickers were similarly instructed to proceed, the first set to be delivered within nine months, the next three sets by October 1938, and thereafter at the rate of three sets every two months.

[1] Air Ministry File S.39518. [2] Air Ministry File S.40079, Minute 29.
[3] *Ibid.*, Minute 40. [4] Air Ministry File S.42780. [5] *Ibid.*, Minute 109.

Preliminary Siting of the Main Chain

In January 1937, at the request of the Director of Scientific Research, Mr. Watson Watt had produced a tentative outline of the requirements of an R.D.F. site.[1] In the first place there was the obvious requirement of proximity to G.P.O. cables, the National Electricity Grid, water supply, and access by road. As to the technical requirements, he stated that the site should be not more than half a mile from the coast and situated on cliffs overlooking the sea. Alternatively the site might be on high ground near the coast. The station might be set back from the coastline without loss of working range at the rate of 20 miles for every 100 feet gain of height above the average level of the country in front of the station. Obstructions in front of the station—buildings, trees and the like—and possible sources of electrical interference were to be avoided.

After the April, 1937 exercise, but before Treasury sanction had been given for the complete chain, Mr. Watson Watt urged that the available resources for R.D.F. production should be used to give preliminary cover over the greatest possible length of coast, leaving the chain to be strengthened in its second stage by the shortening of individual links as required.[2] He also set out the results of his preliminary investigation to determine the action required to erect a twenty-station R.D.F. Chain. He considered that even with extreme pressure exercised on all concerned and maintained throughout the whole time, it would take fully two years to produce the required twenty stations. His plan provided that the five-station Intermediate Chain from Dover to Bawdsey should preserve its existing spacing, but recommended that the Dunkirk station should be replaced by one at North Foreland because it was important to have the most advanced possible observation post on the south side of the Thames Estuary. He recommended that the Dunkirk site should be retained in its present state for use first as a base for inland R.D.F. experiments, and later as one of the additional full-scale R.D.F. stations required round the Thames Estuary. He also recommended that the Bawdsey operational station should be replaced by a station at or near Lowestoft.

The Main Chain stations outside the important front covered by the Intermediate Chain were to be separated by approximately 40 miles which would allow for detection of aircraft flying at moderate to great heights but not at low altitudes. The spacing suggested would not provide any margin for loss of any station by enemy action, and it was therefore desirable to have a second stage of the Main Chain to cover the provision of further stations for improved location of low-flying aircraft, and the reduction of risk of a break in cover by destruction of individual stations. Dunkirk was to be kept in view as a station in this later stage of the chain.

Siting of Main Chain Stations

The approximate positions suggested for the Main Chain stations were Portland or St. Albans Head, St. Catherine's Point, Worthing, Peacehaven, Ore or Fairlight, Dover, North Foreland, Canewdon, Great Bromley, Bawdsey, Lowestoft, Cromer, Skegness, Spurn Head, Flamborough Head, High Whitby, Seaham, Coquet Head, St. Abb's Head or Fast Castle, St. Andrews (Strathkiness),

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[1] Air Ministry File S.35982, Encl. 68A (1) and (2).
[2] Air Ministry File S.40174, Encl. 2B.

St. Cyrus. The sites proposed had been selected from the map having regard to the required spacing of the Chain. It remained to examine in detail the positions chosen in order to determine the exact locations most nearly satisfying the requirements for a good R.D.F. site. Accordingly survey parties were formed including representatives of Bawdsey Research Station, Fighter Command, and the Air Ministry Works Directorate. Technical requirements were the first consideration, followed by vulnerability to attack from the air and the sea.[1] No real difficulty between technical requirements and those of the Works Services arose. Regarding vulnerability it was realised that as the sites would be between 2 and 10 miles from the sea they would mostly be visible from surface vessels, but as they were not considered good targets the risk of bombardment was accepted.

As a result of this survey Mr. Watson Watt recommended that fifteen stations, including the five stations of the Intermediate Chain already being built and modified to give full main station performance, would give almost the same cover originally calculated for the Main Chain of twenty stations.[2] He suggested that the sites for the remaining five stations should be delayed for eighteen months when the knowledge of R.D.F., which was growing rapidly, would have still further increased. It would then be possible to site them to the best advantage, either to reinforce the Main Chain where necessary or to extend it in a northerly or westerly direction. No question of moving any of the fifteen stations would arise, since each occupied the most favourable site which could be found anywhere in a length of front comparable with the main spacing between stations. The proposal for a first group of fifteen stations also allowed for a small reserve from among the equipments being manufactured. These proposals were agreed and the fifteen sites were selected, to include those of the original five-station or Intermediate Chain.[3] Further adjustment was still necessary, however.

Owing to opposition from local authorities, the site chosen at Alfriston (08) was replaced by one at Poling (08) near Arundel.[4] The relinquishment of the Fairlight site (06) meant its substitution by two stations at Rye (05) and Pevensey (07), necessitating increasing the number of stations to sixteen.[5] The site at Steng Cross (40) also had to give way owing to opposition from the landowner, and a site was selected in the Cheviots at Ottercops Moss (40). The sixteen sites thus became :—[6]

02	Dunkirk	04	Dover
05	Rye	07	Pevensey
08	Poling	10	Ventnor
22	Canewdon	24	Great Bromley
26	Bawdsey	28	High Street
30	Stoke Holy Cross	32	West Beckham
34	Stenigot	36	Staxton Wold
38	Danby Beacon	40	Ottercops Moss

Research on Operations and Filter Rooms, Communications, and Display (1937)

The Spring exercises for testing R.D.F. had thrown into relief the need for intensive work on a scientific basis on communications and Operations Room technique, including methods of transmitting and displaying the information

[1] Air Ministry File S.42747, Encls. 7A and 9A. [2] *Ibid.*, Encl. 7A.
[3] *Ibid.*, Minutes 6–10. [4] *Ibid.*, Encl. 36A. [5] *Ibid.*, Minute 53.
[6] These sites are indicated on Map No. 1.

obtained by the R.D.F. Chain. This line of research was no less important and urgent than that of the radio detection system itself, a point which was stressed by the Air Officer Commanding-in-Chief, Fighter Command. The Air Staff and the Operational Commanders considered that since raid reports would be received from several R.D.F. stations, and from other sources, such information must first pass through a Filter Centre for evaluation of the data supplied on position, track and speed of individual raids before it reached the Operations Room table. It was therefore agreed that research should be undertaken on methods of communication, interpretation and display of raid reporting information. This called for a separate laboratory and staff at Bawdsey formed under Mr. E. J. C. Dixon in August 1937, for the purpose of improving the technique and equipment of the standard type of Operations Room and the development of Filter Rooms.[1] A full-scale experimental Operations Room, modelled and equipped on the lines of the best existing Group Operations Room was provided at Bawdsey, and Warrant Officer R. W. Woodley at H.Q. No. 11 Group was temporarily attached to Bawdsey on account of his exceptional experience of Operations Room development and planning.

Communications for Raid Reporting

It was clear that a most efficient communication system between the reporting stations, the centres of control and the operational squadrons associated with them would be required. Since R.D.F. stations would be the main source of raid reporting traffic to be passed to Operations Rooms it was decided that the Superintendent of Bawdsey should become a member of the Technical Development Committee for Air Defence Communications, which had been set up in March 1936, under the chairmanship of the Assistant Engineer-in-Chief of the General Post Office, and whose members were representatives nominated by the Air and Army Councils.[2] The duties of this Committee were to make technical arrangements for the Air Defence landline system, including the standardisation of equipment to conform with the best modern technique and to deal with the safeguarding of landline installations in time of war. After the formation of this Committee, there was a considerable increase in the use of teleprinters for communications, and pneumatic tubes for internal distribution of messages in Operations Rooms. This was followed by the introduction of the Defence Teleprinter Network.

A scientist, who had been working on communications problems at Bawdsey, was transferred to the General Post Office Research Station, Dollis Hill in June 1937, to collaborate with the G.P.O. Transmission Group.[3] The remoteness of most R.D.F. stations from the G.P.O. trunk network and the realisation of the need for quick and accurate reporting led to the development of a transmission system which gave one secret (inverted) speech channel and four teleprinter or signalling channels. This system, however, was not adopted, and in its place one speech channel with a superimposed signalling channel was agreed upon. In co-operation with the G.P.O., work was also started on the development of optical and automatic switch devices for R.D.F. communications which, after the outbreak of war, led to the installation of automatic calculators at Chain Stations.

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[1] Air Ministry File S.46357.
[2] Air Ministry File S.36965, Encl. 43B.
[3] Air Ministry File S.40089.

In the Air Ministry towards the end of 1937, the communications problem was energetically tackled by the Signals Branch with the aim of establishing communication links between R.D.F. stations and the Headquarters concerned as each R.D.F. station was completed.[1] The Air Staff considered the completion of the R.D.F. Chain so urgent that it was decided the communications system should be completed without delay, even if this eventually might prove uneconomical. It was decided that two routes, running through separate G.P.O. centres, would be provided to each R.D.F. station, so that interruptions to one route would not disrupt the system, and that the following circuits would be provided and divided between the two routes :—[2]

(*a*) Main reporting circuit.

(*b*) Spare reporting circuit.

(*c*) A lateral in each direction.

(*d*) Exchange line in each direction.

(*e*) Probable D/F circuits.

These cables were terminated at a Main Distributing Frame in the Receiver Hut.

By May 1938, sufficient experience had been gained from the two existing R.D.F. stations for future policy to be firmly determined. It was decided that the Central Filter Room should be located at Headquarters, Fighter Command, Bentley Priory, Stanmore.[3] All R.D.F. plots were to be reported to the Central Filter Room where they would be plotted on the table and built up into continuous tracks ready for telling to the Operations Rooms. The filterer officer would instruct individual R.D.F. stations as to which particular raids they were to report. From three tellers' positions in the Filter Room, lines would run direct to the three Fighter Group Operations Rooms (Numbers 11, 12 and the anticipated 13 Group). A line would also run from each teller's position to a plotter's position in the Fighter Command Operations Room. The incoming plots from the Filter Centre to the Groups would be relayed automatically to the Sectors under the Groups. High quality speech lines were necessary, especially in view of the fact that the information at the Groups would be redistributed simultaneously to a number of places. The possibility of teleprinters was borne in mind as a later development.

The original line requirement between each R.D.F. station and Headquarters, Fighter Command Filter Room, was four telegraph channels for plotting, and one speech channel to enable the Filter Room to be in touch with the R.D.F. station.[4] In December 1938, however, the G.P.O. refused to accept this proposal, and it was decided that the Post Office Research Station at Dollis Hill and the Bawdsey Research Station should together investigate the provision of a special circuit with control signalling injected at a suitable point of the speech spectrum, and having a sufficiently good intelligibility to enable plots to be passed without need of repetition. In the meantime, special circuits were used for plotting by speech, and R.D.F. stations were linked to the nearest Fighter Command Voice Frequency Centres, which, in the majority

[1] Air Ministry File S.37237, Encls. 203A and 204A.
[2] *Ibid.*, Encl. 227B.
[3] *Ibid.*, Encl. 236A.
[4] *Ibid.*, Encl. 314A.

of cases were the nearest Sector Headquarters. Finally, arrangements were made for two alternative landline routes between each new station and the Filter Room to be connected shortly after the station was occupied.

In March 1939, the Air Officer Commanding-in-Chief, Fighter Command proposed additional landline communications to be laid between the R.D.F. stations and the Fighter Sectors. In the event of the Filter Room, or important cables to the Filter Room, being put out of action, Sector Headquarters should be able to obtain R.D.F. information direct from the R.D.F. stations. This proposal was accepted by the Air Ministry, and the necessary lines were installed by the G.P.O. The lines could have been converted into teleprinter lines, making it possible for the R.D.F. stations to teleprint plots to plotter positions in the Operations Rooms, but although this facility existed, it was never used.

In accordance with usual procedure, all the cable and telephone equipment on R.D.F. stations was taken over from the G.P.O. by the Royal Air Force and became Air Ministry property, the G.P.O. laying the lines as an agency service, and in the event of failure, replacing and repairing them on a cost and time repayment basis.[1] The advantage of this arrangement was that the Royal Air Force could legally make alterations to the lines on the stations.

Calibration of R.D.F. Stations

The need for accuracy in locating aircraft detected by R.D.F. Stations brought the need for careful calibration into prominence. Calibration was not necessary to secure accuracy in the matter of range, for the type of terrain surrounding an installation had little effect on the timing of radio transmissions and reflections. The methods of determining bearing and height of aircraft were both materially affected, on the contrary, by the contour and quality of the earth in the neighbourhood of the R.D.F. equipment. Most of the signal picked up by the receiver arrived by the shortest path, or direct ray as it is called, but some of it was received after ricocheting off the surrounding part of the countryside. When a R.D.F. station was sited on perfectly flat smooth land, the behaviour of the reflected ray, as the ricocheting signal was called, could be anticipated and the equipment would give readings of bearing and height approximating to theoretical accuracy. The perfect site was rarely found in practice, however, with the result that accuracy of bearing was affected by reflected rays which ricocheted sideways, and accuracy of height was lost because some rays had been abnormally reflected in the vertical plane. The effect of the site on height-finding was, in point of fact, far more serious than it was on direction finding. In the latter an irregularly reflected ray was merely a contributory factor, but in height-finding the direction of the reflected ray was of basic importance in the calculation.

The type of site from which the greatest accuracy in height and direction finding was to be expected was a peninsular at sea level, around which the sea would act as a non-distorting reflector. Such sites had a grave disadvantage in practice, however, because the lack of effective height of the aerials imposed a serious limitation on the range of the equipment at low elevation. In order to obtain good low cover, therefore, accuracy of measurement was usually sacrificed to obtain maximum range. Although the best possible sites were

[1] Air Ministry File S.37237, Encl. 239A.

selected, errors of the order of 15 miles transverse to the line of shoot and of thousands of feet in height at long range were to be expected from an uncalibrated station.[1]

Methods of Calibration

The method of calibration was for the station to take readings on an object whose actual bearing and elevation were known. Corrections for the difference in the two could then be incorporated in the equipment. It was estimated that the average station required calibration for ten target heights at each of ten points on a semicircle of 30 miles radius centred on the station, for each of four wavelengths, so that four hundred primary observations, with a few check observations at other ranges, were required for each station. Two methods of calibration were adopted. The first method, that of taking observations on returns from London aircraft of R.A.F. Station, Felixstowe, was not very successful.[2] At that time there was no method of amplifying the signal from the calibration aircraft to make the indications distinctive and easy to read, and observations required much checking. The pilot reported his position by radio telephone when he was over points of known position, such as lightships, and several hours of flying were necessary to obtain these transitory observations. Moreover, minor modifications to the equipment were sometimes required, and as bad weather might then delay further observations, progress was often slow. It was held that observations on aircraft, while necessary, were not alone sufficient.

The second method, that of taking observations on returns from a dipole aerial carried on a kite-balloon, seemed more promising. An experiment in June 1937 was successful, and this method of calibration was made applicable to both Chain and transportable ground installations for location inland.[3] Bawdsey Research Station proposed the formation of a mobile section, comprising transport for taking the balloon and accessories to points within 20 or 30 miles from Bawdsey. Ascents were required to heights between 5,000 and 15,000 feet. This proposal was implemented in September 1937, when the inland station at Dunkirk, Kent, was calibrated by balloons flown at Manston, Eastry, Charing and the Isle of Sheppey.[4]

For stations on the coast, it was suggested that attempts should be made to procure from the Admiralty a vessel suitable for the work, which would involve cruising at distances up to 50 miles from the shore. As a temporary measure, it was suggested that a Royal Air Force surface craft should be allocated, to work at distances up to 20 miles from the shore, where useful calibration could still be done.[5] The formation of the mobile crew was approved, and the question of the allocation of a boat investigated. Progress was, however, slow. In February 1938, Bawdsey Research Station reported that calibration work had made no substantial progress during the preceding five months.[6] Until stations were calibrated, it was not possible to assess the requirements for a filtering process, or to study the general problem of recording and communicating data on a number of raids. Bawdsey urged that consideration should be given to the immediate provision of a balloon, having a ceiling of 7,000 feet, capable of operating out to sea at a distance of 30 miles from the

[1] Air Ministry File S.42719, Encl. 65A.
[2] Air Ministry File S.41722, Encl. 32A.
[3] *Ibid.*, Encls. 1A and 3A.
[4] *Ibid.*, Minute 4 and Encl. 23A.
[5] *Ibid.*, Minutes 5 and 6.
[6] *Ibid.*, Encl. 32A.

coast. If a ceiling of 7,000 feet were not immediately realisable, a ceiling of 5,000 feet would be useful. This recommendation resulted in the supply of a 60-foot Diesel Pinnace carrying a small balloon with a ceiling of 5,000 feet, with which a certain amount of progress was achieved.[1]

In September 1938, Mr. Watson Watt stated that if the Air Staff requirements for the R.D.F. Chain to be working on one wavelength by April 1939, and on all wavelengths by the end of December 1939, were to be met, two balloon units, working simultaneously, would be required for calibration.[2] He recommended that authority should be sought for the acquisition of two vessels capable of carrying LZ–A balloons, which had a ceiling of 7,000 feet and could be used for continuous operations. Financial sanction was given for the charter of two ships, and the Admiralty was approached regarding the loan of a trawler. As no trawler was able to be released, the S.S. *Ialine*, a motor tanker, and the S.S. *Recovery of Leith* were chartered.[3] The former, after fulfilling part of the programme, was considered too small for the duty, and, in December 1938, the vessel was returned to the owners, and the motor vessel *Miss Elaine* chartered in addition to the *Recovery of Leith*. Balloons continued to be used during 1939, a number of additional vessels being used for this purpose. However, it was realised that the method, in addition to its inherent slowness, would be seriously hampered in the coming winter and by restrictions on balloon flying in the event of war.[4] Consideration was therefore given to alternative methods.

Aircraft were known not to be very useful for azimuth calibration, since they could not fix their position accurately, nor could they stay in the same place to allow bearings to be taken on them with precision. On the other hand, for the purpose of height calibration they could be relied on to maintain accurate height, and also to keep on course to within the required accuracy which was less than was needed for azimuth calibration. These considerations suggested the use of autogyros for azimuth calibration. In December 1939, Fighter Command obtained three of these machines.[5] They were fitted with pulse transmitters to assist in taking accurate bearings and tests were carried out with the aircraft hovering over known landmarks. In March 1940, this method was approved as an alternative to balloons.[6] The autogyro was not much use for height calibration owing to its low ceiling and slow speed, and the use of orthodox aircraft for this purpose was continued with the carrying of a pulsed oscillator as in the case of the autogyro.

The story of calibration from this time onwards is one of continually increasing work as more and more stations were erected. The work was inevitably a source of some friction in that the technical staff, in their efforts towards perfection, were always anxious to re-adjust and calibrate stations, particularly when the equipment had been modified or the aerial system repaired, as frequently occurred. Fighter Command's concern, on the other hand, was to have the stations in as nearly continuous operation as possible. The sparing of aircraft for calibration flights was also a source of difficulty. The need for a generous allowance of calibration flying became more fully appreciated as time went on, for without it R.D.F. information could be unreliable and misleading.

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[1] Air Ministry File S.41722, Encl. 43A.
[2] *Ibid.*, Encl. 65A.
[3] *Ibid.*, Encls. 75A and 87A.
[4] Air Ministry File S.42719, Encl. 17A.
[5] *Ibid.*, Encl. 18B.
[6] *Ibid.*, Encl. 29A.

Formation of a Directorate to be responsible for R.D.F. Development (June 1938)

The rapid development of R.D.F. during 1937 and early 1938 created the need for a separate authority at a high level to deal with the growing research and development. Mr. Watson Watt had advocated the formation of a separate R.D.F. Directorate as early as August 1936, at the time of his transfer from the Directorate of Scientific and Industrial Research to the Air Ministry.[1] At that time, however, the Secretary of State for Air was unwilling to undertake a re-organisation which would " entail a complete redistribution of responsibility for these communications and their development," and wished to centre the R.D.F. responsibilities at Bawdsey Research Station.

In practice, it was found that much liaison on R.D.F. matters had to be carried out away from Bawdsey. Mr. Watson Watt was consequently often absent from the Research Station, and at these times the duties of Superintendent devolved upon Dr. Paris, who in addition to supervising the work of the War Office group became involved in general administrative duties.[2] When, in March 1938, a concentration of effort was required on War Office work, it was found he could no longer carry out the duties of Deputy Superintendent. Consequently Mr. A. P. Rowe, previously Co-ordinator of Air Defence at the Air Ministry, was appointed to the Research Station as Deputy Superintendent, with the additional duty of supervising the Air Ministry programme. In view of this vastly expanded programme of R.D.F. research and development, a new Directorate was formed in June 1938, to deal with the development of all equipment required for radio communication, with Mr. Watson Watt as its Director.[3] It was named the Directorate of Communications Development (D.C.D.). The Research Station at Bawdsey was transferred to the new Directorate, Mr. A. P. Rowe becoming the new Superintendent in place of Mr. Watson Watt.

The Formation of No. 2 Installation Unit

It was the Air Staff plan that the Main Chain should reach a stage of completion by 31 December 1939. The responsibility for the organisation and planning of the installation programme had at first fallen upon Bawdsey Research Station. Close co-operation existed between the Research Station and the Directorate of Works in the design of suitable tower structures, buildings and electrical and other services, but the responsibility of co-ordinating the ground equipment and the internal layout of transmitter and receiver buildings lay with No. 10 Department of the Royal Aircraft Establishment, which had assumed this responsibility in January 1938.[4] The co-ordinating officer for all matters affecting the R.D.F. Chain was Squadron Leader J. W. Rose of this Department, he being the link between Bawdsey, the equipment contractors, and Air Ministry Works Directorate.

It was apparent early in 1938 that the work associated with the installation of R.D.F. stations to complete the Chain in accordance with Air Staff policy would increase considerably. Consequently in June of that year it was decided that a special Installation Unit should be formed to bring the R.D.F. Chain into operation.[5] The new unit became known as No. 2 Installation Unit. As its functions would be similar to those of the fitting Party of No. 1

[1] Air Ministry File S.37745, Encl. 14A.
[2] Air Ministry File S.37211, Encl. 35A.
[3] *Ibid.*, Minute 43 and Encl. 73A.
[4] Air Ministry File S.45121.
[5] *Ibid.*, Encl. 2A.

Maintenance Unit which was already functioning, it was decided that No. 2 Installation Unit should also be formed at No. 1 Maintenance Unit, which became the Accounting Unit. For administrative matters, No. 2 I.U. came under the authority of the Directorate of Equipment, the Directorate of Signals (which was responsible for co-ordinating the installation policy) and the Directorate of Communications Development. In July 1938, the Officer Commanding transferred his headquarters from the Royal Aircraft Establishment to the new Headquarters of No. 2 I.U. at Kidbrooke. In the same month, Mr. A. C. Gray of R.A.E. was appointed to assist him in the installation of the R.D.F. Chain. By August, the new Unit had begun work on extensions to the R.D.F. station at Bawdsey.

Completion of the Intermediate Five-Station Chain

It will be recalled that in the autumn of 1935 Air Ministry decided to erect a chain of five stations covering the Thames Estuary. This chain was to be ready by August 1936, with Bawdsey, Canewdon and Dover equipped with transmitters and receivers, and Great Bromley and Dunkirk fitted only with transmitters to enable the other three stations to fix or D/F the position of aircraft. Thus, regarding stations as centres providing location data, there were effectively only three. However, owing to shortage of staff and the intensity of research work, little of Bawdsey's effort could be spared for this five-station project so that even by the beginning of 1937 little progress had been made, though the masts had been erected.[1] The Superintendent of Bawdsey in January 1937 suggested that, since the Main Chain could not in any case be in operation before January 1939, consideration should be given to equipping fully the five stations of the Intermediate Chain and thus have them ready by the beginning of 1938, a full year before the completion of the Main Chain.[2] He suggested that Great Bromley and Dunkirk should be made into complete self-contained transmitter-receiver stations. This was possible since, as has been described, technique had developed to a stage where azimuth could be determined by a single station, the use of an adjacent transmitter for this purpose being dispensed with. There would thus be five stations each independently capable of determining range, bearing and height. Provision might also be made to mitigate the effects of deliberate jamming and to simplify the apparatus so that it could be operated by Service personnel.

These proposals were agreed by the Air Staff, and provision for the erection of extra masts and installation of the necessary equipment was made in the Main Chain scheme for which Treasury sanction was received in August 1937.[3] Extra land was accordingly acquired and the additional towers erected. At Dunkirk, however, it was found impossible to incorporate the existing transmitter tower in the new scheme, so three new towers were erected, the original tower being retained for experimental purposes. The construction of Great Bromley and Dunkirk proceeded concurrently with the early work on the remaining Main Chain Stations. By the end of July 1938, Great Bromley was completed, calibrated, and ready for operation, whilst that at Dunkirk was completed though not calibrated.[4] These stations together with Bawdsey, Dover and Canewdon were able to take part in the Home Defence Exercises of 1938 and, shortly afterwards, to provide R.D.F. cover for the Thames Estuary during the international crisis of September.

[1] Air Ministry File S.40493, Minute 9.
[2] *Ibid.*, Encls. 1A and 2A.
[3] Air Ministry File S.35982, Minute 66.
[4] Air Ministry File S.40493, Minute 52.

The 1938 Air Exercises

In August 1938, the annual Royal Air Force Home Defence exercises took place and were planned for the defence of a line from Lincoln to the Thames Estuary against air attack coming from East of this line.[1] For the first time there existed a chain of R.D.F. stations ready to give warning of incoming hostile raids. All five stations were operational, although Dunkirk had not been calibrated. One frequency only, 22·64 megacycles per second (13·25 metres), was used.

Bawdsey Research Station had decided that the success of R.D.F. in the exercises should be made the first claim on the work of the establishment. Scientists were attached to each station to assist the Royal Air Force personnel on duty at the transmitters, receivers, and landline termination equipment, and a close supervision was kept over the store and workshop organisations to ensure the most efficient maintenance of the stations. The power of the transmitters was stepped up as far as was practicable, to give the greatest possible R.D.F. cover. At Bawdsey itself, the civilian scientific staff took the rare opportunity of observing R.D.F. reactions in conditions of high raid density by carrying out a continuous watch with Royal Air Force operators, while at the other four stations a fixed period of three hours was made during which the scientists took over the manning of the sets from the Service personnel, and records were taken of all data received from the Chain stations. As a result of this detailed maintenance watch, the R.D.F. stations remained notably free from breakdowns throughout the exercises.

Results of the Exercises. The First Experience of Large Raids

The Exercises provided the R.D.F. Chain with its first experience of dealing with large numbers of aircraft, and the reporting system was inevitably swamped by the number of tracks which it was trying to report.[2] The situation was complicated by the fact that the aircraft which were simulating enemy raids had to begin their flights in a "neutral" capacity from their inland bases and fly out to sea through the R.D.F. illuminated area before they reached the predetermined point where they turned to fly in as "hostile" raids. This gave the R.D.F. stations a confused picture of friendly patrols, outgoing future "hostile" raids, circling masses of aircraft in their transitional stage, and incoming "hostile" raids. Echoes were also visible from aircraft as far as 80 miles behind the station, flying overland.

It had been discovered in a rehearsal prior to the exercises that if four stations produced information on four crossing tracks, which they did without difficulty, the resulting accumulation of plots on the Filter Room table was too great for the tracks to be filtered intelligently. The period for which each plot remained on the table had consequently been reduced from ten to five minutes. This meant that if a station were to maintain a continuous report on all the activity in its area, it would need to report each aircraft at least once in five minutes. During the busy periods of the exercises, so many tracks were visible on the cathode ray tubes of the R.D.F. stations that it was impossible to plot every one of them at five minute intervals, and even at the stations' existing rate of plotting, the Filter Room received more information than it could handle. In periods of great activity, therefore, all raids detected by the stations were not depicted on the Filter Room table.

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[1] Air Ministry File S.45848 gives details of R.D.F. in the 1938 Exercises.

[2] Air Ministry File S.45848, Encl. 23A, para. 25.

The filterers were further handicapped in their work by the fact that many of the raids reported were not flying on definite tracks, but were circling in the neutral zone, preparatory to turning and becoming "hostile." The filtering of a track should have begun as soon as the track was reported by the R.D.F. stations, but at some periods of the exercises, filtering was only possible when definite tracks emerged from the clutter of circling aircraft. Sifting of the reports of individual raids was therefore troublesome; but the filtering of the information on the massed formations was even more difficult. Estimation of the number of aircraft in a formation from the echo which appears on the cathode ray tube could only be made reliably by experienced operators, and at that time none of the observers at the R.D.F. stations had had previous experience of echoes from large formations of aircraft. The R.D.F. estimation of raid strength was consequently very unreliable. The aircraft flew in very open formations, the echo from one massed raid being sometimes nine miles wide, and such echoes often masked smaller echoes from individual raiders, which flew to the coast unreported.

Height Reporting

Before the Home Defence Exercises took place, the Filter Room plotters had only had facilities to display on their filter tables the plan positions and the raid strengths which the stations reported. The R.D.F. stations were by that time, however, capable also of reporting the heights of the aircraft in their cover,[1] and the reports were considered sufficiently accurate to warrant the introduction of separate height counters, whereby height reports could be plotted in the colour corresponding to the colour on the plan position counters of the station, and also a distinctive filtered height counter which was displayed against the filtered track.

There was a tendency of the stations to report exaggerated heights on distant aircraft, due largely to the lack of experience of the height calibration section. It was technically impossible to read accurate heights at very low angles of elevation, and stations attempting to do so gave inaccurate information.[2] To offset this, orders were given for the height reading area to be curtailed and aircraft which gave indications of being below a certain angle were plotted with a non-committal "No Height" report. In 1938, the selected angle of elevation was too low, and aircraft flying just above this angle were consequently inaccurately measured. The error in reported height caused by an erroneous measurement of angle of elevation was greater at long ranges than at short ones, and as the aircraft approached the station the reported height would consequently be a little more accurate. Simultaneously, if the aircraft maintained a steady height, its angle of elevation from the station would increase, and would therefore be read more accurately. The net result was the apparent variation of accuracy of height measurement with range. Later, in 1940, the angle of elevation at which height measurement ceased was raised, and this tendency of accuracy variation then ceased to be apparent.

The Need for Low Cover

A disturbing feature of the exercise was the confirmation of the already anticipated inability of C.H. (Chain Home) stations to observe low-flying raids.[3] One low-flying aircraft flew towards the R.D.F. station at Dover,

[1] Air Ministry File S.45848, Encl. 26A.
[2] Narrator's comment.
[3] Air Ministry File S.45848, Encl. 8A and Minute 35.

and actually passed over it without being reported. The distribution of the R.D.F. cover depended on a combination of the height of the aerials and the radio frequency on which they operated. The higher the aerial, and the higher its radio frequency, the lower would be the cover achieved. The C.H. frequency of 22·64 megacycles per second (13·25 metres) was comparatively low, and although the stations had been sited on high ground so that the effective height of their aerials might be as great as possible, their cover below 2° of elevation was scanty. As the C.H. installation was the only R.D.F. equipment then designed which had given any appreciable range of detection, the lack of low cover was an extremely serious matter.

Operations and Filter Rooms

In addition to the faults originating from the R.D.F. stations, errors were also made in filtering. Some filterers allowed their preconceived ideas on the direction the tracks would take to bias their translations of the R.D.F. plots, which resulted in wrong interpretations of accurate information. When such errors in filtering became realised, they were often only corrected gradually, in order that a continuous track might be kept, and this delayed the receipt of new data in the Fighter Operations Rooms. The plotters performed their duties accurately, but their efficiency dropped noticeably towards the end of long shifts. On this account it was decided that the maximum length of time that they should work should be four-hour shifts. The Bawdsey Filter Room, which had been specially treated acoustically, was much quieter than were the normal Operations Rooms, and similar treatment was recommended for all Operations Rooms.

The entire exercises were handicapped by bad weather conditions, causing an excessive amount of circling in the neutral zones, since visibility was poor and the aircraft found difficulty in locating their land and sea marks.[1] Electrical storms played havoc with the ordinary radio communications, but these storms did not seriously affect the R.D.F. performance.

Conclusions on the use of R.D.F.

As so many features of the exercises were new to the R.D.F. Chain, it was natural that its performance, though indicative of what could be achieved, was rudimentary.[2] The problem of the way in which the R.D.F. Chain and Filter Room reached a saturation point in dealing with a high density of raids was perhaps best appreciated by Bawdsey Research Station, who held that the best way of dealing with R.D.F. data during such periods had not been discovered. While Fighter Command and Air Ministry stressed the need for practising the existing system, the Research Station emphasised the need for operational research as distinct from operational training.

In spite of its many teething troubles, however, the R.D.F. system can be said to have shown signs of its future capabilities. Its performance had won the approval of the Air Officer Commanding-in-Chief, Fighter Command, who was the chief "customer". He considered that, for the first trial, the R.D.F. system had worked remarkably well. The intelligence system, which lacked experience, had not convinced the Air Ministry that it was ready to replace the

[1] Air Ministry File S.45848, Encl. 23A, para. 25, and Minute 13.
[2] *Ibid.*, Encl. 23B, paras. 96–98.

system of continuous air patrols, but it had shown enough promise for their eventual replacement to be forecast. The final opinion was summed up by the Deputy Director of Operations (Home), Air Ministry, in his report on the exercises :—[1]

> " (*a*) Although the conditions of this year's exercises led to standing patrols being adopted, it is considered that when all D/F and R.D.F. stations are completed, the standing patrols would not be needed, except for interception patrols when enemy raids were so numerous as to cause saturation on Group Operations tables.
>
> " (*b*) The artificial conditions caused by 'enemy bombers' setting out from within or near the defended area, and in many cases not going sufficiently far out to sea, led to difficulties and confusions which would not arise in actual warfare."

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[1] Air Ministry File S.45848, Encl. 18A.

CHAPTER 4

FINAL PREPARATION OF THE HOME CHAIN FOR WAR

The five-station chain had proved itself capable of prolonged operation during the 1938 Home Defence Exercises. At the beginning of September, when the Sudetenland problem became acute, the R.D.F. stations were brought into continuous operation. Between them, they afforded warning of aircraft at 10,000 feet to a distance of 80 miles from the coast between Suffolk and the South of Kent sufficient to provide warning of potential attacks on London and the Thames Estuary. But cover was also required for the north, in the areas of Forth–Clyde, Tyne and Humber. The Main Chain sites being insufficiently advanced, the situation was met by the emergency erection of three mobile installations, which were under construction for the overseas R.D.F. programme.[1] On 16 September 1938 the Director of Operations and Intelligence, Air Ministry, gave orders for the immediate completion of these mobile sets. Positions were found on two sites originally selected for Main Chain stations at Drone Hill (for the Forth–Clyde area) and West Beckham (for the Wash area). The third site was at Ravenscar (for the Tyne area), which, although it was not a Main Chain site, had been previously ear-marked as likely to give good early warning.[2] These sites were chosen for their height above sea-level, and it was hoped that the stations would provide warning of aircraft at 10,000 feet to a range of 60 miles.

On 25 September the erection of the stations was begun by No. 2 Installation Unit, under the direction of an emergency Installation Group which had been formed at Bawdsey Research Station under Mr. H. Dewhurst. Bawdsey's estimate for the erection of the stations, which comprised experimental hand-made transmitters and receivers housed in wooden huts with aerials erected on 70-feet masts, was three weeks, with calibration taking a minimum of one week after the installation had been completed.[3] The buildings of the "Advance" stations, as they were called, were erected between the Final Transmitter and Receiver sites in positions that avoided the possibility of their interfering with future work on towers, buildings and roads. Air Ministry was responsible for the provision of the exchange telephone links and private wires to Operations Rooms, while Bawdsey provided the inter-communication system.

Training of personnel at Bawdsey was intensified to meet the requirements of the new stations. There had been some slight controversy as to the ability of Service personnel as R.D.F. observers about the time of the 1938 Air Exercises. Mr. Watson Watt and the Deputy Director of the Bawdsey Research Station decided on an investigation under Mr. E. C. Williams on the accuracy of the R.D.F. Stations and the ability of the operators.[4] One outcome of this

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[1] *See* Chapter 5 of this Volume.

[2] Air Ministry File S.46200, Encl. 7A.

[3] *Ibid.*, Encl. 25A.

[4] This was the forerunner of Operational Research Sections. Mr. Rowe and Squadron Leader R. G. Hart made an informal arrangement that if war broke out a small group of scientists would remain in the south when the Bawdsey Research personnel moved to Dundee, and form a Research Section at Headquarters, Fighter Command. That group became the first official Operational Research Section attached to a Royal Air Force establishment. So successful was this deliberate application of the scientific method to the operational use of weapons that Air Ministry decided to set up Operational Research Sections very widely in the Royal Air Force during the summer of 1941.

operational research was an agreement that Royal Air Force personnel who had been observing for some two or three hours daily for a period of six months were even more competent operators than the scientists who, by comparison, lacked experience on the observer side of R.D.F. operations. The technical establishment of each station comprised one Signals Warrant Officer, three aircraftmen Wireless and Electrical Mechanics, and three corporals and six aircraftmen Wireless Operators. Of these, the aircraftmen Wireless Operators could be picked from newly-trained ex-boy-entrants, but the Wireless and Electrical Mechanics needed to be tradesmen of some experience.

By 6 October all three stations were completed and handed over to the Royal Air Force crews for continuous operation. Drone Hill was capable of detecting aircraft at 7,000 feet at a distance of 60 miles out to sea, which would afford Edinburgh about 20 minutes warning of a raider flying at a speed of 240 miles an hour.[1] Ravenscar could detect aircraft at 10,000 feet at a distance of 80 miles, which would afford 30 minutes warning to the Middlesbrough–Newcastle area; West Beckham, owing to its low height above sea-level, could not detect aircraft at 10,000 feet at ranges greater than 30 miles. The stations' facilities for height-reading were inadequate, and this substantially decreased their usefulness for interception purposes; but apart from small, local faults, their performance as early warning stations was satisfactory. For the time being each station acted as its own Filter Centre, and it was proposed that the information should be passed to the local sectors. With the establishment of the Filter Room at Headquarters, Fighter Command, the new stations were connected normally to the Central Filter Room.[2]

While the first three "Advance" stations were still being erected, it was decided that five other "Advance" stations should be installed.[3] These were to be sited at Ventnor (Isle of Wight), Shotton (Yorkshire), Stenigot (Lincolnshire), High Street (Darsham, Suffolk) and Beachy Head. As the international crisis passed, however, it was decided to abandon the sites at Shotton and Beachy Head. At the other three, which were Final station sites for the Main Chain, aerial equipment, temporary huts and emergency power supplies were provided. As the work of aerial erection was the most protracted part of bringing a station "on the air," these provisions ensured that any emergency could be quickly met by using the experimental mobile transmitters and receivers from the Bawdsey Research Station, at the expense of denuding that unit of its research resources.

Transfer of Filter Room from Bawdsey to Fighter Command

It had previously been decided in May 1938 that a new Filter Room should be established at Headquarters, Fighter Command. During the Munich crisis, this new Filter Room was fitted out in the basement of the Headquarters at Bentley Priory. An operations table covering the central area was transferred from Bawdsey, and extensions to the north and south of the map were carried out by Fighter Command staff. A 54-pair telephone cable was laid from the new Filter Room to the main distribution frame at Fighter Command, and telephone wiring arrangements were made so that the contemplated Main Chain of stations might be connected to the Filter Room. In October 1938 these preparations were completed, and the new Filter Room at Bentley Priory took over the

[1] Air Ministry File S.46200, Encl. 52A. [2] Air Ministry File S.37237, Encl. 268A.
[3] Air Ministry Files S.42600 and S.42690.

duties of the Bawdsey Filter Room.[1] It was manned by Service personnel who had previously been responsible for the practical development and practice in the art of filtering.

Allocation of R.D.F. Frequencies

The frequencies which were to be allocated to the C.H. Chain of stations were the subject of discussion between Bawdsey Research Station and the G.P.O. The G.P.O. were anxious for the R.D.F. stations to avoid interference with the Cross-Channel Ultra-Short-Wave service between Dover and Calais (75 and 84·5 megacycles per second), the London Television service (44·78 and 41·67 megacycles per second), and the proposed Birmingham television service.[2] It was advisable for reasons of security to avoid the use of the 27–30 megacycles per second frequency band used by radio amateurs. The Lorenz Approach Beacons (30 to 40 megacycles per second) were another possible source of interference, but it was felt that if necessary the frequencies of these beacons could be altered. In November 1938, Bawdsey Research Station proposed that four frequencies in the band 25 to 52 megacycles per second should be allotted to each C.H. station. On 10 January 1939 a special meeting of the W/T Board was held, and the following four spot frequencies were allotted to the C.H. stations for use in peacetime: 22·69 megacycles per second (13·22 metres), 27·00 megacycles per second (11·00 metres), 48·00 megacycles per second (6·25 metres) and 50·50 megacycles per second (5·94 metres).[3] In peacetime, it would not be necessary for each C.H. station to operate on more than one frequency. These allocations were subject to the following restrictions :—[4]

(*a*) There should be 20 miles separation between any station using 22·69 megacycles per second or 27·00 megacycles per second, and any Cable and Wireless Company's receiving station.

(*b*) There should be no interference by stations using 48·00 megacycles per second and 50·50 megacycles per second with peacetime television programmes.

In March 1939 instructions were issued to Bawdsey to proceed with the design of aerial systems for the " Final " Chain on the basis of the following frequency schedule prepared for the stations by the Director of Communications Development :—[5]

		Frequency in Megacycles per Second.			
Station.	*No.*	22·69	27·00	48·00	50·50
Exmoor	18	—	x	—	—
Prawle Point	14	—	—	—	x
Ventnor	10	x	—	—	—
Poling	08	—	—	—	x
Pevensey	07	—	x	—	—
Rye	05	—	x	—	—
Dover	04	—	—	—	x
Dunkirk	02	x	—	—	—
Canewdon	22	—	x	—	—
Great Bromley	24	—	—	—	x
Bawdsey	26	x	x	—	—
High Street	28	—	x	—	—

[1] Air Ministry File S.4038, Encl. 6A.
[2] Air Ministry File S.45502, Encl. 13A.
[3] *Ibid.*, Encl. 10A.
[4] *Ibid.*, Encl. 23A.
[5] *Ibid.*, Encl. 25A.

Station.	No.	22·69	27·00	48·00	50·50
		Frequency in Megacycles per Second.			
Stoke Holy Cross	30	—	—	—	x
West Beckham	32	x	—	—	—
Stenigot	34	—	—	x	—
Staxton Wold	36	—	—	—	x
Danby Beacon	38	x	—	—	—
Ottercops Moss	40	—	—	x	—
Drone Hill	42	—	—	—	x
Douglas Wood	44	x	—	—	—
Stonehaven	46	—	—	x	—
Kirkwall	50	—	—	—	x

By the outbreak of war eighteen of these stations had been erected, but each could operate only on one frequency, in the 27–22 megacycles per second band.[1]

The Main Chain—Progress to the Outbreak of War

Reference has been made to the " Intermediate " and Main or " Final " Chains ; that is, the five-station chain and the twenty-station chain originally proposed, and also to " Advance " stations. Roughly it may be said that the " Intermediate " Chain consisted of " Intermediate " stations destined to be enlarged to " Final " stations, whilst the remaining stations needed to complete the Main or " Final " Chain would be erected directly in the " Final " form. The " Advance " stations were mobile stations originally designed for overseas use but hastily erected at the time of the Munich Crisis to reinforce the " Intermediate " Chain. A brief description of each type of station is given below.

The "Advance" Type or A.C.H. Station

The equipment was housed in wooden huts and its aerials were mounted on two 70-foot, or in some cases 90-foot, towers. The receiver tower carried a single pair of crossed dipoles for direction-finding. The transmitting tower carried a single dipole and a reflector for sense-finding. The radio equipment was experimental in the earlier A.C.H. stations and later a type M.B.1 transmitter was used. Power was provided by a 9 kva. Meadows generator. These stations could only operate on one frequency and could not measure height.

The " Intermediate " Type Station (I.C.H.)

The I.C.H. station consisted of R.D.F. equipment housed in wooden huts. Its aerials were erected on 240-foot towers ; the receiver tower carried a single pair of crossed dipoles with a reflector, and a single height dipole with a reflector at 80 feet, while the transmitter tower carried a three element array with a single curtain reflector. The equipment used was experimental, or in the case of later stations, an MB1 transmitter with an R.F.5 receiver. The station operated on one frequency only. Power was obtained from the mains, with a standby power supply of 7 kilowatts.

The " Final " C.H. Station

The " Final " C.H. station consisted of equipment housed in protected buildings. The transmitter aerials were erected on 350-foot steel towers, and carried a six-element array. The receiver aerials were erected on 240-foot

[1] Air Ministry File S.45502, Encl. 33A.

wooden towers, and carried a double stack of crossed dipoles with reflectors, and a single height dipole with a reflector at 80 feet. Each of the first twenty stations was equipped with two C.H. type transmitters, while the later stations of the Chain Overseas (C.O.) pattern were equipped with MB2 transmitters. Each station was equipped with two RF6 receivers, and was designed to be operational on any of four frequencies. The RF6 receiver was provided with anti-jamming devices. Power was obtained from the mains, with a standby power supply of 75 kilowatts.

The Accelerated Programme

It will be remembered that the existing five I.C.H. stations were brought into continuous operation for the Munich crisis, and that three A.C.H. stations were rushed up to cover the vulnerable areas of Forth, Tyne–Tees and Humber. Further measures were taken for a chain of thirteen stations to be provided in the event of a similar emergency, but at the expense of the Bawdsey research programme. It is true that in June 1938 two further sites had been chosen at the northern end of the Chain, stretching it from the Scottish border to Dundee.[1] Moreover, the Air Staff had agreed early in September to extend R.D.F. cover westward from the Isle of Wight to Start Point, but when the crisis arose no action was taken to obtain this extension.[2] It was evident, however, that more permanent measures needed to be adopted in order to be ready for the next political crisis. A meeting was therefore called by the Deputy Chief of the Air Staff on 6 October 1938 where it was agreed " That the R.D.F. Chain be hastened so as to be completed by 1 April 1939."[3]

From August 1937, when the Air Staff decision was taken to erect the Chain of stations, to the Munich crisis in September 1938, the time had been spent in the acquisition of the necessary sites and the erection on those sites of wooden towers. At no station had any steel towers been erected, and technical apparatus had been installed only at the five I.C.H. and three A.C.H. stations operational during the crisis. At the time of the meeting on 6 October 1938, the building of wooden towers at the sixteen sites originally chosen was far from complete. Three sites had four towers completed and one site had three. At none of the remaining sites had more than one wooden tower been completed, though eight towers were in course of erection. Four sites had no towers erected and two of the sites had not yet been acquired.[4]

It was apparent that if all the stations were to be erected by 1 April 1939, drastic measures would have to be taken. These were :—[5]

(*a*) That negotiations with landowners for acquiring sites should cease and compulsory powers of acquisition should be immediately applied.

(*b*) That manufacturers of steel masts should work 24-hours a day for seven days a week, both in the shops and in erecting the masts.

(*c*) That manufacturers of wooden masts should increase their output, in order to provide an extra number of wooden masts equivalent to the number by which steel masts fell short of requirement.

(*d*) That contractors of technical and electrical equipment should work to maximum output on a 24-hour day, seven-day week basis.

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[1] Air Ministry File S.42747, Minute 49.
[2] Air Ministry File S.41234, Encl. 55A, 61A and Minutes 57 and 59.
[3] *Ibid.*, Encl. 62A and Minute 63.
[4] Air Ministry File S.45174, Encl. 13A.
[5] Air Ministry File S.41234, Encl. 62A.

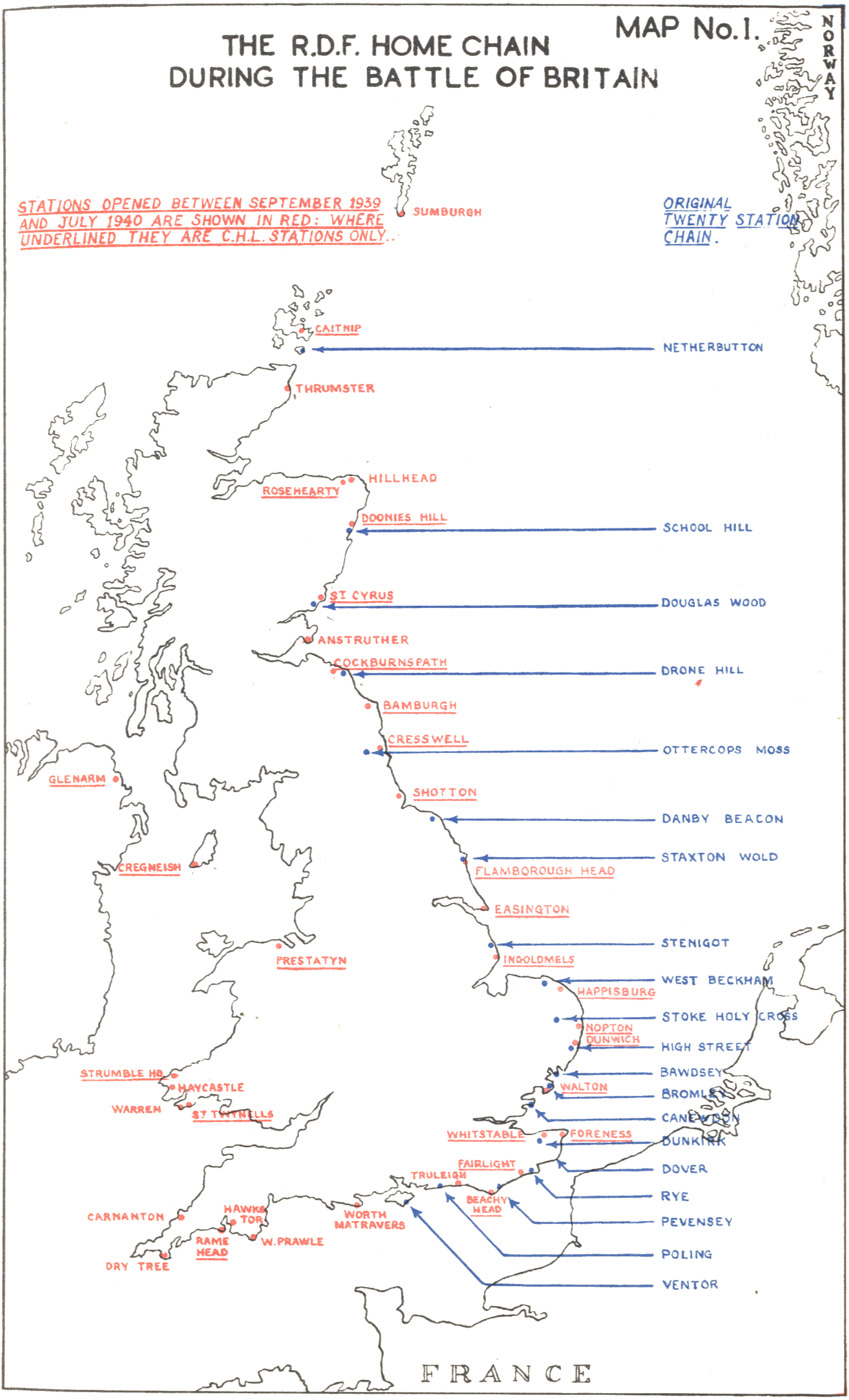
(*e*) That there should be no delay in obtaining financial sanction for the various works required, and in particular for the necessary Works Services involved. It would have to be accepted as a principle that the needs of security out-weighed financial considerations where R.D.F. was concerned.

If these conditions were fulfilled, it was thought possible to have a chain of eighteen stations operating on a semi-permanent basis, including the completion of the buildings, the partial completion of the total number of masts required, and the installation of the necessary receivers and transmitters.[1] In addition, it was thought possible to complete any two stations in the East Anglian salient to their final design, with all buildings completed, total number of masts erected and all necessary machinery installed. Action was immediately taken to bring the essential conditions into effect, and contracts were placed for six emergency transmitters, Type MB, and twelve emergency receivers, Type RF5.

By 15 October, Mr. Watson Watt (at that time Director of Communications Development) was able to define the emergency provision. He said that the stations would be limited to working on a single frequency without duplication of transmitter or receiver units, and with very restricted spares.[2] It was probable that not less than six of the stations would have full-powered transmitters, Type CH, made by Metropolitan Vickers ; the remainder would have mobile transmitters, Type MB, made by the same firm, or emergency transmitters manufactured at Bawdsey. The stations would be incompletely calibrated for direction-finding and height-finding, but calibration would proceed continuously as far as weather permitted. He considered that it would be necessary to accelerate the programme of provision of telephone lines to the Chain Stations, and to expand the training programme to provide for the considerable increase in personnel requirements. It would also be necessary to strengthen D.C.D. headquarters staff, Bawdsey Research Station staff for technical supervision of chain provision, and No. 2 Installation Unit staff for the fitting of stations. In November 1938, it was decided that in view of the lack of manpower available for erecting and lining-up stations, and in order to avoid interference with contractors working on the buildings for the " Final " programme, the " Intermediate " programme should be extended to embrace layouts of temporary wooden huts on the receiver sites, the layouts to be clear of the " Final " layouts.[3] This was held to be the best method of securing an " Intermediate " Chain by 1 April 1939, despite the extra cost thus involved at each of the outstanding eight stations.

It was essential in the interests of research, that the whole responsibility of the new programme should not fall upon Bawdsey. The installation of stations was therefore taken over completely by No. 2 Installation Unit, Bawdsey providing all the necessary drawings, sketches, instructions and materials to enable the unit working parties to proceed.[4] While the first stations were erected, Bawdsey provided assistance from its technical staff to train the No. 2 I.U. foremen. It was also Bawdsey's responsibility to provide scientific personnel immediately after the delivery of transmitters and receivers for testing the apparatus, lining-up the aerials, and for final calibration.[5] In

[1] The sites of these stations are shown on Map No. 1.
[2] Air Ministry File S.41234, Encl. 64A.
[3] Air Ministry File S.47412, Encl. 3A.
[4] Air Ministry File S.46200, Encl. 63A.
[5] Air Ministry File S.47412, Encls. 23c and 3.


MAP No. 1.
THE R.D.F. HOME CHAIN
DURING THE BATTLE OF BRITAIN
STATIONS OPENED BETWEEN SEPTEMBER 1939 AND JULY 1940 ARE SHOWN IN RED: WHERE UNDERLINED THEY ARE C.H.L. STATIONS ONLY.
ORIGINAL TWENTY STATION CHAIN.
NORWAY
SUMBURGH
CAITNIP
NETHERBUTTON
THRUMSTER
HILLHEAD
ROSEHEARTY
DOONIES HILL
SCHOOL HILL
ST CYRUS
DOUGLAS WOOD
ANSTRUTHER
COCKBURNSPATH
DRONE HILL
BAMBURGH
CRESSWELL
OTTERCOPS MOSS
GLENARM
SHOTTON
DANBY BEACON
STAXTON WOLD
CREGNEISH
FLAMBOROUGH HEAD
EASINGTON
STENIGOT
PRESTATYN
INGOLDMELS
WEST BECKHAM
HAPPISBURG
STOKE HOLY CROSS
NOPTON
DUNWICH
HIGH STREET
BAWDSEY
STRUMBLE HD
HAYCASTLE
WALTON
BROMLEY
WARREN
ST TWYNELLS
CANEWDON
WHITSTABLE
FORENESS
DUNKIRK
FAIRLIGHT
DOVER
TRULEIGH
RYE
BEACHY HEAD
PEVENSEY
CARNANTON
HAWKS TOR
WORTH MATRAVERS
RAME HEAD
W. PRAWLE
POLING
DRY TREE
VENTOR
FRANCE

December, to meet this responsibility, a new group was formed at Bawdsey under Mr. H. Dewhurst, consisting of seventeen of the staff previously engaged on research. It was this group which became the Base Maintenance Headquarters, and later formed the nucleus of Headquarters, No. 60 Signals Group, Royal Air Force. At the same time, the nucleus of a D.C.D. headquarters group was formed for the control of R.D.F. development.[1] This was known as RDC3, and later, on expansion, as RDC4.

Financial sanction for the I.C.H. programme was obtained on 14 November 1938. Such was the urgency of the programme that no delays were admissible, and where these might have been caused by the normal process of tendering for contracts, sanction was obtained from the Permanent Under-Secretary of State to dispense with the normal process and for contracts to be placed direct with the manufacturers.[2] Work had been put in hand before the sanction had actually been obtained, and by December, the following progress was forecast for the end of February 1939 :—[3]

(*a*) The erection of two wooden towers on each site.
(*b*) The erection of all necessary buildings.
(*c*) The erection of two 350-foot towers at Bawdsey, Canewdon and West Beckham.
(*d*) The availability of all essential mechanical and electrical supplies.

The urgency of the programme had forced the schedule of construction to be made without any margin for delays due to bad weather, unusual sickness among workmen, and other such factors, and when at the beginning of December severe weather conditions set in, the erection of wooden towers began to drop behind schedule. It was not surprising that contractors found great difficulty in inducing their men to work on the high timber structures during periods of strong wind and very cold weather. This delay in the erection of the masts threw the entire installation programme into jeopardy, since the installation of equipment and aerials was scheduled to follow the completion of the masts. The Superintendent of Bawdsey, in a strong protest to the Director of Communications Development stated that if it were not possible for the towers and huts to be provided by the dates specified in the schedule, it would not be possible for the Chain to be completed by 1 April 1939. He submitted that the effort being put into the erection of the masts did not seem to be commensurate with the sacrifices in research made by Bawdsey. This protest had the desired effect of accelerating the works programme, but by January 1939, there were still many sites where two towers had not been erected.

Conditions at some of the sites made constructional work extremely difficult.[4] At Ottercops Moss, the highest and most exposed site on the Chain, the weather since October had been so severe that constructional work had been impracticable. The greater part of the site was described as " a useless bog in which no satisfactory foundations could be found at a depth of 25 feet." Even the sites in Southern England presented difficulties. Rye was on a marsh exposed to high wind, and the general subsoil water was only a foot below surface level. The whole of the Pevensey site was under water, and the buildings were sited on silt subsoil. Their foundations had therefore to be taken 8 or 9 feet below ground level, the floor raised 18 inches, and continuous pumping was necessary to keep the trenches clear of water and running silt. To minimise the effects

[1] Air Ministry File S.4038, Encl. 6A.
[2] Air Ministry File S.47412, Minute 65.
[3] *Ibid.*, Encl. 21A.
[4] *Ibid.*, Encl. 46A.

created by the delayed erection of towers, departures from the scheduled order of installation were made. The Officer Commanding No. 2 I.U. installed ground R.D.F. equipment separately at sites where two towers did not exist, leaving the aerial installations to be completed when such towers became available, and the Bawdsey Research Station directed its first installation efforts to the four stations where two towers existed and aerial equipment had already been fitted.

By the end of January 1939, two stations (Ventnor and West Beckham) in addition to the five Thames Estuary stations had reached an operational stage as " Intermediate " Stations.[1] By the end of February, two more were ready for operation, and by 1 April, the target date for the completion of the programme, all but two of the stations were completed. The Chain therefore comprised sixteen I.C.H. stations, and the one A.C.H. station remaining at Ravenscar. At the remaining two I.C.H. sites, Ottercops Moss and Rye, the receiver towers were not completed, although all other apparatus had been installed. Consequently it was not until the end of May that the Officer Commanding No. 2 I.U. was able to report that all stations were capable of operation, and had been handed over to their Royal Air Force crews.

" Gap-Filling " Modifications

During the process of installation, another commitment had been given to No. 2 I.U. Since the earliest trials of R.D.F. it had been anticipated by the scientists that responses of uniform strength would not be received from aircraft in every position within range of a R.D.F. station. The cause of this variation of echo strength was the fact that the field of transmitted radiation from the R.D.F. station did not spread evenly at all angles of elevation, but varied. The variation was caused by a combination of the energy directly transmitted from the station aerials with the energy transmitted from the aerials and then reflected by the surface of the ground. The resulting field fell into regular regions of strong transmission and regions of zero transmission. The regions where the station was transmitting no energy were known as " gaps," and the regions where the energy was strong enough to return a recognisable response to the receiver were known as " lobes." Each gap was separated from the gap above and below it by the same number of degrees of elevation. The angle by which the gaps were separated was decided by two factors—the frequency of the station and the height of the aerials above the earth's surface. The conditions that governed the transmitter field also governed the receiver field, which consisted similarly of gaps and lobes.

As a result of the gaps described above in R.D.F. cover, the response given by an aircraft flying a steady course would periodically disappear from a station's receiver, reappearing again as the aircraft flew into the region of the next lobe. The disappearance of an aircraft on the instrument at one station was often unimportant, however, because the filter room would receive plots of the aircraft from a neighbouring station whose lobes covered the gaps of the first station. But when the Chain stations began to be used as experimental ground control stations of fighter interception aircraft, the fading became a serious difficulty. In the autumn of 1938 it became essential to find some method of filling the gaps.[2] The position of the lobes and gaps being dependent

[1] Air Ministry File S.45174, Encls. 30B and 34B. [2] *Ibid.*, Encl. 163A.

on frequency and aerial height, it was necessary to find a way of varying one of these. In practice the frequency was retained and additional aerials were provided in such positions that they radiated lobes and gaps at different angles of elevation from those transmitted by the main array. In February 1939 instructions were issued for the fitting of an additional dipole aerial and reflector at all transmitters, permanently connected to the transmission line, and for the lower height receiver aerial to be rearranged as a crossed dipole, with an additional transmission line. This work ensured that the transmitter "gap-filler" was continuously radiating at a quarter of the strength of the main transmitter; while the receiver "gap-filler," which became known as the "B" System, could be switched into operation when it was needed, without prejudice to the height-finding facility of the station. Work on the installation of the "gap-filling" equipment was begun while the main installation programme was still in progress, and by the middle of August 1939 all the stations of the Chain had been fitted with the new aerials.[1] The alterations were an improvement but did not give entirely satisfactory results, and eventually the transmitter "gap-filler" was also controlled by the switch on the receiver, so that when it was brought into operation it could radiate the full power of the transmitter.

Defence of R.D.F. Stations

In October 1938, the policy for the passive defence of R.D.F. stations was :—[2]

(*a*) Technical buildings should be separated as far as was practicable.

(*b*) All technical buildings should be protected against a direct hit with a 25-pound bomb, made gasproof, and protected by revetments against the effect of blast and splinters.

(*c*) W/T towers should be multiplied, in order to provide facilities for quick change of transmitting and receiving frequencies, as a protection against jamming and damage to or destruction of one or two masts.

(*d*) The transmitter and receiver installations should be duplicated, and separate buildings should be provided for the transmitters and the receivers.

(*e*) Personnel not on duty should be accommodated in a camp sufficiently far from the R.D.F. station to form a separate target. Where possible, this small camp should be placed in natural cover, such as that given by trees. No action was to be taken to establish these camps in peace-time, but sites were to be ear-marked. On the outbreak of war, personnel would be accommodated in camouflaged tents, which would later be replaced by hutments.

It was decided in October 1938, that the R.D.F. equipment would not be buried deep underground. The advantages gained by doing so were slight in comparison with the technical disadvantages which would be involved. It was thought that R.D.F. stations offered a target which could only be attacked with success by low-flying aircraft, and to such aircraft the high masts would offer a considerable deterrent.[3] As the small sites were unsuitable for night attacks, it was expected that attacks would be limited to daylight hours, when the attacking aircraft could be intercepted.[4] One of the best methods of

[1] Air Ministry File S.45174, Encl. 45B.
[2] Air Ministry File S.41234, Encl. 62A.
[3] *Ibid.*
[4] *See* Parts 2 and 5 of Volume V for the interception technique.

assuring the defence of the R.D.F. stations, therefore, was to develop the interception technique to a point where hostile aircraft could be intercepted either at the coast or while they were still out to sea. It was agreed, however, that each station should be provided with eight machine guns, and should ultimately be provided with two-pounder pom-pom defences, and all R.D.F. stations were scheduled as Royal Air Force vital points.

Maintenance Organisation

During the time occupied by the construction of the I.C.H. Chain, the maintenance organisation which had grown with the original five stations continued. Spares for the equipment were requisitioned by Bawdsey Research Station, who stored them at Bawdsey Manor, and issued them to the stations as required.[1] When breakdowns occurred which were beyond the scope of the station personnel, assistance was sent from Bawdsey to deal with the faults. With the expansion of the R.D.F. Chain and its continuous employment, it was clear that a new scheme of maintenance responsibility was needed. R.D.F. commitments of the Bawdsey Research Station, both for home and overseas use, were increasing rapidly, and the accommodation at Bawdsey Manor was too small to house the quantity of spares needed by the continuously operating Chain of nineteen stations. Breakdowns on stations distant from Bawdsey were liable to be prolonged while assistance was on its way ; and the sending of such assistance might interfere with the research programme.

At a meeting on 14 April 1939 it was suggested that the Directorate of Equipment, Air Ministry, should assume the responsibility for the supply of spares, which could then be stored at the appropriate Maintenance Units. The Director of Equipment was unwilling to accept this responsibility, as so much of the I.C.H. Chain, which might have to remain operational for a period of two years before it was replaced by the " Final " equipment, had been assembled at Bawdsey from non-standard components. It was therefore decided as an interim measure, that the D.C.D. department RDC4 should assume the responsibility for the supply of stores. Bawdsey undertook to compile a schedule of the I.C.H. components, which would enable the Director of Equipment to accept the commitment as soon as possible. It was decided that each R.D.F. station should itself hold 100 per cent. supply of consumable spares, and that adequate supplies of other essential stores should be held at three suitably-located R.D.F. stations. It was also decided that a maintenance party should be established in a convenient position, from where it could be rushed to any R.D.F. station in need of its services. It was to cover three fields, and comprise—

(*a*) *Transmitter and Receiver Maintenance*
- 1 Scientific Officer.
- 2 Technical Officers.
- 3 Technical Assistants, Grade II or III.

(*b*) *Aerial Maintenance*
- 1 Technical Officer.
- 2 Assistants, Grade II or III.

(*c*) *Communications Maintenance*
- 1 Technical Officer.
- 2 Assistants, Grade III.

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[1] Air Ministry File S.2286, Encl. 1A.

The party was formed at Bawdsey, coming under the authority of the Director of Communications Development, and became known as the Base Maintenance Headquarters. It was decided to establish subordinate sections at three R.D.F. stations selected to house essential spares. These were known as Technical Maintenance Sections, and were the forerunners both of the later Radio Servicing Sections, and eventually the Royal Air Force Signals Wings of No. 60 Group.

The three technical Maintenance Sections were located as follows :—

Section.	*Area.*	*Distribution.*
Southern ..	Isle of Wight to Thames ..	Aerial parties and technical stores at R.A.F. Station, Hawkinge. Transmitter and receiver parties at Pevensey.
Eastern ..	Thames to Wash	Complete section at Bawdsey.
Northern ..	North of Wash	Aerial parties and technical stores at R.A.F. Station, Driffield. Transmitter and receiver parties at Staxton Wold.

These sections operated unchanged until September 1939, when the expansion of the chain to the north made the Northern Section too large and unwieldy an area. By that time Bawdsey Research Section had been renamed Air Ministry Research Establishment (A.M.R.E.) and transferred to Dundee, and a fourth technical maintenance section was formed there, which became responsible for the stations between the Forth and the Shetlands. The original Northern Section then became known as the North-Eastern Section, the new one becoming the Northern Section.

The maintenance system finally evolved, therefore, was that all technical stores were supplied through Base Maintenance Headquarters, who demanded the stores from D.C.D. and could also, when necessary, buy the non-standard items direct from civilian firms by local purchase order.[1] This local purchase power was increased, in August 1939, to an allowance of £100 for a single order within a limit of £1,000 a month, for the maintenance of the Chain. The raising of contracts to the firms was carried out by the Director of Equipment, Air Ministry, as requested by Air Ministry Research Establishment.

It had been realised that Bawdsey, with its exposed position, conspicuous towers, and continuously radiated signals, would, in time of war, offer a very likely target for air attack and it was inadvisable for the Research Station and the Base Maintenance Headquarters to remain there. As already stated a site was found for the Research Station near Dundee, but the Base Maintenance Headquarters needed a more centralised position. In June 1939 accommodation was found at Carlton Lodge, Leighton Buzzard. On 1 September 1939 the evacuation of the Research Station to Dundee, and of the Base Maintenance Headquarters to Carlton Lodge was effected.

Training of Personnel

As the I.C.H. stations became operational, the problem of providing trained crews to man them became an urgent one. In August 1938 the Air Ministry had accepted the responsibility for recruiting and training personnel for the

[1] Air Ministry File S.4038, Encl. 6A.

C.H. Chain, for the mobile ground equipment used by the Army and the Royal Air Force, and for R.D.F. apparatus used in Royal Air Force aircraft.[1] In addition, it had undertaken to train a limited number of instructors to assist the training programmes of the Admiralty and the War Office. Bawdsey Research Station housed the only R.D.F. training facilities in the Royal Air Force, and even these were very limited. When, in September 1938, training was accelerated to provide crews for the five I.C.H. and three emergency A.C.H. stations, the largest number of trainees which could be accepted at one time was 11 Wireless Operator Mechanics for maintenance duties and 9 Wireless Operators for operating duties. To bring the personnel of the eight stations to full establishment, which necessitated the training of 2 Senior N.C.O. Mechanics, 3 Corporal Mechanics, 13 Aircraftmen Mechanics, 9 Corporal Operators and 27 Aircraftmen Operators, training at Bawdsey had been greatly speeded up ; but the accelerated installation programme continued to keep ahead of the training programme.

The wartime establishment of an R.D.F. station was :—[2]

1 Warrant Officer, in charge.
3 Wireless Operator Mechanics, maintenance.
3 Corporal Wireless Operators, i/c watches.
6 Wireless Operators, watchkeepers.

The requirement of trained personnel to man the home chain of nineteen stations, and three mobile stations for the overseas programme, was 286 men ; and, with the provision of 50 per cent. reserve, the total number of men required was 429.

In November 1938, it was suggested that an R.D.F. school capable of training fifty operators at a time should be established with eight receivers incorporating training devices, and a staff of nine instructors. The site was selected for it at the Royal Air Force station at Tangmere.[3] Building was begun, and it was hoped that the school would be ready by June 1939. The length of the course was two months ; so the earliest output of fifty operators could not be expected before August 1939. An interim programme was therefore evolved.[4] Two sets of six instructors were trained at Bawdsey, and distributed among the operational stations of the Chain. Training attachments, manufactured at Bawdsey, were provided for the receivers of these stations, and the instructors were able to train two crews of operators each in three months. The training of the mechanics was more difficult, as the apparatus at the stations, being in continuous use, was not often available for demonstrations of servicing and repair.

By the beginning of 1939, it became apparent that requirements for R.D.F. personnel for both ground and airborne equipment at home and abroad would be very great. By April 1939, the total possible requirements had risen to :—

Operators :

For the Home Chain and Overseas programme ..	876
For Airborne R.D.F.	600

Mechanics :

For the Home Chain and Overseas programme ..	389

[1] Air Ministry File S.3910, Encl. 162A.
[2] Air Ministry File S.43697, Encl. 68A.
[3] Air Ministry File S.39100, Encl. 192A.
[4] *Ibid.*, Encl. 193A.

The training facilities of the proposed school at Tangmere would obviously be too small to deal with these requirements and the Director of Training, Air Ministry, was asked to provide a larger school. In the meantime, it was decided to train six operators at each of the 19 Chain stations, which would yield an output of 114 men every six weeks.[1] Approval was sought for an instructor to be established at each station, who, in addition to training the operators, would also try to train six mechanics every three months. For this programme, each of the stations would need an extra receiver and a training attachment. It was decided also that selected reservists should be sent for training to the I.C.H. station. The employment of women as R.D.F. operators was considered, as it had already been decided that women could be employed as plotters. Mr. Watson Watt (D.C.D.) had expressed the opinion in February 1937 that they might make better operators than men, but at Air Ministry it was considered that it was not known how women would react if flustered by heavy air activity. In June 1939, a site for the large training school required was selected at the Royal Air Force station at Yatesbury, in Wiltshire.[2] This school was to be capable of training courses of 126 operators on a one-shift basis, or 252 operators on a two-shift basis, and 126 mechanics.

Administration of R.D.F. Stations

Personnel for the manning of the stations were drawn from the trades of Wireless Operator and Wireless Operator Mechanic, as no R.D.F. trade existed.[3] At first, these men remained on the strengths of their original stations, and were expected to be returned to these stations at the end of their R.D.F. training. But in October 1938, it was decided to absorb them into the permanent R.D.F. organisation, and withdraw them from their parent units. As they remained in their original trades, however, it was necessary to provide training not only in R.D.F. but in the normal wireless operating technique.

When R.D.F. stations were first taken over by the Royal Air Force, Fighter Command was generally responsible for their administration and each station was administered by the nearest Fighter Command station ; personnel were based on this parent unit.[4] In times of emergency, it was necessary for R.D.F. stations to be manned continuously, and the personnel were then billeted in the local villages. Normally, it was possible for one crew to man the R.D.F. station, leaving the other two crews at the parent unit, where they were available for training in their basic trades. No definite ruling had been made on the duration of time for which they would remain on R.D.F. duties. In November 1938, Fighter Command suggested that the system should be altered.[5] Some of the R.D.F. stations were at great distances from their parent units, West Beckham, for example, being 70 miles away from Wittering, and this made administration difficult. Fighter Command proposed that the responsibility for the administration of the R.D.F. stations should be transferred to their nearest Royal Air Force stations, irrespective of the Commands in which these stations were. A list of the proposed parent units was prepared, which included stations of all the three operational Commands, but avoided where possible the allocation of more than one R.D.F. station to each parent unit.[6] This proposal and the suggested distribution were accepted by the Air Ministry. To preserve

[1] Air Ministry File S.39100, Encl. 199A. [2] Air Ministry File S.48327, Minute 33.
[3] Air Ministry File S.39100, Minute 28.
[4] Air Ministry File S.43697, Minute 38. [5] *Ibid.*, Encl. 63A. [6] *Ibid.*, Encl. 66A.

secrecy the stations were described as " Air Ministry Experimental Stations " (A.M.E.S.). Although the new allocation was more convenient geographically than the old one had been, the change contained the seed of future confusion, as the R.D.F. stations now came under any one of three different administrative systems. The R.D.F. stations were secret, entry to them by the parent unit was restricted to the commanding officers of the stations, and few of the administrative officers were familiar with them. In some cases, the parent units had no operational association with their R.D.F. stations, and some of them displayed very little interest in their affairs.

In November 1938, a design was approved for the small camps which were to be the living quarters of the R.D.F. stations, and the establishment was increased to include a cook, an aircrafthand assistant cook and cleaner, an aircrafthand N.C.O. to assist the warrant officer in charge, and an aircraftman clerk.[1]

Chain Operations (1939) prior to the Outbreak of War[2]

In March 1939, a new state of tension arose in Europe. German troops moved into Czechoslovakia. Fighter Command was given the responsibility of ensuring that Britain would not be surprised by air attack delivered before a formal declaration of war. Guns and searchlights were brought to prepared positions in the inner artillery zone ; the Air Raid Warning system was made ready to be put into action at immediate notice ; skeleton crews were brought into the Operations Rooms and the essential telephone lines were taken over from the G.P.O.[3] In April the R.D.F. Chain was brought into continuous operation. Fighter Command, with an Operations Table depicting the aerial activity over and around all the watched areas of the British Isles, was the authority best suited to issue the National Air Raid Warnings. Authority was vested in the Air Officer Commanding-in-Chief, Fighter Command, therefore, to issue an initial warning in the event of a hostile formation crossing the three-mile sea boundary of the British coast with the obvious intention of flying inland.

The Air Officer Commanding was also given the authority to intercept and engage the first raiders as soon as they had crossed the international boundary, and to intercept subsequent formations without regard to the limit of territorial waters.[4] He could also order action to be taken by the anti-aircraft gun defences. In order that such formations could be easily identified as hostile raiders, it was arranged between the three Services that prior notification should be given to Fighter Command of any friendly formation of six or more aircraft by day or of any number of single aircraft by night, flying within 120 miles of the coast between Saint Abb's Head to Dover. This area was modified in June to include the coast between the Humber and Dover. At the beginning of June, German aircraft began to operate in the North Sea and the English Channel. These flights were officially assumed to be training flights, but as one of them covered the entire British coast from Wick to Selsey Bill, there was a strong appearance of reconnaissance.[5] The aircraft did not, however, violate the territorial boundary, and consequently no offensive action was taken against them. Fighter Command, however, took the opportunity of testing and practising its interception system.

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[1] Air Ministry File S.43697, Minute 74.

[2] Details of the equipment of the chain of nineteen stations as at the end of June 1939 are shown at Appendix No. 56.

[3] Air Ministry File C.S.1033, Encls. 1A and 4A.

[4] *Ibid.*, Encls. 4B, 10A and B. [5] *Ibid.*, Encls. 8A, 21A, 23A.

The I.C.H. Chain, so hurriedly installed, supplied the information necessary for the Air Raid Warning System, but in its existing state was not able to provide the accuracy and reliability required for interception purposes, and the continuous watch was a serious strain on the apparatus. By the end of June 1939 it was obvious that certain essential modifications and maintenance would have to be carried out on the stations if they were to continue to provide efficient early warning cover, and to reach a state of full war preparedness. They were required by the Air Staff to reach such a state by 7 August 1939. On 26 June the Superintendent of Bawdsey Research Station undertook to complete by August the following requirements stipulated by the Director of Communications Development :—[1]

(*a*) The " Intermediate " Chain should be " cleaned up ".

(*b*) Vertical gap fillers should be fitted and connected at eighteen stations.

(*c*) Rough height-finding should be provided at all stations except Ventnor (whose site was technically unsuitable for height-finding).

(*d*) D/F and height calibration should be done for all stations.

(*e*) Anti-spark (the afterglow cathode ray tube) and anti-C.W. (the I.F.R.U.) should be fitted at all stations (except at two stations using old and unsuitable receivers).[2]

It was impossible for stations to remain operational while they were being serviced. The servicing programme was at variance with the Fighter Command requirement that the whole chain of stations should be available during their Group exercises and the annual Home Defence Exercise. The servicing required would also interfere with the 24-hour watch system. To enable the work to be carried out, a compromise was effected.[3] Each R.D.F. station was paired with one of its neighbours, the programme being arranged so that one of each pair was always operational while the other was being modified and serviced. The " cleaning-up " operations were begun on 22 June. Bad weather handicapped the work, but by 7 August the programme had been substantially fulfilled.[4] All of the stations had been overhauled, and the calibration of ten stations was the only outstanding commitment. The performance of all stations was good, with the exception of Ottercops, whose cover was considered insufficient.

Formation of the Inter-Service Committee on R.D.F. (November 1938)

The construction of the Early Warning Chain was the first operational R.D.F. commitment, but R.D.F. was beginning to develop applications in many other branches of the three Services. By the middle of 1938 these applications were so numerous that close co-ordination on R.D.F. research and development became essential. It was, therefore, decided to form an Inter-Service Committee for this purpose, with the following terms of reference :—[5]

(*a*) To examine the progress of research and development on R.D.F. from the point of view of strategic and tactical applications.

(*b*) To decide relative priorities in R.D.F. research and development.

(*c*) To recommend to the Vice-Chiefs of Staffs relative priorities in application and production.

[1] Air Ministry File S.47214, Encl. 157A.
[2] An anti-jamming device which is described in Chapter 14.
[3] Air Ministry File S.47214, Encl. 148A, Minutes 150 and 151. [4] *Ibid.*, Encls. 157A-C.
[5] Minutes of the Inter-Service Committee on R.D.F.—AHB/IIE/68.

(d) To recommend to the Vice-Chiefs of Staffs provision for research, development and production in R.D.F.

(e) To recommend to the Vice-Chiefs of Staffs the action required to avoid or mitigate mutual interference between R.D.F. and other organisations.

(f) To arrange facilities for large-scale tactical trials and operational research work involving one or more of the Services.

(g) To consider, and, if necessary, recommend to the Vice-Chiefs of Staffs submissions from Service R.D.F. Panels.

It was proposed that the committee should have three panels, one for each Service, which would deal with detail work on the application of R.D.F. to the individual Service. The terms of reference of the panels were "To consider and report to the Inter-Service Committee on matters within the terms of reference of that body, predominantly affecting one Service." The first meeting of the Inter-Service Committee on R.D.F. was held on 2 November 1938, under the chairmanship of Air Vice-Marshal W. S. Douglas.

Extensions to the Home Chain

On 19 January 1939, the Deputy Chief of the Air Staff held a meeting to consider the extension of the R.D.F. Chain in the light of the increase in the Fighter Force to a 50-Squadron basis.[1] After closely considering suggestions made by the Air Ministry and Fighter Command, D.C.A.S. decided that the only extensions justified on the grounds of strategy were :—

(a) To extend the Northern flank of the chain to Scapa, to give early warning of air attack on the Fleet, by the provision of two full-scale stations at Kirkwall and Stonehaven.

(b) To extend the Western flank of the chain by two reduced-scale stations, one at Prawle Point to extend R.D.F. observations beyond Portland to cover the waters in which convoys would be passing, and to give warning of attack in the Bristol–South Wales industrial area from the South ; and the other at Exmoor, to extend the observation to the Bristol Channel, and to reinforce the cover of the Prawle Point station. (Reduced-scale stations operated with two instead of four frequencies, and though they gave the same performance as full-scale stations in plan location and height-finding, were thus a little more vulnerable to jamming. D.C.A.S. considered that, in view of the remote positions of the two stations, these disadvantages were acceptable.)

(c) To provide three mobile sets, as a reserve for stations damaged by attack, or to strengthen the chain at points of weakness.

Treasury sanction was therefore sought and obtained for these stations, and sites were chosen at Netherbutton, near Kirkwall ; School Hill, near Stonehaven; West Prawle, near Plymouth ; and Simonsbath on Exmoor.[2]

In May 1939, the question of R.D.F. cover for the defence of the Forth–Clyde area, Birmingham, Liverpool, and Belfast was raised at an Air Ministry meeting called to discuss future R.D.F. requirements for the defence of Great Britain. The Air Officer Commanding-in-Chief, Fighter Command, pointed out that the

[1] Air Ministry File S.41234, Encl. 69A.

[2] *Ibid.*, Minute 122 of 13 Jul. 1939.

Observer Corps areas of Lancaster and Carlisle were sparsely populated, and communications there were poor.[1] He believed that R.D.F. might give better results there than the Observer Corps. The Director of Communications Development agreed with him, and suggested that a station should be placed on the Isle of Man. Such a station would be capable of detecting aircraft over the sea at a height of 3,000 feet at a range of 60 miles, or, at a height of 10,000 feet at a range of more than 100 miles, although the mountainous nature of the North-Western coast of England and of the adjacent coast of Scotland would prevent detection far inland. Similarly, detection could not occur far inland over Ireland, but Belfast would be covered. As the height indications of such a station would not be good, he proposed that a second station should be located at Stranraer, where plan location would be poor, but height-finding accurate.

The R.D.F. cover for the rest of Britain was reviewed. It was decided that the station at Simonsbath (Exmoor) was not likely to give the results that had previously been expected of it, in that its cover in the English Channel would not be good. It was therefore decided to abandon the station. This meant that a gap would exist between Ventnor and Prawle Point. The Air Officer Commanding-in-Chief, Fighter Command, however, felt that small gaps in the screen were not greatly important, particularly at the western end of the Chain, as the enemy could be detected and probably intercepted before he had reached the gap. On the northern coast, another small gap existed at the approach to the Moray Firth, but it was considered improbable that the enemy would know of such a gap and be able to navigate through it. More concern was felt over the inability to track raids over the Scottish Highlands ; but as it was considered technically impossible for R.D.F. to operate in mountainous areas, and the area was too sparsely populated for an Observer Corps network to be organised, reliance had to be placed on seaward detection and the local Forth–Clyde Observer Corps posts. The defence of Belfast presented an easier problem than did that of the defence of vital points elsewhere in Britain, as Belfast constituted the only likely target for enemy raids approaching Northern Ireland, and fighter aircraft would therefore know where to find the enemy. The result of the meeting was agreement to establish two full-scale Chain stations at Stranraer and the Isle of Man, with the following priority of provision :—

(*a*) The immediate establishment of an I.C.H. station at Stranraer.

(*b*) The establishment of a full-scale C.H. station on the Isle of Man, following immediately upon the completion of Netherbutton to full scale.

(*c*) Following upon the provision of the station on the Isle of Man, Stranraer to be built to full scale.

Both the two new stations were to illuminate a full circle of 360°. It was also decided that the abandoning of the station at Simonsbath would necessitate the strengthening of the station at West Prawle, by the addition of a second line of shoot.

Emergency Provision of R.D.F. Cover for Scapa Flow (June 1939)

When Treasury sanction had been obtained for the northern stations at Netherbutton and Stonehaven, there had been no provision for their establishment in " Advance " or " Intermediate " form before they were erected as " Final "

[1] Air Ministry File S.41234, Encl. 87A.

stations.[1] It was a matter of urgency that the Royal Naval base at Scapa should be given immediate R.D.F. cover, and it was decided to transfer the temporary station from Ravenscar to the Scapa site as soon as the Ottercops I.C.H. station was completed. The selected site for the Scapa station (Netherbutton) had not been finally purchased, but authority was obtained for No. 2 Installation Unit to transport the station by local contract and to take local contract action for the works side of the project.[2] In order that the station might be erected in the shortest possible time, a new site was chosen. On 1 May 1939, Ravenscar was dismantled, and the equipment reached the Royal Naval Dockyard, Rosyth, by 5 May.[3] Masts dismantled from Drone Hill were at the quayside at the same date. It was hoped to erect at Netherbutton within a fortnight, when the station would immediately be put into continuous operation. The Officer Commanding No. 2 I.U. arrived at Kirkwall on 1 May. There, he had to mark out and agree with the local agent the boundaries of the proposed site, arrange for the work on the site such as excavations for tower foundations and the laying of concrete roads, arrange for the estimates to be accepted, interview G.P.O. officials for line terminations and ducts, and liaise with contractors for the transport of huts and towers from Stromness, before beginning the work of installing the equipment. It was due to this officer's drive that the installation was completed on 25 May. The Bawdsey installation party arrived on 23 May, and by the 26th, the RF2 receiver and the TM1 transmitter had been installed and tested. The aerials and transmission lines were then erected and phased on a line-of-shoot of 130° and a test run was arranged for 1 June. During this test, a Blenheim aircraft flying at 8,000 feet was detected at a range of 60 miles when flying on the station's line-of-shoot, and at 30 miles when flying nearly 90° from the line-of-shoot, where the cover was weakest.[4] The performance of the station was considered satisfactory, and Netherbutton was handed over to the Royal Air Force on 2 June 1939.

Decision to Equip the R.D.F. Chain with C.D. Apparatus for the Detection of low-flying Aircraft (August 1939)

The inability of the C.H. stations to detect low-flying aircraft had early been realised, and this disadvantage had been thrown into prominence during the Home Defence Exercises of 1938. Air Ministry interest was therefore aroused when the War Office R.D.F. equipment known as the C.D. set (Coastal Defence), which had been developed for the detection of ships from the shore, began to show signs that it could detect not only ships but also low-flying aircraft.[5] The C.D. set had been under development by the War Office group at Bawdsey since 1936. It differed radically from the C.H. type of equipment in that, while the C.H. covered its illuminated area by " floodlight " and located the bearing of its target by means of radio goniometer, the C.D. covered its illuminated area by means of a sweeping radio " searchlight " beam.[6] The beam could be swung anywhere over the area, and automatically registered the bearing of any target it illuminated. The narrow beam of the C.D. was achieved by the use of multiple aerial arrays. A bay of four full-wave aerials placed horizontally end-to-end gave a horizontally narrow beam ; while each bay consisted of a stack of four aerials one above the other, to give a vertically narrow beam. The resulting aerial array, consisting of a total of thirty-two

[1] Air Ministry File S.41234, Minute 122. [2] Air Ministry File S.47412, Encl. 99A.
[3] *Ibid.*, Encl. 117A. [4] *Ibid* Encl. 132A. [5] Air Ministry File S.45843, Encl. 8A.
[6] Air Ministry File S.42928, Encl. 6B.

half-wave aerials, was mounted on a frame which had to be rotated by hand. To make this possible, the aerials, and therefore the wavelength of the C.D., had to be small, and a wavelength of less than two metres had been adopted. To obtain a narrow beam it is essential that the aerial system shall be of large dimensions compared with the wavelength used; thus a short wavelength allows a narrow beam without too bulky an aerial system.

The success of an R.D.F. system in detecting low-flying aircraft is dependent on its aerial system being a large number of wavelengths above the neighbouring land or sea to minimise the interference between the direct radiation from the aerial and its reflection by the surface of the earth. The lower cover of the C.D. was achieved by the employment of short wavelength, and the placing of the aerials at a great height from the ground either by the use of high towers or by siting the station at the edge of a high cliff.[1] The development of the apparatus had been delayed because it was difficult to obtain valves capable of transmitting a high power on what was then considered a very short wavelength. In view of this difficulty, the development of C.D. set had been placed on a lower priority than that of C.H. equipment which was giving promising results. But research had not been abandoned, and the group of scientists working on the C.D. set were even then looking ahead to the time when the wavelengths used would be measured in centimetres rather than metres.

Slow progress was made at first, but in June and July 1939, the War Office scientists, working under Dr. Paris at Bawdsey, began to make considerable advances with the apparatus.[2] It was named C.D.2, and, in addition to locating ships with great accuracy, located aircraft flying at 500 feet at ranges up to twenty-five miles with far greater accuracy than could a C.H. Mr. Watson Watt recommended the placing of a C.D.2 at every C.H. station in the Chain. On the 3 August 1939, the Assistant Chief of the Air Staff agreed to this recommendation, and action was taken to obtain 24 C.D. sets for the Air Ministry.[3] When modified for use against aircraft, the C.D. stations became known in the Royal Air Force as C.H.L. (Chain Home Low-Cover) stations, and it is under this name that they are henceforth referred to in this narrative.

The Main Home Defence Exercise 1939

On 8 August 1939, the R.D.F. Chain participated in the annual Main Home Defence Exercise.[4] By that time, the R.D.F. stations and their Filter Room at Stanmore had been in continuous operation long enough to have developed a standard procedure, and their performance was very different from their experimental debut of 1938. The Exercise consisted of the defence of a line from the Humber to the English Channel, and lasted for a period of three days. The R.D.F. system was in operation throughout this time. In his report on the Exercise, Air Chief Marshal Sir Hugh Dowding, A.O.C.-in-C., Fighter Command, commented :—

> " The R.D.F. System worked extremely well. The Bawdsey staff had made strenuous efforts to calibrate and overhaul all stations used in the Exercise, and their work is much appreciated. The Filter Room at Command Headquarters worked well, and the system, although doubtless capable of improvement as the result of experience, may now be said to have settled down to an acceptable standard.

[1] Air Ministry File S.42928, Encl. 21A.
[2] Minutes of the Inter-Service Committee on R.D.F.—AHB/IIE/68.
[3] Air Ministry File S.1686, Minutes 1, 4, 5, 14 and 20.
[4] Air Ministry File S.1659, Encl. 10A.

" Two partial gaps were discovered in the R.D.F. screen, one north-east of the Norfolk coast and one south-west of Dover.

" Members of the Bawdsey staff were in the Command Filter Room throughout the Exercise, and their report has been very helpful. Counting of numbers by R.D.F. was inconsistent throughout the Exercise. This will doubtless improve with training, but for the time being, R.D.F. can only be relied on to give a very rough indication of the strength of raids. The plotting in the Filter Room is capable of considerable improvement ; the " telling," on the other hand, was excellent."

The ineptitude of the plotter as compared with the other personnel was a feature noticeable in all the Operations Rooms.[1] The Service plotters, who were drawn from the unskilled trade of Aircrafthand General Duties, were liable to reposting to aircrafthand duties at the end of their period of training, which tended to decrease their interest in plotting. The Volunteer Reserve plotters were better, but remote sectors were unable to recruit the full number of one and a half watches of Volunteer Reserve plotters. The Air Officer Commanding-in-Chief, Fighter Command, recommended that the aircrafthands who were trained as plotters should remain on plotting duties for a period of fifteen months, three of which should be occupied by training, so that experience would improve their standard of plotting.

A new R.D.F. feature of the Exercise was the fitting out of several types of bomber aircraft with an automatic identification device, known as I.F.F. (Identification of Friend or Foe).[2] This I.F.F. set, which was carried in the aircraft, contained a receiver sensitive to the C.H. frequencies, which, on the reception of a C.H. pulse, triggered a transmitter which sent back an amplified pulse to the receiver of the C.H. station.[3] Aircraft equipped with I.F.F. were thus recognisable at the C.H. stations by their frequent emission of this amplified pulse. The development of I.F.F. had been continued at Bawdsey concurrently with the other R.D.F. applications, and, by an effort on the part of the Bawdsey Research Staff, some of the bombers were equipped with I.F.F. sets in time for the Exercise. As it had not been possible to carry out Service trials of the equipment, it was not surprising that technical failures occurred on a large scale ; but the Bawdsey staff were confident that these could easily be remedied. The performance of the identification device was sufficiently impressive to cause the Air Officer Commanding-in-Chief, Fighter Command, to forecast its eventual necessity to all friendly aircraft, and the Inter-Service Committee on R.D.F. to estimate a requirement of 24,800 sets for aircraft of the Royal Air Force and the French Air Force.

[1] Air Ministry File S.1659, Encl. 10A, para. 22.
[2] I.F.F. is dealt with fully in Volume V, Part 1.
[3] Air Ministry File S.1659, Encl. 10A, para. 25.

CHAPTER 5

R.D.F. OVERSEAS—PRE-WAR

By the autumn of 1937 proposals were forthcoming that R.D.F. should be included in the defence organisations of British territories overseas. The United Kingdom was to have prior claim on the initial supply of R.D.F. equipment when it came off production and there was little likelihood that R.D.F. apparatus would be available for use overseas for at least a year.[1] Nevertheless, R.D.F. missions visited Overseas Commands ; sites were selected, and plans drawn up.

R.D.F. Missions to Overseas Commands

Despite the many difficulties in the supply of equipment, the Chief of the Air Staff, Air Chief Marshal Sir C. L. N. Newall, ordered that Mr. A. P. Rowe, the Co-ordinating Officer for Air Defence in the Air Ministry Radio Development Department, should proceed to the Mediterranean on 2 October 1937.[2] The purpose of this visit was to inform the Air Officer Commanding, Royal Air Force, Malta, and the Air Officer Commanding, Royal Air Force, Middle East, of the newly developed R.D.F. system for the detection of enemy aircraft by radio. In addition, this officer was to report on how best R.D.F. could be used in Malta and the Middle East and to suggest sites for the erection of the necessary stations.

About the same time, the Deputy Chief of Air Staff thought that the Director of Scientific Research, Mr. H. E. Wimperis, who was visiting Australia, should visit some of the Far Eastern Ports on his return journey, which would be near mid-1938. The places it was suggested he should visit were Singapore, Hong Kong and Aden, the intention being that he would make a report of the problem of erecting and operating R.D.F. stations in the Far East.[3] Mr. Watson Watt prepared a memorandum for the guidance of Mr. Wimperis in his impending consultation with the Air Officer Commanding, Far East, on the methods by which R.D.F. could be employed for the defence of Singapore against air attack, suggesting possible sites for stations. Mr. Wimperis's " Missionary Journey," for so he termed it, was naturally of longer duration than that undertaken by Mr. Rowe, whose report was available by 24 November 1937.[4]

R.D.F. Recommendations for Middle East

Among the places visited by Mr. Rowe were Malta, Alexandria, Cairo, Suez, Ismailia and Port Said. After considering the requirements of both secrecy and mobility he recommended most strongly the use of mobile R.D.F. equipment for both Malta and Egypt.[5] In Malta the erection of the 240-foot Fixed Aerial Array Towers would have provided too conspicuous a target to an enemy from both sea and air. In Egypt, the erection of such fixed installations would necessarily have involved permission from the Egyptian Government—dictated by Egypt's new status under the Anglo-Egyptian Treaty of 1936. This would have placed the secrecy of R.D.F. in jeopardy. It was considered that full use of R.D.F. overseas would only be gained in conjunction with a highly-organised defence system, and the maintenance of secrecy had to be weighed against the comparatively small advantage which would be derived from R.D.F. installations at ports abroad without the support of a fighter organisation. It was

[1] Air Ministry File S.40952, Encl. 54A. [2] *Ibid.*, Encls. 18A and 34B.
[3] *Ibid.*, Encls. 10A and 49A. [4] *Ibid.*, Encl. 42A. [5] *Ibid.*

decided that the only places where benefit would outweigh the risk to the security of the new radio technique were Malta and Egypt, where it could be of considerable use in conjunction with the existing passive defences.

The British Air Attaché, Rome, considered there was an important peacetime application for R.D.F. in Malta, as the island was on a direct line between Sicily and Tripoli, and it was likely that movements of Italian aircraft would be observed, thus supplementing Intelligence sources. This would also provide an excellent means of training personnel in its use. Owing to the isolation of the island, the warning of the civilian population and A.A. defences of an approaching attack, in addition to the above function, led Mr. Rowe to recommend the despatch of a mobile R.D.F. set to Malta as soon as production permitted.

In Egypt, where the political factors were accepted as precluding the erection of permanent stations anywhere but in the Suez Canal Zone, Mr. Rowe suggested that the use of R.D.F. within the near future seemed to be confined to the provision of early warning at strategic points such as Alexandria, and recommended that a mobile set should be sent, complete with power supply, in order to test the most likely sites for the protection in war of Egypt and the Libyan border.

Although attention was focussed chiefly on the claims of Malta and Egypt for R.D.F. cover, every consideration was being given to its extension to all strategic bases abroad. In December 1937 Sir H. Tizard, Scientific Adviser to the Air Council, in consultation with the Senior Air Staff Officer of Air Headquarters, Royal Air Force, Aden, selected a suitable R.D.F. site in Aman Khal Fort, Aden.[1]

Initial Decision on R.D.F. Policy for Malta and the Middle East

After consideration of Mr. A. P. Rowe's report, the Chief of the Air Staff decided on 7 February 1938 that two mobile R.D.F. sets should be prepared, with the object of sending the first available equipment to Malta and the second one to Egypt.[2] The Chief of the Air Staff urged also that the use of R.D.F. should be extended to Singapore without waiting for the report of the Scientific Officer visiting Singapore to be received. The main object in providing these mobile R.D.F. installations was to establish the operational value of R.D.F. at places where prior warning of an enemy attack would be of great value to garrisons where no air defence organisation similar to that for Home defence was in existence.[3] The Air Staff also advised that all relevant matter concerning R.D.F. and its value in defence against air attack should be put before the Joint Oversea and Home Defence Committee of the Committee for Imperial Defence, with the object of determining the scope of this equipment for use at defended ports abroad.

Queries were forwarded to the Bawdsey Research Station, how best the supply of two mobile R.D.F. sets for overseas use could be met. In order to meet this commitment in the shortest possible time it was decided[4] that :—

(*a*) The R.D.F. installations then operating at Dunkirk in the Home Chain should be modified for overseas mobile use—thus becoming available for shipment by August 1938.

(*b*) A second set should be obtained by ordering a receiver through trade channels while the transmitter was to be made and general assembly carried out at the Bawdsey Research Station. This equipment was to be available by November 1938.

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[1] Air Ministry File S.40952, Encls. 55A and c. [2] *Ibid.*, Minute 47.
[3] *Ibid.*, Encl. 44A, para. 12. [4] Air Ministry File S.44211, Encls. 2A and 8A.

(c) A third set should be produced by the modification of R.D.F. equipment which had been housed in Army lorries during earlier tests,[1] and might be retained at Bawdsey for the training of personnel.

A minute was sent by the Director of Operations and Intelligence, Air Ministry, to the Secretary of the Joint Oversea and Home Defence Committee,[2] in which the established uses and possible further applications of R.D.F. were disclosed, its limitations explained, and the approximate costs of such installations estimated. In addition, the details of the number of personnel required to operate the different types of stations, the existing provision for their training, and the difficulties of production of R.D.F. equipment were explained. The then-existing intention of the Air Staff to send mobile R.D.F. equipment to Malta and Egypt for experimental purposes was made known to the Committee. Finally, the minute asked for the consideration of the Joint Oversea and Home Defence Committee which of the defended ports overseas were to be provided with R.D.F. and the priority in which the equipments were to be provided.

This disclosure was discussed at the next meeting in March 1938, and a considerable broadening of the R.D.F. policy resulted. The Admiralty and War Office representatives issued a Joint Memorandum to the Committee in which a priority list for the provision of R.D.F. detection equipment was given.[3] This was :—

(a) Air Defence of Great Britain—Detection of aircraft.
(b) Major ports abroad—Detection of aircraft.
(c) Fleet bases abroad—Detection of ships.
(d) Minor defended ports abroad—Detection of aircraft.
(e) Fleet bases and naval anchorages at home—Detection of ships.
(f) Defended ports at home other than (e) above—Detection of ships.
(g) Defended ports abroad other than Fleet bases—Detection of ships.

Bearing in mind the limitations of production the immediate requirements were :—

(a) Air Defence of Great Britain—Detection of aircraft with large fixed sets.
(b) Seven overseas port areas, Singapore, Hong Kong, Malta, Aden, Gibraltar, Ceylon and Alexandria—Detection of aircraft.

This was indeed a heavy programme when one considers that the Research Station at Bawdsey was struggling to produce three sets of Mobile Equipment.

Mr. Wimperis had by now visited Hong Kong, Singapore, Colombo, Trincomalee and Aden, and had submitted a detailed report on the possibilities of R.D.F. in these localities.[4] This was to prove of the greatest assistance in determining the policy of R.D.F. for the Far East.

Secrecy—its retarding effect on production

It was inevitable that the stringent secrecy restrictions of R.D.F. information would hold back production. This question was raised at the next meeting of the Joint Oversea and Home Defence Committee, the 54th Meeting, on 20 May 1938.[5] At this time only two radio firms were employed on the manufacture of R.D.F. sets and each made roughly one half of the apparatus, thus giving additional secrecy. The Deputy Director of the Scientific Research and Experiment Department of the Admiralty pointed out that a recent

[1] Air Ministry S.44211, Encl. 10A.
[2] Air Ministry File S.40952, Encls. 56A, 57A.
[3] *Ibid.*, Encls. 62A and B.
[4] Air Ministry File S.44211, Encls. 26A and B.
[5] Air Ministry File S.40952, Encl. 64A.

account in an American newspaper, the "Herald Tribune" on 21 March 1938, had given a very accurate and comprehensive description of the R.D.F. idea.[1] The Admiralty thought consideration should be given to the whole question of whether it would not be desirable to publish the fact that Britain had R.D.F. apparatus, describe the general principle on which it worked and even quote ranges, exaggerating them in order to have a deterrent effect on potentially-hostile nations. It was suggested also that in view of American knowledge of R.D.F. and possible development by them unknown to Britain, it might have been worth while to offer to exchange information with the American Government. In this manner too, assistance might also be obtained in the development of the apparatus from American wireless firms who were highly skilled and working in close touch with their Government. Air Chief Marshal Sir Hugh Dowding pointed out that although it was quite impossible to conceal the existence of the R.D.F. stations themselves, it was essential in his view to safeguard the secrecy of the actual apparatus. Broadening the basis of manufacture might compromise secrecy. The Meeting decided :—

(*a*) To invite the Admiralty and War Office to notify the Air Ministry of a forecast of their essential needs for the immediate future of the various types of R.D.F. sets they would require for all purposes, at home and abroad.

(*b*) To invite the Air Ministry, on receipt of these forecasts, to consider :—

- (i) the extent of the existing industrial capacity available for R.D.F. production ;
- (ii) what acceleration could be made in production, if existing secrecy restrictions were to some extent relaxed without compromising the secrecy of the vital elements in the apparatus.

Subsequent correspondence from Air Ministry pointed out the fallacy of the argument that other nations were in possession of information on R.D.F.[2] The "reflection" of radio waves from aircraft was known generally several years before. Other nations had worked on methods involving search by a highly directive transmitting beam ("radio searchlight") and a highly directive receiving beam ("radio telescope"). The term "R.D.F." did not refer to this, the essence of R.D.F. being "radio flood-lighting" of a large volume with a static watch over the whole volume, giving range-finding, azimuth-finding, and height-finding on any one, and all in turn, of many aircraft in this "floodlit" volume, without losing sight of the others. With this clarification of the meaning of R.D.F., the Joint Oversea and Home Defence Committee decided not to press for any public statement of the knowledge, but merely urged a greater production within the limitations of essential secrecy regulations.

The impending use of R.D.F. overseas meant an ever-widening circulation of information on this subject within the Services. With the erection of R.D.F. stations, it was to be no longer possible to maintain secrecy in regard to its existence. Air Ministry therefore notified all Royal Air Force Commands at home and abroad during April 1938, of the fact that in the near future one or more mobile R.D.F. stations were to be despatched to certain Commands overseas.[3] It was laid down that the subject of R.D.F. should never be

[1] Air Ministry File S.40952, Encl. 66B. [2] *Ibid.*, Encl. 66A.
[3] Air Ministry File S.35982, Encl. 119A.

discussed in public places or with anyone not essentially concerned. It was stressed that the strictest secrecy should be preserved in regard to :—

(*a*) The technical aspect of R.D.F. and the equipment of stations.

(*b*) The tactical employment of R.D.F. in the detection and interception of aircraft.

(*c*) The organisation of R.D.F. in a defence system.

The Munich Crisis and the R.D.F. Overseas Programme

The Munich crisis interfered with the programme for the use of R.D.F. overseas. In connection with the emergency preparations, the three mobile R.D.F. stations prepared at Bawdsey Research Station were used to augment the Home Chain on the East Coast.[1] The provision of R.D.F. cover at Malta and Egypt was therefore once more delayed owing to shortage of equipment. At this stage the mobile R.D.F. sets were not now expected to be manufactured before June 1939, but due to a determined effort to speed up production, the planned mobile equipment for both Malta and Egypt was delivered at an earlier date.[2]

The War Office advised Air Ministry during the first week of April, 1939, of a scheme for Mobile (M.B.) and Fixed (C.H.) R.D.F. stations for gun defended areas overseas.[3] All these stations were to be maintained and manned by Royal Air Force personnel. These requirements were therefore a Royal Air Force responsibility, and were submitted to the Inter-Service Committee on R.D.F. for approval as follows :—

Priority No.	*Destination of Set.*	*M.B. Stations. Category A.*	*Category B.*	*C.H. Stations.*	
1	Malta ..	1	—	1	In each case the C.H. Station replaces an M.B. Station.
2	Alexandria ..	1	—	1	
3	Aden	1	—	1	
4	Gibraltar ..	1	—	1	
5	Port Said ..	1	—	1	
6	Suez	1	—	1	
7/8	Singapore ..	1	1	1	
9	Cairo ..	1	—	1	
10/19	Field Force ..	—	10	—	
20	Hong Kong ..	1	—	1	
21	Rangoon ..	1	—	—	
22	Trincomalee	1	—	—	
23	Freetown ..	1	—	—	
24	Haifa ..	1	—	—	
25	Mersa Matruh	—	1	—	
26	Port Sudan ..	—	1	—	
27	Colombo ..	1	—	—	
28	Penang ..	1	—	—	
29	Trinidad ..	1	—	—	
30	Kilindini ..	1	—	—	

Note.—Category A—Unlikely to be moved. Category B—Mobile role.

[1] Air Ministry File S.44501, Encl. 39A and Minute 40. S.40952, Encl. 79B.
[2] Details of this are given later, under the progress made at individual bases.
[3] Air Ministry File S.44211, Encl. 47A and B.

In view of the interruption in the delivery of anti-aircraft equipment to certain ports, the Inter-Service Committee deferred their agreement to R.D.F. equipment at Rangoon, Colombo, Penang, Port Sudan and Kilindini.[1]

At the 68th meeting of the Joint Oversea and Home Defence Committee on 11 July 1939, the position of the production of R.D.F. stations was outlined in some detail by Mr. Watson Watt, as Director of Communications Development at Air Ministry.[2] He explained that there were three stages of provision to be considered. Firstly, the " Advance " provision of sets then in production, of the type which had been sent already to Malta and Egypt. Secondly, there was an " Intermediate Scale," *i.e.*, similar equipment to that already provided, using only one frequency, but with high 240-foot towers. Thirdly, there was the " Final Scale," having permanent buildings and provision for four frequencies. Although production was not due to start until mid-September 1939, it was stressed that the deliveries of radio gear were now likely always to be ahead of the execution of the Works Services required ; nine months was the normal figure for the execution of the works for a station. It was thought that this time could be reduced to six months, but the provision of timber for the 240-foot towers took time. Only Douglas fir from British Columbia or Jarrah wood from Australia were suitable. As a result, the technical equipment, though not produced at the date of this meeting, would always be on sites overseas awaiting the completion of the Works Services. The meeting therefore agreed that the production of R.D.F. sets and their provision for ports abroad had now reached a satisfactory position and that there did not seem to be any means of materially improving the rate of production.

Progress of Installations prior to the Outbreak of War

The only overseas bases actually to receive R.D.F. Mobile Stations before September 1939 were Malta, Egypt and Aden. The progress made in these territories and elsewhere is shown in the following paragraphs.

Malta

One Mobile R.D.F. station arrived in Malta on 21 March 1939.[3] Erection was begun immediately on the site selected at Dingli as a result of Mr. A. P. Rowe's visit late in 1937. The first tests indicated that the site was most satisfactory ; a range of 50 miles all round for aircraft flying at 5,000 feet was obtained. Despite the experimental nature of this equipment, it proved of such a vital and immediately urgent service that it was reorganised on a semi-permanent basis by the provision of a duplicate electric power supply plant and a stone building, pending the arrival of the permanent C.H. equipment.[4] Good progress was made with the planning of the permanent R.D.F. station requirements also nearby at Dingli. Thus, at the outbreak of war, although working on mobile equipment, the island had reasonably satisfactory R.D.F. cover.

Egypt

By 28 April 1939 the mobile R.D.F. station had been unloaded at Alexandria. Extensive tests over a period of one month were carried out on a site at El D'Aba.[5] Owing largely to transmitter defects arising from lack of spare

[1] Air Ministry File S.44211, Encl. 49c. [2] Air Ministry File S.40952, Encl. 111A.
[3] Air Ministry File S.47124, Encls. 21A, 41A. [4] *Ibid.*, Encls. 63A, 99A.
[5] Air Ministry File S.47125, Encls. 24A, 31A.

replacement parts, the tests were not completely conclusive. However, it was agreed that the mobile (M.B.) R.D.F. set was not sufficiently efficient in range for the defence of Alexandria. At that time a continuous sea patrol off the Egyptian coast was the intended method for early warning of the approach of hostile aircraft. It was therefore decided that 240-foot permanent aerial masts would have to be erected in the vicinity of Alexandria in order to obtain adequate R.D.F. cover and obviate the necessity of the sea patrol.[1] This raised two points of difficulty, namely :—

(a) Such masts could not be made in Egypt. Only Australia or Canada could supply the timber required.

(b) Delicate negotiations were necessary with the Egyptian Government to obtain its approval for the erection of permanent stations at Alexandria and Wadi Natrun without infringing essential conditions of secrecy.[2] The matter was handled successfully by the British Ambassador, Sir Miles Wedderburn Lampson, enabling plans to be made for the erection of permanent stations to cover the Alexandria–Cairo–Suez–Port Said Area.

With the outbreak of war then, only one mobile R.D.F. station was functioning in Egypt and this was not to the satisfaction of the Command.

Aden

Although this important base had been visited as early as December 1937, by Sir H. Tizard, Scientific Adviser to the Air Council, for consultation with the local Command authority on a suitable R.D.F. site, it was not until July 1939 that the final site was selected when Mr. Atherton, a technical officer of Bawdsey Research Station, went to Aden by air to choose a site for a mobile R.D.F. station.[3] The personnel and equipment were then en route by sea. On the arrival of this equipment on 12 August 1939, the erection of the station was begun. The outbreak of war occurred just as the aerial towers were being erected.

Singapore

During the visit of Mr. H. E. Wimperis to this important base, a meeting took place at the Headquarters, Far East, in April 1939, at which the Officers Commanding the three Services were present. Mr. Wimperis attended this meeting and advised the Officers Commanding on the progress of R.D.F., its advantages and limitations.[4] The Air Officer Commanding, Air Vice Marshal A. W. Tedder, pressed for the erection of a single R.D.F. station near Singapore as soon as possible, to determine any local peculiarities which might exist there as being common to this area. A site was selected at Bikut Pengerang, some 15 miles to the east of the city.[5] Because of lack of equipment, no R.D.F. cover could be provided for Singapore by the time war broke out.

Hong Kong, Colombo, Trincomalee and Gibraltar

R.D.F. sites had been selected for these ports but it was impossible to supply the necessary equipment. No R.D.F. cover was available therefore when war broke out.[6]

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[1] Air Ministry File S.47125, Encl. 32A.
[2] Air Ministry File S.5734, Encl. 4C and D, and Air Ministry File S.47125, Encl. 53A.
[3] Air Ministry File S.1056, Encls. 11A, 13A, 21A and 29A.
[4] Air Ministry File S.44211, Encl. 26D, para. 6. [5] *Ibid.*, Encl. 26B. [6] *Ibid.*, Encl. 26A.

India

Towards the end of January 1939, the Air Officer Commanding, Royal Air Force, India, Sir Philip Joubert, requested the loan of a mobile R.D.F. station for making experiments as to the feasibility of employing R.D.F. on the Frontier and in defence of the four main ports.[1] The Chief of the Air Staff, Air Chief Marshal Sir C. L. N. Newall, had to inform the Air Officer Commanding, India, that no such set would be available for at least a year, as the whole output of this equipment had been allocated to higher priorities. Despite further correspondence on this subject in the form of urgent requests from the Air Officer Commanding, India, war broke out without any provision of equipment.

Disclosure of R.D.F. Information to the Dominions

Resulting from a discussion between Mr. Watson Watt and the Deputy Chief of Air Staff, it was suggested that the Dominions should be informed in general terms of R.D.F., a brief paragraph to be inserted in the draft of the Chief of the Air Staff's quarterly Dominions Liaison Letter dated September 1938. However, on the instructions of the Chief of the Air Staff, it was deleted so that they could be advised in a separate communication, the circulation of which could be reduced to an absolute minimum.[2] The War Office and Admiralty were opposed to disclosure at this time and the matter was raised to Cabinet level, as it was considered necessary to advise the Dominion Governments concerning a defence weapon which was already in operation in this country. Approval was given for the Secretary of State for Air to convene a meeting for the purpose of expounding the position as regards R.D.F. to representatives of Canada, Australia, New Zealand, and South Africa, and of concerting arrangements for communicating this information to the Governments of the Dominions in question. The Secretary of State accordingly arranged to see the respective High Commissioners on 24 February 1939, when a statement, which had been prepared in conjunction with the Admiralty and War Office, was made. This statement which described the use of R.D.F. as a weapon and the progress made is considered worthy of inclusion in this narrative and is as follows :—

> "STATEMENT ON R.D.F. FOR THE DOMINIONS REPRESENTATIVES
>
> It has been found that wireless waves are reflected by aircraft in flight, and a technique of causing and measuring such echoes has been developed, by means of which it is possible to determine the range, bearing and height of distant aircraft. The system, which is called R.D.F., enables a single ground station to determine the position and height of single aircraft and formations in a wide and deep forward sector, and also to give some information about the size of each formation. The system is particularly suitable for dealing with high-flying raids, and it enables continuous watch to be maintained over the sector under observation.
>
> The information provided by an R.D.F. screen enables the Fighter organisation to effect interception further forward than is possible with ground observation by observers or by means of acoustical apparatus ; and in fact it has been shown as a result of tactical exercises that it is possible by means of R.D.F. to intercept the enemy on the coast or, in favourable circumstances, out to sea.

[1] Air Ministry File S.1315, Encl. 1A and D, 2D.
[2] Air Ministry File S.40952, Minutes 73–75, Encl. 73A, and S.50307, Encl. 12A.

The range at which aircraft can be detected by this means depends on the height at which they are flying. The higher they fly the greater the range of detection. Aircraft flying at 10,000 feet can be detected at a distance of approximately 100 miles to within an order of accuracy of 1 mile. At 1,000 feet on the other hand the effective range of the apparatus falls to the order of 20–30 miles. The height of the aircraft can be measured to within 500 feet, and as has already been stated, an estimate can be made of the number of aircraft in a formation.

A chain of R.D.F. stations is in the process of construction along the whole of the east coast from Portsmouth to the Tay. Of the 18 stations required to cover this front, 12 are now working and the remainder will be working by the early summer of this year.

There is a number of other applications of the R.D.F. principle which are now under development. A type of R.D.F. apparatus has now been developed which can be carried in reconnaissance aircraft for the detection of surface ships. Its effective range exceeds that of normal visibility in British waters and is independent of visibility conditions either by day or night. This equipment will greatly increase the effectiveness of reconnaissance over the sea, by increasing the area searched by each aircraft in a sweep, by increasing the closeness with which the area can be searched, and by extending to conditions of darkness and of restricted visibility the times at which sweeps can be carried out.

Another form of R.D.F. equipment is being developed for use in ships. Its function is to give long range warning of the approach of aircraft to enable a naval unit either at sea or in harbour to be ready for air attack.

There are other types of R.D.F. apparatus under trials for application to the ranging of anti-aircraft guns and the direction of searchlights on an enemy aircraft. Finally a type of apparatus is being developed for coast defence purposes, by means of which the presence of ships can be detected, and their position determined with sufficient accuracy for barrage fire.

The Dominions Governments will no doubt desire to study the R.D.F. technique, in order that advantage may be taken of our knowledge and experience in connection with the development of their own future plans for defence. It is suggested that, as and when the plans of the Dominions Governments reach the point when a study of the technical and operational aspects of R.D.F. appears desirable, facilities to examine the working of the system in this country will be given to an Air Staff and a technical representative from the Dominions Governments.

We do not think that other countries have got as far as we have in this technique. The need for the greatest secrecy in regard to the information that I have just given you is therefore obvious, and I would accordingly ask you to treat it as most secret."

At the meeting it was agreed that the High Commissioners should cable their Governments to the effect that they had been informed of a security device connected with air defence which was of sufficient importance to warrant the despatch of a physicist to this country at an early date to study it. The following physicists were given facilities for studying the scientific development of R.D.F. at Bawdsey :—

Canadian Government ..	Dr. J. T. Henderson.
Australian Government ..	Dr. D. F. Martyn (Senior Radio Physicist of the Commonwealth Radio Research Board).
New Zealand Government ..	Ernest Marsden, C.B.E. (Secretary of the D.S.I.R., New Zealand).
South African Government ..	Major-General Hoare (S.A. Ministry of Defence) and Major Wilmott.

On the departure of these representatives to advise their respective Government authorities, copies of drawings, descriptive data and blue prints were supplied.[1]

Australia

In the case of the Australian Commonwealth certain types of equipment were requested, to ensure that in the event of an emergency arising which would interfere with deliveries from Great Britain, full information would be available to admit of local production.[2] It was proposed that the Commonwealth should proceed with the production of ship detection sets for use in aircraft and in coastal gun batteries in any event, but at our request they agreed not to undertake production until we were satisfied this would not involve grave loss of secrecy. In June 1939, a request was made by the Right Honourable S. M. Bruce for a ship set (Type 79Z) for installation in H.M.A.S. " Perth," to which the Admiralty had to reply that these sets were still in the experimental stage, and blue prints and specifications would not be available before the autumn, while the actual equipment could not be supplied for over a year.[3]

The forecast of the initial requirements in R.D.F. equipment for Australia based on data discussed at the 3rd meeting of the Inter-Service R.D.F. Committee on 13 June 1939, was :—[4]

C.O. Stations	5
Mobile Stations	1
Gun Laying Sets	6
Coast Defence Sets	6
A.S.V. Sets	6
I.F.F. Set	1
S.A. equipment	1

The production of this equipment was to be reserved to Great Britain ; Australia was to provide the aerials and Works Services for the erection of these stations.

New Zealand

As a result of demands from New Zealand after the disclosure of R.D.F. information to its representative in London, the approved initial requirements of R.D.F. sets were :—[5]

C.O. Stations	2
Mobile Stations	3

[1] Air Ministry File S.50307, Encl. 46A. [2] *Ibid.*, Encl. 43A. [3] *Ibid.*, Encls. 53A and C.
[4] Air Ministry File S.41234, Encls. 111A and 121A. [5] *Ibid.*

Canada

The Canadian Government requested blue-prints of the R.D.F. equipment used in C.H. stations and the Air Ministry approved of their issue.[1] During April 1939, the Canadian Government raised the point of the manufacture of R.D.F. equipment in the Dominion. Up to the outbreak of war, however, no production had been commenced there, as production of this equipment had been reserved to Great Britain only, in the interests of secrecy. It was agreed in June 1939, by the Inter-Services R.D.F. Committee that the following equipment should be supplied initially to Canada :—[2]

C.O. Stations	2
M.B. Stations	6
A.S.V. Sets	15

South Africa

Following the disclosure of R.D.F. information to the Dominions, a preliminary discussion was held on 23 March 1939, between the Deputy Chief of the Air Staff and Major General Hoare, of the South African Ministry of Defence, on the subject of the possible requirements of R.D.F. in the Union.[3] The increased importance of Cape Town in the chain of Imperial Communications in the event of the Mediterranean being closed was visualised. R.D.F. aids to the Cape Town defences required were :—

(*a*) Three Coastal Defence (C.D.) sets for ship detection from the shore ;

(*b*) Sets for ship detection from aircraft ;

(*c*) One mobile M.B. set primarily for co-operation with fighter aircraft, but also to be used in a subsidiary role in connection with air raid warning systems. The Inter-Service R.D.F. Committee proposed that the initial scale of issue of R.D.F. equipment to South Africa would be :—[4]

C.O. Stations	2
M.B. Stations	5
Coast Defence Sets	5
A.S.V. Sets	15

Eire

No information on the development of R.D.F. was given to the Government of Eire. During April 1939, a request was received from the High Commissioner for Eire for Irish officers at present in this country to visit a Fighter Group Operations Room, for the purpose of studying our methods of fighter control.[5] Permission was given but instructions were issued on the advice of the Committee for Imperial Defence that every precaution was to be taken to avoid the R.D.F. topic, although its existence was not to be denied. If it became necessary, the Irish officers were to be told that Standing Orders were that the subject could not be discussed, and any request for information would have to be put through higher authority. If this situation arose, the Air Ministry were informed that a decision would have to come from the Cabinet.

[1] Air Ministry File S.50307, Encls. 46A and B, Minute 32.
[2] Air Ministry File S.41234, Encls. 111A and 121A.
[3] Air Ministry File S.4052, Encl. 95A.
[4] Air Ministry File S.41234, Encl. 111A.
[5] Air Ministry File S.50307, Encl. 33A.

R.D.F. Overseas prior to the War, summarised

It is clear from the foregoing that, though plans were in an advanced stage to exploit fully the advantages to be gained from the use of R.D.F. at defended ports overseas, Malta alone had satisfactory R.D.F. cover when the war commenced. Despite careful planning, the delay in establishing R.D.F. stations overseas during 1938 and the first half of 1939 was due to the shortage of radio equipment for the purpose and to the extension of the Home Chain of R.D.F. stations immediately after the Munich Crisis of September 1938. The subsequent time-lag between planning and actual installation overseas was caused largely by the period required for the Works Services in erecting such stations—approximately six to nine months, varying with local conditions.

Proposed Provision of R.D.F. to France

On 16 March 1939, at a meeting of the Committee of Imperial Defence, it was pointed out that on balance this country stood to gain more than we had to lose by taking the French completely into our confidence with regard not only to our plans but also in the matter of such secret equipment as R.D.F. on the grounds that, as the French were to be our allies, it was to our advantage that they should be as effective as possible. Accordingly, the Committee decided that the forthcoming Staff Conversations should include disclosure to the French of most secret equipment, such as R.D.F., subject to the stipulation that such of our secret equipment as the French desired to adopt must be manufactured in this country.[1] The Committee appreciated that this conclusion was somewhat in conflict with the Cabinet decision "That the Chiefs of Staff should have authority to impart to the French such information as to our plans and resources (*other than certain technical details*) as is necessary to ensure co-ordination in peace and efficient co-operation in war."[2] The Minister for Co-ordination of Defence was invited to bring the conclusion regarding R.D.F. of the Committee for Imperial Defence to the notice of the Cabinet for their approval, which was given on 30 March 1939.[3]

Disclosure of R.D.F. information to the French Air Staff was made in Air Staff discussions under this Cabinet sanction. Initial scales of demand of R.D.F. equipment by France were formulated in conference between the French Mission, the Director of Contracts, and the Director of Communications Development at Air Ministry.[4] The initial requirements for the purpose of the French Defence Service were :—

C.O. Stations .. 14 Transmitters,
14 Receivers,
and accessories for 7 stations.

The French to provide their own Works Services and aerials.

M.B. Stations .. 47 complete stations for the French Army.

In addition a forecast was made of requirements for 128 Gun Laying sets for the French Army, and 300 I.F.F. sets for the French Air Force.

Arrangements were made for six French officers, two from each of the three Services, to be attached to the Bawdsey Research Station for an eight weeks'

[1] C.I.D. 1546B, para. 3, sub-para. (*d*). [2] Cabinet 6 (39). [3] Cabinet 16 (39).
[4] Air Ministry File S.41234, Encls. 111A, 114A and 121A.

course on R.D.F. which commenced on 5 June 1939.[1] During this course these officers not only were instructed in the operation of a R.D.F. station but also saw the collation of information and its use in Operations Room technique.

The Inter-Service R.D.F. Committee considered the initial demands for R.D.F. equipment by the French among the tentative estimate of the total requirements of the full R.D.F. programme for both home and overseas.[2] These demands were accepted at the meeting on 11 July 1939, it being agreed that the production of R.D.F. equipment was to be reserved to Great Britain. By September 1939 none of the equipment had been supplied. The outbreak of war occurred with the French in possession of R.D.F. information, other than production details, and six of their officers trained in its use.

[1] Air Ministry File S.1336, Encl. 1A.

[2] Air Ministry File S.41234, Encl. 121A.

CHAPTER 6

THE R.D.F. HOME CHAIN FROM THE OUTBREAK OF WAR TO THE FALL OF FRANCE (SEPTEMBER 1939–JUNE 1940)

The development of the Early Warning Chain of R.D.F. stations up to the outbreak of war has already been described. The Chain had never been tested fully, only the stations between Bawdsey and Dover having taken part in full-scale exercises. Technical imperfections were known to exist ; production difficulties of equipment for the further expansion of the R.D.F. cover were great, and the personnel required to man the stations and filter rooms were not available in the strength or experience required. The Home Chain had been placed on a 24-hour watch-keeping basis at Easter 1939, and on 24 August 1939 the code-word " Afidock " was passed to Headquarters, Fighter Command, bringing it to a war basis.[1]

Very severe air attacks were expected in the early stages of the war but, in fact, these did not occur. At the outset then, the chief value of the home R.D.F. screen was that it rendered standing patrols by fighter aircraft unnecessary, thus conserving the small number of aircraft available to the Royal Air Force at the opening of hostilities. Without the R.D.F. chain of stations our aircraft would have had to maintain patrols, involving wastage of aircraft, the fatigue of pilots, and the heavy consumption of petrol before the enemy started to attack this country in strength. The R.D.F. Home Chain thus enabled aircraft and crews to be conserved for the Battle of Britain.

R.D.F. Chain at the Outbreak of War

When war was declared on 3 September 1939, the R.D.F. Chain in operation connected to the Stanmore Filter Room consisted of eighteen C.H. stations.[2] The two remaining C.H. Stations of the twenty-station Chain, at Netherbutton and School Hill in the north, were operating locally but were not reporting to the Central Filter Room.

None of these stations was a " Final " installation. In the rapid expansion of the R.D.F. Chain before the war along the south and east coasts, it had been necessary to establish improvised apparatus in temporary accommodation in order to provide the maximum of R.D.F. cover in the minimum of time.[3] Most of the stations were poorly phased and calibrated, although Great Bromley, with experimental facilities for avoiding D/F and height errors, was a notable exception. The measurement of the height of an aircraft was limited to below about 7° angle of elevation from the station. In addition the height estimation was unreliable at low angles of elevation.[4] Thus the plotting of very high or very low-flying aircraft was beyond the scope of the available equipment. Back-to-front sense discrimination was provided, that is, the operator could tell whether an aircraft was in front or behind the R.D.F. station when the aircraft was within a reasonable angle of the line-of-shoot. There was, however, no side reflector, so that ambiguities could occur when the aircraft was at right angles to the line-of-shoot. Since no high-powered vertical gap fillers were in use, it was possible to miss high-flying aircraft altogether.

[1] Headquarters, Fighter Command O.R.B., Aug. 1939 (Signals Branch).
[2] These locations are indicated on Map No. 1.
[3] Sir Henry Tizard's R.D.F. Committee, Interim Report, 28 Nov. 1939—A.H.B./IIE/5, Encl. 3A, para. 4 and para. 7 (*b*).
[4] O.R.S. Memorandum on *Chain Performance in Peace and War*.

During the first days of the war there were many mis-identifications of tracks due to our own aircraft lacking I.F.F. (Identification—Friend and Foe) equipment and also to the inability of damaged bombers returning to this country to fly in the pre-arranged lanes for making a landfall. On 6 September 1939, the plotting of twenty unidentified aircraft tracks in the Thames Estuary by R.D.F. and the Observer Corps caused intercepting fighter aircraft to attack each other.[1] Three friendly aircraft were shot down, one by anti-aircraft fire, although no hostile aircraft were present. In addition, many false alarms were given by sirens to the civilian population.

To effect an improvement in the use of R.D.F. in air defence, two measures were applied as vigorously as circumstances would permit. The first was to effect a more accurate interpretation of the available R.D.F. information and an improvement in the efficiency of the control of our fighter aircraft. The second was to increase the technical efficiency of the existing R.D.F. cover and to increase the number of R.D.F. stations. Neither of these measures was capable of instant implementation. The success of the former would depend largely on the skill, speed, and experience of all ground personnel, from the Controller, down through the Filter Room staff, to the R.D.F. operator. Such experience could only be gained as operations continued and there was the additional difficulty of the shortage of trained R.D.F. personnel. The efficiency of the Filter Room was increased on 7 September 1939 by the appointment there of Controllers, these officers becoming known as Filter Officers on 20 September.[2] On this date also, the first W.A.A.F. watch were on duty at the Stanmore Filter Room.

During the first month of the war, the Air Officer Commanding-in-Chief, Fighter Command, laid down that experiments should proceed at Bawdsey in the first instance, to achieve the interception of enemy aircraft by a Controller operating the R.D.F. receiver himself, with no plotting of tracks, the intercepting fighter aircraft being directed to the enemy bomber by radio telephone by the same Controller.[3] He would bring the two aircraft together, both in range and bearing, on the R.D.F. cathode ray tube itself. In practice, it was found that the drawbacks of this method were that the Controller had too much to do. While solving the interception problems in his head he had to operate the R.D.F. receiver and also exercise control of the fighter aircraft by radio telephone. Moreover during such interception control, the normal raid reporting work of the station ceased. From these experiments, Squadron Leader Tester, who had acted as the Controller, developed a simple plotting R.D.F. method giving successful interception with a minimum of interference to the normal R.D.F. plotting.

The identification of friendly aircraft in use at the beginning of the war had proved unsatisfactory.[4] The provision of I.F.F. equipment for all aircraft was regarded by the Air Officer Commanding-in-Chief, Fighter Command, as of the utmost importance.[5] Accordingly, during September, 500 I.F.F. sets were being made by hand and an order was to be placed for 10,000 sets, the design for which was almost completed. These sets were to operate on the frequencies of the Home Chain Stations, but later sets would respond to the G.L. (Gun Laying) R.D.F. equipment as well.

[1] Headquarters, No. 11 (Fighter) Group, O.R.B., Sept. 1939.
[2] Headquarters, Fighter Command Signals Branch, O.R.B., Sept. 1939.
[3] Air Ministry File S.43174, Encl. 61c, para. 2.
[4] The full story of identification systems is given in Volume V, Part 1.
[5] A.H.B./IIE/68—Inter-Service Committee on R.D.F., Minutes of 4th Meeting, para. 39.

By 19 September two of the Home Chain stations were working on full power, thus extending their range. Plans were being implemented to enable the remainder of the Chain to be similarly equipped at the rate of about one per week.[1] The Main Chain was also being extended by three further stations with a possible fourth near Kinnaird Head to cover the approach to Scapa Flow.

The most immediate requirement was cover against low-flying aircraft, based largely on the need for giving protection to coastal convoy shipping. Trials had been carried out at Bawdsey using the type C.D. (Coastal Defence) R.D.F. set, its effectiveness being well demonstrated in the detection of both surface ships and low-flying aircraft.[2] The Inter-Service Committee on R.D.F. agreed to the Air Ministry requirement of twenty-four of these sets which were to be installed at C.H. stations, though all the sets were not to be available before the end of the year. A priority list of the areas of installation of these equipments was as follows :—

Thames Estuary.	Firth of Forth.
Flamborough Head to the Wash.	Tyne and Tees Area.
Southwold to Clacton.	Scapa Flow.

These sets became known as C.H.L. sets (Chain Home Low Cover) and Pye Radio, Ltd., were given the order to manufacture them immediately.[3] The full operational capabilities of this equipment were not known until after the sets were manufactured. If its sole function was to be the detection of low-flying raiders then it was essential to site the station at the coast, because any inland site could be expected to produce standing echoes on the cathode ray tube which would impede the operator considerably. Over the sea, the range of a C.H.L. station was thirty-five miles but the effect of land reflections on this range was quite unknown.[4] Arrangements were therefore made to carry out practical tests as soon as the equipment became available.

Radio stations near the coast with such prominent features as 240-foot aerial towers obviously presented an attractive target to the enemy—the more so if his Intelligence discovered the purpose of such stations. A conference was held at Air Ministry on 24 September 1939 to consider the means to be adopted for the protection of R.D.F. stations against air attack, as the stations in their " Advance " and " Intermediate " stages depended on light A.A. defences—also in short supply.[5] The conclusions of this conference were considered by the Chief of the Air Staff and he directed that :—

(*a*) Stand-by mobile R.D.F. stations were to be provided, kept in reserve and so disposed that any one might be quickly moved and installed to provide cover where necessary to replace any Chain station which had been put out of action. A reconnaissance for suitable sites for these mobile stations was to be carried out.

(*b*) The " Intermediate " sets, when replaced by Main Chain " Final " sets at each R.D.F. station, were to be used for stand-by purposes and housed in buildings which were to be sunk to ground level at least 300 yards from the main buildings and were to be turfed over for concealment.

Steps were at once taken to implement these directions but owing to the general shortage of equipment, progress was slow.

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[1] A.H.B./IIE/68—Inter-Service Committee on R.D.F., Minutes of 4th Meeting, para. 34.
[2] *Ibid.*, para. 38.
[3] Air Ministry File S.55153, Encls. 27A and 43A.
[4] *Ibid.*, Encl. 45B.
[5] Air Ministry File S.47412, Encl. 168A and B.

By the middle of October 1939, a very serious position had been reached with regard to the paucity of certain essential R.D.F. spares.[1] Radio valves, condensers, and resistors for the Chain stations were in extremely short supply, and as a result the Chain operated on a hand-to-mouth basis. These deficiencies of radio parts, which should have been in stock at each C.H. station, resulted in the unserviceability of Chain stations for unnecessarily long periods. Certainly, had the Chain suffered the effects of hostile action, its maintenance might well have become an impossible problem due to the lack of replacement parts. Air Chief Marshal Sir Hugh Dowding, Air Officer Commanding-in-Chief, Fighter Command, made urgent representations to the Under Secretary of State for Air stressing that the Air Defence of Great Britain was in jeopardy owing to the lack of spares for the maintenance of the Home Chain of R.D.F. stations.[2]

A meeting was held at Air Ministry on 19 October, under the chairmanship of Air Vice Marshal R. H. Peck, Director-General of Operations, to discuss the measures necessary to produce an immediate improvement in the reliability of the R.D.F. Chain.[3] Decisions were taken on the broad methods of accelerating the production of R.D.F. spares. Because of this shortage the Air Officer Commanding-in-Chief, Fighter Command, had taken every opportunity provided by weather conditions and other operational considerations, to rest the apparatus in Chain stations. He was also informed by this meeting that the life of the radio valves used could be prolonged considerably by a reduction of 15 per cent. in the power output. This would have produced only a small falling-off in the range of detection. The performance of the R.D.F. Chain was causing some concern. Perhaps too much was expected of it in its existing form. The Director of Signals, Air Ministry, had put forward a scheme for a Communications Command which would unify control and ultimately provide a solution for the various maintenance problems which were the principal difficulty as far as the C.H. stations were concerned.[4] This matter was being considered by the Assistant Chief of Air Staff.

Although the Air Officer Commanding-in-Chief, Fighter Command, was reassured that efforts were now being made for the adequate provision of spares, he was not satisfied with the existing machinery of the Chain organisation.[5] In his reply to Air Ministry on 20 October 1939, he pointed out several factors which did not tend towards efficiency in the working of the R.D.F. Chain. Fighter Command was responsible for operating the R.D.F. stations but the organisation for maintaining them was not under its direct control, but under the Research Branch which had been responsible for designing and erecting them. A few of the many R.D.F. failures which had occurred were due to faulty operation and lack of detailed technical knowledge on the part of the operators, although the general standard in the circumstances was highly creditable. These personnel had been intensively trained for a short period and then sent out to distant and often inaccessible localities where adequate supervision was difficult, yet the responsibility for the efficiency of these personnel devolved upon Fighter Command. The actual Chain equipment in use had not been properly calibrated and modernised, largely due to the insistence of the Air Staff that a 24-hour watch should be maintained for the six months prior to the outbreak of war. Air Chief Marshal Sir Hugh Dowding therefore suggested that a small committee should be formed, under the

[1] Air Ministry File S.51906, Encl. 38A.
[2] Air Ministry File S.2286, Encl. 1B.
[3] Air Ministry File S.51905, Encl. 49B.
[4] *Ibid.*
[5] Air Ministry File S.2286, Encl. 2C.

chairmanship of Sir Henry Tizard, to investigate the working of the R.D.F. system and to make recommendations for its improvement. The Air Staff immediately approved this suggestion and the committee was set up, composed as follows :—[1]

Sir Henry Tizard, K.C.B., A.F.C. (Chairman).
Air Marshal Sir Philip Joubert, K.C.B., C.M.G., D.S.O.
Director of Communications Development.
Director of Signals.
A representative of Director-General of Operations.
A representative of Fighter Command.

Sir Henry Tizard's R.D.F. Committee

There was no delay in dealing with this important question of the improvement of the working of the R.D.F. Chain. The Committee held its first meeting within two days of being set up, and produced a detailed interim report by 28 November 1939.[2] After examining the existing technical imperfections of the C.H. stations then working, the Committee pointed out that it was a surprising fact that the stations were working so well. Although in the remainder of their report they dealt with defects rather than the successes of the Chain, the Committee stressed that it was not with the object of criticising the remarkable technical achievements and progress made in the past but rather to help in bringing about improvements in the future.

The Committee then commented on certain defects in the operation of the chain which were of special importance to Fighter Command. Coverage was insufficient owing to lack of stations, lack of special equipment such as the new C.H.L. sets for the detection of low flying aircraft, and lack of sufficient power supply. All these defects would disappear when the new equipment, already planned and in production, was available. There was also a loss of coverage which resulted in the observed track of an aircraft disappearing. The underlying cause of this defect, the gaps between the lobes of R.D.F. transmission, was well understood and could be removed by improved installations, though some cases might need investigation by scientific personnel. There were serious errors in bearing and height, but the notable exception of the station at Great Bromley showed that this specially designed equipment, combined with careful calibration, could eliminate such faults. There was a real inability to track with certainty aircraft flying above 25,000 feet at moderate ranges which called for special experiments. On some occasions operators had reported aircraft which were behind them as if they were in front, with consequent confusion. Instrumental defects had contributed to this confusion in the early days of the war, but there had been no defects since and only mistakes by operators could account for such ambiguities, provided that the aircraft were well within range.

The Committee decided that everything which could have been done to remove criticisms of the C.H. Chain in operation was now being done under the present system, but expressed their conviction that the operation of the Chain would not be satisfactory until the system of responsibility was changed. They recognised the important contribution to the defence of this country which the Chain had made whilst most of the responsibility had rested on the Director of Communications Development, but feared that unless the system of responsibility were changed, the position in another year's time would be

[1] Air Ministry File S.2286, Encl. 8A. [2] *Ibid.*, Encl. 9A and B, and A.H.B./IIE/5, Encl. 3A.

unsatisfactory. It was therefore strongly recommended in the report that there was much to be said for the formation of a separate Command solely for the purpose of organising the various means of tracking aircraft. The Director of Communications Development was to have experimental control of a complete operational R.D.F. Unit in at least one station in the Chain in order that new experimental equipment could be installed or altered. Such a station would be primarily a research unit and secondarily an operational unit reporting its observations into the main R.D.F. system.

In submitting this report to the Chief of the Air Staff, Sir Henry Tizard pointed out the unanimity of the views of the members of his Committee, except on the question of when such a change of responsibility should occur.[1] The Chief of the Air Staff did not concur with these views but upheld the view of the Air Officer Commanding-in-Chief, Fighter Command, that he should control and administer the R.D.F. Chain, leaving the training of R.D.F. personnel to some outside organisation like a Signals Group.[2]

First C.H.L. Emergency Programme

While the question of improvement in the complete organisation of the R.D.F. Chain was under consideration, concrete progress was being made in establishing increased coverage. As an interim measure only, on 12 October 1939, a trawler screen, which might be described as fulfilling the role of a ship-borne Observer Corps, was temporarily posted in the North Sea to augment R.D.F. information.[3] This screen reported by wireless telegraphy to the R.D.F. stations at Stoke Holy Cross and Stenigot. Within the limitations of aural and visual observation, its timely reporting was quite a success. An increase in the range of observation of this trawler screen by fitting R.D.F. sets on the ships themselves was not possible as no R.D.F. set suitable for trawlers had yet been designed ; no ship smaller than a cruiser could carry and use such a set as the C.D. equipment.[4]

By November, seven C.H. stations of the 20-Station Chain were working on full power. This gave an estimated increase of coverage per station of 30 per cent.[5] The C.H.L. programme was being pushed ahead with all speed, and on 1 November the first of these stations came on the air at Fifeness, to be followed shortly by Foreness and Walton (7 December), Easington (19 December), Shotton (24 December), Happisburgh (25 December), Dunwich (1 January 1940), Cockburnspath (26 January), and Dover (11 February).[6] The completion of this first "crash" C.H.L. programme was an achievement, as the extremely severe winter weather severely retarded progress. These C.H.L. sites were in exposed coastal positions and much of the equipment had to be man-handled on to the sites and dragged into position.[7]

This programme for the establishment of C.H.L. stations was begun originally because of the inability of the C.H. stations to "see" low-flying aircraft, and was intended to give protection to our coastal shipping convoys against direct enemy air attack. It was, however, carried out with emergency speed because

[1] Air Ministry File S.2286, Encl. 13A. [2] Air Ministry File S.4038, Minute 3.
[3] Headquarters, Fighter Command Signals Branch, O.R.B., Oct. 1939.
[4] A.H.B./IIE/68—Inter-Service Committee on R.D.F., 5th Meeting, Minutes, page 5.
[5] A.H.B./IIE/5, Encl. 3A, para. 5. Sir Henry Tizard's R.D.F. Committee, Interim Report.
[6] Headquarters, Fighter Command Signals Branch, O.R.B., November/December 1939 and January/February 1940. These locations are shown on Map No. 1.
[7] Air Ministry File S.45174, Part 1, Encl. 78B.

of the enemy's use of mine-laying aircraft.[1] The original intention of establishing one C.H.L. set on each C.H. station had to be left in abeyance, the sites of the C.H.L. stations being selected to combat to the maximum effect the new enemy tactics. Owing to the delay in the production of C.H.L. sets, G.M. sets (Modified Gun-Laying sets) were used in lieu, though the term C.H.L. station was used because of the role they were employed in. Each C.H.L. station was placed under the administrative control of the nearest Royal Air Force station as its parent unit and linked by telephone lines to the Filter Room.

Second C.H.L. Emergency Programme

Owing to the increasing tempo of enemy attacks upon our shipping a second "crash" programme of C.H.L. station installation was started in January 1940 to give additional East Coast R.D.F. cover.[2] C.H.L. stations were installed at Ingoldmells, Flamborough Head, Bamburgh, Cresswell (near Morpeth), Doonies Hill (near Aberdeen), Rosehearty (Kinnairds Head) and St. Cyrus (near Montrose). All these seven stations were working before the end of February 1940.

The strain of these two "crash" C.H.L. programmes, one immediately following the other, was felt most of all by No. 2 Installation Unit, Kidbrooke, and it became necessary to call on personnel normally employed on C.H. fitting work.[3] Mr. Watson Watt expressed concern that C.H. installation in a dependable form was being delayed by the installation work on C.H.L. stations. He stressed the point that the C.H. Chain had given valuable military results—not so far demonstrated by the C.H.L. installations. Above all, a good C.H. system, which had not yet been developed fully, was essential to the successful functioning of the C.H.L. system, the latter being designed to supplement the work of the C.H. Chain. As a result of these observations, Air Ministry agreed that No. 2 Installation Unit would revert to devoting itself wholly to C.H. station work.

Plans for the extension of the R.D.F. Chain to the South-West and West Coasts

Enemy aircraft were now making deeper penetrations ranging over the western districts of England and the Irish Sea—though not in strength. The Home Chain covering the East and South coasts only was obviously insufficiently extensive to provide the necessary early warning system. This was so urgent a requirement that on the 2 January 1940, the Prime Minister accorded the highest order of priority to the provision of R.D.F., the Air Staff having pointed out the gaps of greatest importance in our defences.[4] These were :—

Area.	*Deficiency.*
Weymouth—Torquay.	High and low cover.
Bristol Channel.	High and low cover.
Liverpool.	Low cover.
Clyde.	High and low cover.
Cromarty Firth.	Low cover.
Central Scotland.	High cover.
Shetlands (No Observer Corps).	High cover.
Devonport.	Low cover.
Scillies.	High cover.

[1] Air Ministry File S.1686, Minute 49, Encls. 12A and 28A.
[2] Air Ministry File S.3142, Minute 17, and Encl. 107A.
[3] Air Ministry File S.44282, Part 1, Encl. 287A.
[4] W.P.G./40/327 and Air Ministry File S.1686, Encl. 113A.

The Chief of the Air Staff approved a list of additional C.H. and C.H.L. stations as the minimum requirement to fill these gaps :—

C.H. Stations.	*C.H.L. Stations.*
Portland Bill.	Rye.
Lyme Regis.	Poling.
Bristol Channel (2).	Ventnor.
Clyde.	Pevensey.
Ben Nevis.	Scapa.
Shetlands (2).	Cromarty.
Orkneys.	Clyde.
Scillies.	Liverpool.
	Bristol Channel (2).
	Devonport.
	Weymouth.
	Scillies (anti-submarine).

The Director of Communications Development submitted this list to the Air Ministry Research Establishment during January 1940, in order that the general siting problems arising from these proposed extensions could be faced.[1] A special survey party was formed in order to speed up the work, having representatives from the Director of Signals, Fighter Command, the Director of Communications Development Department, and the Directorate of Works, together with a G.P.O. representative—thus establishing the correct degree of liaison between the interested Departments, a feature which had been lacking in previous sitings.[2] For such an urgent and large programme of extensions to the Home Chain in the South and West it was obvious that only the minimum requirements could be supplied. At a meeting at Air Ministry on 27 February 1940, it was decided that for these new stations the scale of provision would be two frequencies (instead of the normal provision of four frequency working) with unprotected buildings wholly above ground.[3]

Formation of No. 60 Signals (R.D.F.) Group

The Tizard Committee had pointed out the inadequacy of the organisation for maintaining and controlling the existing Home Chain at the end of November 1939, and suggested the formation of a separate Command for this purpose.[4] In December, it was decided to form an R.D.F. Group with the least possible delay. Establishments were developed and some fifty technicians from the Director of Communications Development's Department were transferred to this new Group under Mr. H. Dewhurst, who had been running the Maintenance Establishment previously. On 23 February 1940, the new formation, known as No. 60 Group, was formed at Leighton Buzzard under Air Commodore A. L. Gregory, taking over from No. 2 Installation Unit the responsibility for all Chain maintenance and modifications.[5] There were twenty-two C.H. stations and fifteen C.H.L. stations in operation at this time. Most of the C.H. stations were incomplete and plotting instructions were vague. They were working on " Intermediate " equipment with optical convertors for height estimations, though one electrical calculator for this purpose planned

[1] Air Ministry File S.44282, Part 1, Encl. 254A.
[2] A.H.B./IIE/64—*The Organisation of No. 60 Group*—Encl. 10A.
[3] Air Ministry File S.44282, Part 1, Encl. 317A.
[4] A.H.B./IIE/64, Encl. 1A, and Air Ministry File C.S.2824, Encl. 8A.
[5] Headquarters, No. 60 Group, O.R.B., February 1940.

in February 1939, was ready for testing at the C.H. station, Poling.[1] There was a large legacy of outstanding work to be hurried on. For aerial installation and phasing alone there were eighty receiving towers and one hundred and sixty C.H. aerial arrays awaiting immediate attention. A vast programme of work therefore confronted the new Group.

The responsibilities of No. 60 Group were laid down as :—[2]

(*a*) Planning and developing the operation of the R.D.F. Home Chain to meet operational requirements.

(*b*) Continuously examining and, where necessary, improving the operational, technical and administrative efficiency of the Home Chain, including the well-being of personnel.

(*c*) Examining new developments in R.D.F. with a view to their adoption and efficient tactical application.

(*d*) Liaison through Air Ministry with the Admiralty, War Office and R.A.F. Commands abroad on R.D.F. questions.

(*e*) Supervision of installation, calibration, equipment, maintenance and manning of the Home Chain.

(*f*) Assisting Air Force Units by technical liaison in the maintenance of all aircraft equipment.

(*g*) Ensuring the training needs of R.D.F. operating personnel were adequately and promptly represented to the Air Ministry.

(*h*) Collating and disseminating technical information concerning the operation and maintenance of R.D.F. apparatus.

Because of the numerous interests involved the chain of responsibility was necessarily complicated. Briefly, technical policy was to be controlled by the Air Ministry, but operational control in all its aspects remained under the Air Officer Commanding-in-Chief, Fighter Command. It was estimated that it would be April 1940 before No. 60 Group would be able to assume full duties, because the change-over of control had to be sufficiently smooth not to interfere with the efficient working of the Chain.[3]

The inception of the new Group was not without its troubles. Prior to its formation, personnel of the Air Ministry Research Establishment, No. 2 Installation Unit, Signals Staff from Headquarters, Fighter Command and representatives of the Director of Communications Development had all had access to R.D.F. stations and all had some responsibilities in connection with the drive for greater efficiency of the Chain. As No. 60 Group took over its responsibilities, the former state of affairs tended also to continue due to the zeal of the individuals concerned.[4] Thus the No. 60 Group new organisation received some interference from the formerly directly-interested parties. A firm attitude was taken by the Director of Signals, Air Ministry, who sent a signal to all Commands and Departments concerned stressing that entry to all R.D.F. stations was forbidden unless the purpose and details of such visits had been approved by the Air Officer Commanding No. 60 Group.

By 1940 the maintenance of the Chain was found to be beyond the capacity of the four Maintenance Sections, owing to the large increase in the numbers

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[1] O.R.S./4/10/2, *Electrical Calculators and Optical Converters*, and Air Ministry File C S.2824, Encl. 8A.

[2] Air Ministry File C.S.2824, Encl. 13A.

[3] A.H.B./IIE/66, R.D.F. Organisation—General, Encl. 2A.

[4] *Ibid.*, Encl. 6A and 11A.

of R.D.F. stations. The total of stations operating and proposed by that time amounted to thirty-three C.H. and forty C.H.L. This situation was to be aggravated by the planned duplication of frequency channels and the resulting increased maintenance work. In addition, the handling and issue of spares and technical knowledge had become centralised at the former Base Maintenance Headquarters, Leighton Buzzard.[1] Both for security against enemy action and for facility in distribution, a much more effective decentralisation of equipment was necessary. The Air Officer Commanding, No. 60 Group therefore recommended on 3 April 1940, that the various R.D.F. stations should be grouped into Radio Wings, each Wing being administered and technically maintained by a Unit which would replace the inadequate Maintenance Sections. These Units, named Radio Maintenance Units and later Radio Servicing Wings, eight in number, were formed on 10 July 1940.[2]

Calibration of Chain Stations

By January 1940, a few R.D.F. stations had been re-calibrated and re-phased for both height and direction finding, but technical experts were doubtful that these calibrations would remain true for any worthwhile period.[3] The variation was due mainly to the fact that end-sealing insulators were not fitted to the receiving transmission lines. A further complication was that there were no recognised methods for phasing the receiver aerial arrays and no two scientists used the same method for aerial phasing. When a method was eventually prescribed it involved frequency-measuring instruments of a standard accuracy. Such instruments for the frequency range of the C.H. stations were then non-existent. Thus the R.D.F. information passed to Filter Officers was in many cases based on information which was probably inaccurate.[4] On 25 March No. 60 Group became responsible for the calibration of all Chain Stations. To face this enormous task there was one detached flight of aircraft from the Special Duty Flight, St. Athan, which combined height and performance calibration duties with interception training for Ground Controllers at Bawdsey. Three autogyros and two pilots, together with two balloon ships and balloons, completed the resources available. To illustrate the inadequacy of the equipment, during the first seventeen days of December 1939, ninety-nine flights were ordered but only thirty were attempted. Only twelve were fully successful and six partially so. From the outbreak of war until the end of March 1940, balloons had calibrated only two stations for direction finding, whilst autogyros, since the middle of January, had calibrated five stations.

It was obvious to the Air Officer Commanding, No. 60 Group, that the calibration of stations was actually falling behind the rate at which new stations could be established, even though Fighter Command had rendered assistance by providing aircraft for performance testing. He therefore recommended that each new Radio Wing should have personnel, technical equipment, and aircraft established on it for adequate calibration. Experimental work continued to attempt to discover simpler methods of calibration of R.D.F. stations.[5] An establishment was agreed in August 1940, but owing to the shortage of aircraft it was not until after the Battle of Britain that the requirement could be satisfied. The whole Chain was then re-calibrated in some 12 weeks.

[1] A.H.B./IIE/66, para. 5. [2] Headquarters, No. 60 Group, O.R.B., July 1940.
[3] Air Ministry File S.42719, Encl. 22A.
[4] A.H.B./IIE/66, Encl. 3A, para. 6, and Air Ministry File S.42719, Encl. 22A.
[5] *Ibid.*, Encl. 3A, para. 11, and Air Ministry File S.42719, Encls. 36Y and 51B.

R.D.F. Personnel

From the beginning of the war there had been a shortage in R.D.F. personnel, both for operating and for maintaining the Chain stations. At the end of November 1939, experimental crews of W.A.A.F. operators were sent to the C.H. stations at Poling and Dover. It was considered by January 1940 that they were quite capable of carrying out the work under Royal Air Force N.C.O.s, so further W.A.A.F. courses were arranged at Bawdsey and W.A.A.F. operators were subsequently generally introduced in Chain stations.[1] The training of R.D.F. mechanics, also originally at Bawdsey, were transferred to No. 2 Radio School, Yatesbury, on 18 January 1940.

Not only had the manning of the Home Chain to be considered. By April 1940, the overseas demands for R.D.F. personnel had risen and some sixteen Transportable or Mobile R.D.F. Units had been formed and manned for use overseas.[2] As a result, No. 60 Group and No. 2 Installation Unit were generally below their establishment in personnel and faced with an overload of work in their increasing responsibilities.

[1] Air Ministry File S.3523, Encl. 8A, Air Ministry File S.47112, Encl. 25A, and No. 2 Radio School, O.R.B., January 1940.

[2] A.H.B./IIE/66, Encl. 10A.

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CHAPTER 7

R.D.F. IN THE FRENCH CAMPAIGN, 1939–1940

Prior to the outbreak of war the French technique for warning against hostile aircraft was based principally upon their "*Système de Guet*," which was similar to the British Observer Corps organisation. This was supported, rather weakly, by a radio system of aircraft detection which the French had developed independently, called "*Détection Electromagnétique*" (*D.E.M.*).[1] This consisted of a chain of alternate radio transmitters and receivers, producing a rough plan position of aircraft by observations on the beating produced between the direct wave from the transmitter to the receiver and the "reflected" wave from the aircraft. This system was inferior to R.D.F., having an approximate range of thirty miles and not giving satisfactory results on more than one aircraft.

The limitations of the French system of raid-reporting were realised by both the French and British Governments. After the disclosure of British R.D.F. information to the French Mission under General Gamelin during April 1939, plans were drawn up for the initial requirements in R.D.F. equipment for the French. It was inevitable that they would require a further considerable supply of apparatus in the near future but the whole of this R.D.F. equipment was to be manufactured in Great Britain for secrecy reasons.[2] No R.D.F. stations had been supplied to France by the time the war commenced, though some French Officer technicians had been trained in our R.D.F. technique.

R.D.F. for the British Field Force—Initial Requirements

Preparations for war included plans for the despatching of three mobile (M.B.1) R.D.F. sets to France with the British Field Force. It was thought that the eventual requirements might be four of the new type mobile (M.B.2) stations.[3] However, the development of the M.B.2 sets proceeded very slowly and the M.B.1 transmitter in production gave disappointing performances : thus when the Chief of the Air Staff called for three complete M.B. stations at the outbreak of war, the only set available was one M.B.1 which was being used for research and development purposes at Bawdsey. The set was re-erected, tested and despatched to France. It was erected on a site between Calais and Gravelines and commenced operating on 24 September, the Unit having previously reported to Headquarters, No. 60 Wing, Allonville.[4]

In order to meet the requirement for two more mobile R.D.F. stations, the Bawdsey Research Station was instructed to develop a mobile set from whatever apparatus was available, giving the best possible range on aircraft and all-round searching. The Army type Gun Laying (G.L.2) set was being produced in quantity, so this was adapted for M.B. purposes.[5] The resulting sets, given the nomenclature "G.M.", were supplied to two other R.D.F. units which proceeded to France during the first week of October 1939.

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[1] Air Ministry File S.2538, Encl. 6A.

[2] Air Ministry File S.1306, Encl. 6B, Air Ministry File S.41234, Encls. 111A and 102A, and C.I.D. 1546B, para. 3.

[3] Air Ministry File S.45967, Encl. 121A.

[4] Air Ministry File S.1796, Encl. 2A (Folder No. 1).

[5] Air Ministry File S.45967, Encls. 117A and B, Encl. 140B, and Air Ministry File S.179 Encl. 7A (Folder No. 2), and Encl. 23A (Folder No. 3).

Initial Deployment of R.D.F. Stations in France

As no experience had yet been gained with a mobile R.D.F. set deployed inland to operate over an area of military activity, it was quite possible that the apparatus might not prove satisfactory. The primary source of raid reporting was therefore a Wireless Intelligence Screen (W.I.S.) in the British zone in Northern France, consisting of Army Observer Posts linked directly to Wing Headquarters by wireless telegraphy.[1] A simple code, based on the British Observer Corps system, was used for rapid reporting of observed aircraft. By this means the Wing Headquarters had a modicum of intelligence on which to direct fighter aircraft.

On 23 September 1939, at a meeting at Headquarters, Air Component of the British Field Force, in connection with the re-deployment of the R.A.F. component in France, it was agreed that one mobile R.D.F. station should be established in the Calais area to provide early warning of low-flying aircraft approaching down the Belgian coast or attacking from seaward across the southernmost portion of the Belgian coast.[2] The second mobile R.D.F. set was to extend the R.D.F. screen south-eastwards to cover the Field Force and to provide the maximum possible warning of the approach of enemy aircraft over Belgium. The locations of the third and subsequent sets were to be related to a comprehensive plan aimed at providing continuous R.D.F. cover for the area occupied by British Forces and the likely avenues of approach thereto. According to these decisions the three available mobile R.D.F. stations were sited near Calais, at Escobecques, near Lille and at Bar-le-Duc respectively.[3] The siting of the R.D.F. stations conformed to the plans already in force for the Wireless Intelligence Screen, and thus the set at Bar-le-Duc was for the protection of the Advanced Striking Force and the other two sets were for the British Expeditionary Force and the Air Component.

The French Grand Plan—R.D.F. Proposals for France

A French chain of sixteen Chain Overseas Stations (C.O.) extending from Abbeville to the Mediterranean was envisaged as the "Grand Plan" for providing R.D.F. cover for the whole of France's threatened frontiers.[4] This was discussed at a conference held in the Air Ministry between representatives of the French Government and the Director of Communications Development on 3 October 1939, after British participation in the selection of suitable sites. The chain was to be in three sections, reporting to three filter centres, and to be built firstly between Abbeville and Auxerre, for the defence of Paris ; secondly, on the North-Eastern Frontier ; and thirdly, covering the Mediterranean coast and Rhone Valley. A fourth chain had been suggested to give warning of the approach of aircraft to the Franco-Italian frontier.[5] It was considered, however, that the R.D.F. system would be impracticable there on account of "permanent echoes" from the mountains. It was therefore suggested that an improved version of the French *D.E.M.* system would be all that was necessary.

Deliveries of C.O. station equipment from Britain were not scheduled to begin until April 1940. It was therefore agreed to supply some mobile G.M. stations to operate on or near the sites selected for the French Chain stations.

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[1] Air Ministry File S.1306, Encls. 16A and 17A. [2] *Ibid.*, Encl. 29A.
[3] A.H.B./IIH/147—D.H.O. Folder, "*R.D.F. in France*," Encl. 6A.
[4] Air Ministry File S.45967, Encl. 189A, para. 23.
[5] A.H.B./IIH/147, Encl. 2A.

In addition, fifty Gun Laying (G.L.2) sets were to be supplied in January 1940, and twenty I.F.F. sets (modified to a special frequency range covering the band 30–37·5 megacycles per second) by 1 November 1939.

A training programme for French personnel was to be put into effect through the provision by the British of three M.B.1 installations complete with aerial towers. Three Scientific Officers were to be lent to the French to set up the equipment and instruct their training staff.[1] Actually two such officers went to France for this purpose, Mr. J. F. Atherton and Mr. E. N. Shaw of the Directorate of Communications Development, Air Ministry. The French Army and Air Force training was to take place at Montpellier and the Naval training at Cannes.

There was a meeting in October between the Chief of the Air Staff and the Air Officer Commanding-in-Chief, Bomber Command.[2] The latter expressed the opinion that R.D.F. in France might be found to be not worth while. It was therefore arranged that a mission, headed by Air Marshal Sir Philip Joubert[3] and including Mr. Watson Watt, would go to France and, after examining the situation, make the necessary recommendations. The first meeting in France with the French representatives, General d'Harcourt, *Inspecteur et Commandant Superieur de l'Aviation de Chasse*, and Commandant Cazenave, of the *Ministère de l'Air*, took place on 2 November 1939 at the residence of Air Marshal A. S. Barratt commanding No. 1 British Air Mission. The discussion was limited to the method of deploying British R.D.F. mobile sets to cover the British Forces and the approaches to Paris, though there was a tendency for the French representatives to turn the conversations towards the French R.D.F. Chain.[4] Sites were agreed for the first eight mobile R.D.F. sets required to provide cover for the British Forces in the field. These would require two filter rooms to be established, the French being responsible for the provision of the necessary landlines. The information from these filter rooms would be utilised by British Fighter stations in France and French *Groupes de Chasse* for active air defence, and by the French *Système de Guet* for inclusion in the air raid warning system.

A further joint conference which was necessary to consider the permanent R.D.F. facilities of the French Grand Plan was held on 7 November, under the chairmanship of General de Division Jullien, *Inspecteur Général Technique des Transmissions de la Défense Nationale.* Some thirty-three officers attended, being representatives of the Navy, Army and Air Forces of both France and Britain.[5] The meeting accepted proposed sites for mobile (G.M.) R.D.F. sets at Bolougne, Lille (two posts), Arras, Cambrai, Avesnes, Sedan, Verdun (Damvilliers), Mont Haut (east of Rheims), Bar-le-Duc and Troyes. Each site had been considered in regard to its suitability from the point of view of landline communications, and whether these would link up with the French Grand Plan stations.

The two filter centres were to be sited at Arras and Rheims and would be called respectively Nos. 1 and 2 Filter Centres. Again, the availability of French landlines was a deciding factor in the choice of these locations. Each

[1] Air Ministry File S.45967, Encl. 189A, paras. 11 and 17.
[2] Air Ministry File S.2538, Encl. 3A.
[3] Air Marshal Sir Philip Joubert de la Ferté was attached to the Department of the Chief of Air Staff for R.D.F. duties on 28 October 1939. He became Assistant Chief of Air Staff (Radio), and held the appointment until June 1941.
[4] A.H.B./IIH/147, Encl. 1A.
[5] Air Ministry File S.B. 65067, Part I, Encl. 94C.

R.D.F. station was to be linked to its nearest filter-room (plotters' circuits) and to its adjacent R.D.F. station (reserve circuits).[1] Nos. 1 and 2 Filter Centres were to be connected to each other and to No. 1 Filter Room, Headquarters Fighter Command, Stanmore, for control circuits. Thus R.D.F. information from the stations on the South coast of England would be available in France.

The conference then proceeded with a consideration of the French Grand Plan, Mr. Watson Watt outlining this in some detail. The meeting accepted his proposition unanimously for the suggested locations and uses of the proposed C.O. chains.[2] The French Naval representatives were very keen to have their own coastal chain of stations as soon as possible. The question of frequencies in use for R.D.F. caused considerable discussion. The British mobile R.D.F. sets in France were operating on 40 and 56·6 megacycles per second, thus interfering with French Fighter aircraft radio telephony and preventing five or six squadrons from operating fully. The French Air Ministry representative, feeling rather strongly on this point, demanded on what French authority these R.D.F. sets were operating in France. It was explained that the lack of such authority was on the grounds of secrecy and that the use of these frequencies by the French Air Force had not been realised by the Royal Air Force. It was subsequently agreed to change the working frequencies of R.D.F. to avoid this clash.

During the visit of the R.D.F. Mission to France the working of the three R.D.F. stations already deployed in the field was examined. The set sited north of Calais in a marsh, was working. The set at Escobecques near Lille was not yet functioning. It was erected but the transmitter was unserviceable. The third set, at Bar-le-Duc, was unserviceable due to a burnt-out resistance. It is not surprising that the Mission decided that no information worth recording had so far been obtained.[3] This was traceable to the complete lack of organisation both on technical, administrative and tactical grounds. No specific unit or formation appeared to be in control of the three R.D.F. stations. The personnel manning them seemed to be living under difficult circumstances. The officers in charge, " young scientists," appeared to be lacking in knowledge of Service methods and procedure. It was evident that some administrative and signals supervision of these and future stations would have to be introduced in France.

Proposal for the Formation of an R.D.F. Wing in France

On his return with the R.D.F. Mission from France in November, Air Marshal Sir P. B. Joubert, in a Minute to the Chief of the Air Staff, pointed out the disorganisation and consequent inefficiency in the situation, and requested authority to set up a separate administrative and operational Headquarters for the purpose of running the developing R.D.F. mobile chain and the Wireless Intelligence Service.[4] The Air Marshal stressed that there was no question of withdrawing any of the existing R.D.F. sets, as suggested by the Air Officer Commanding-in-Chief, Bomber Command, but rather that a vigorous effort should be made to produce the additional sets required for the chain and to organise a proper system of filtering and reporting.

[1] A.H.B./IIH/147, Encl. 6A.
[2] *Ibid.*, Encl. 2A.
[3] Air Ministry File S.2538, Encl. 7A, and A.H.B./IIH/147, Encl. 6A.
[4] *Ibid.*, Minute 1, para. 6.

The fourth and fifth mobile (G.M.) R.D.F. stations arrived in France by the middle of November 1939. The fourth unit was sent to a site at Desvres, where considerable difficulty was experienced in setting up owing to the extremely boggy state of the ground.[1] The fifth R.D.F. unit was sited at Bendrel (Vimy Ridge) but this location was unsuitable by virtue of the large number of permanent echoes which cluttered up the cathode ray tube, caused by steel hoisting gear, large slag heaps, factory chimneys, and other industrial equipment in the immediate vicinity of the site. Meanwhile, considerable liaison work was carried out with the French authorities. Plans for the filter centres at Arras and Rheims and the associated line equipment were agreed between General Jullien, General Technical Signals Inspector of the French National Defence and Air Marshal Sir Philip Joubert.[2] In addition, the extension of the chain of G.M. stations was constantly under review and plans were drawn up for the subsequent deployment of G.M. sets Nos. 6 to 13 inclusive near sites intended later for permanent C.O. stations in the French Grand Plan.[3]

Formation of No. 5 Signals Wing in France

As a result of the recommendations made after the return of the R.D.F. Mission from France, it was decided by the end of November that in order to co-ordinate the arrangements in France for the siting, technical maintenance, control, and administration of all R.D.F. units in France and their associated filter centres, an organisation designated an Air Information Wing should be set up.[4] This was to work under the technical direction of the Assistant Chief of Air Staff (Radio) at Air Ministry but under the operational and administrative control of the British Air Forces in France. Suitable accommodation was obtained at Allonville for the use of the Air Intelligence Centre of the new Wing. This was to be used as a temporary filter centre until the construction of the Arras Filter Centre was complete. The composition of this new unit was met in December 1939 by the establishment of No. 5 Signals Wing, the original title "Air Information Wing" being abandoned.[5] It was decided that the Headquarters would undertake the technical control and specialised maintenance of all R.D.F. stations, filter centres, and Wireless Interception Screens in France; also the Continental Air Movement Liaison Unit and the D/F Identification Service. It was intended that the then-existing British Air Raid Reporting Liaison Sections with the French for the purpose of liaison between Fighter Command and the French aircraft detection system was also to be absorbed by the new Wing, but this was never put into effect.

The move of No. 5 Signals Wing to France began on 30 December 1939 and was completed by 20 January 1940. No. 1 Filter Centre was also formed and moved to France during this period under the control of No. 5 Signals Wing.[6] Both the Wing and Filter Centre were located initially at Allonville, the construction of the Arras Filter Centre and its associated landlines being far from complete. There had been a considerable shortage of spares for G.M. sets in France, so that unserviceability of R.D.F. units in the field had been prolonged by lack of replacement components.[7] The setting-up of the new Wing with a Section to deal with the maintenance of G.M. equipment enabled Air

[1] Air Ministry File S.1796, Encl. 59A. [2] Air Ministry File S.2538, Encls. 21A, B and C.
[3] Air Ministry File S.1796, Encl. 61A.
[4] Air Ministry File S.2538, Encls. 17A and 20A, and Air Ministry File S.1796, Encl. 56A.
[5] A.H.B./IIH/147, Encl. 12A. [6] Air Ministry File S.58993, Encls. 21B and C.
[7] Air Ministry File S.2937, Encls. 4A and B.

Ministry to instruct the manufacturers to deliver spares to Hendon airfield direct for despatch by air to the Signals Wing H.Q. It was arranged that the Equipment Section of the Wing Headquarters should include one month's holding of stores.

Progress of R.D.F. Cover in France under No. 5 Signals Wing

In the despatch of the Air Officer Commanding-in-Chief, British Air Forces in France, Air Marshal Sir A. S. Barratt, it is stated that " active steps " were commenced in January 1940 to build up an R.D.F. Screen on which a more up-to-date Allied Air Defence organisation could be based.[1] The raid reporting screen was intended to extend eventually from Dunkirk to Strasbourg, though in February only five R.D.F. stations were working, located at Desvres (Boulogne), Calais, Escobecques (near Lille), Ficheu (Arras) and Bar-le-Duc. Information from these R.D.F. stations was being filtered at No. 1 Filter Centre, Allonville. Plans were in hand for the deployment of fifteen mobile (G.M.) R.D.F. stations, which were to be increased later to forty. The sixth R.D.F. unit arrived in France early in February and was held at No. 5 Signals Wing Headquarters until hard-standings were ready at Damvillers, and until a replacement receiver trailer arrived from England.[2] The building programme, in the hands of the French, on the Arras and Reims Filter Centres and the work on R.D.F. station sites proceeded slowly. It was considerably delayed by adverse weather conditions during the winter, so progress in extending the mobile chain of R.D.F. cover was slow. No. 6 R.D.F. set was eventually sited at Le Cateau by the end of March.

For all the R.D.F. stations then operating, No. 5 Signals Wing was having difficulty in obtaining aircraft for calibration flights. These were essential if accuracy was to be obtained. The urgent need for aircraft to be allotted to the Wing specifically for performance-testing of individual stations and to obtain scientific data was stressed vigorously in correspondence to Air Ministry.[3]

The work falling on No. 5 Signals Wing Headquarters was quite heavy during March 1940. To enable the Wing to concentrate on the efficiency of the R.D.F. screen, the Wireless Intelligence Screen was transferred from the Wing, and its control divided between Headquarters, Advanced Air Striking Force and the Royal Air Force Component of the Field Force.[4] Planning was going ahead to meet the extension of the R.D.F. mobile system in the event of the Allied Armies moving forward into Belgium. As far as the actual development of the Mobile R.D.F. Chain was concerned, No. 5 Signals Wing was frustrated by circumstances beyond its control. In April 1940 the Wing was informed verbally by Air Ministry that delivery of further G.M. sets to France had been held up, the sets which should have been sent out for erection at the remaining G.M. sites having been side-tracked for other purposes.

It was not until 21 April 1940 that preparations were complete at the Arras Filter Centre, and No. 1 Filter Centre then moved to Arras from its temporary location in the Chateau d'Allonville.[5] The new centre at Arras was

[1] A.H.B./IIH2/414, *Despatch on British Air Forces in France, 15 January–18 June 1940*, Air Marshal A. S. Barratt, page 6, and A.H.B./IIH2/178, "No. 5 Signals Wing—Administration," Encl. 10A.

[2] A.H.B./IIH2/190, Headquarters, British Air Forces in France File, Encls. 1, 4A, and 24A.

[3] A.H.B./IIH2/178, Encl. 28A.

[4] *Ibid.*, Encls. 12A, 33A, and Air Ministry File S.2538, Encls. 26A and B.

[5] *Ibid.*, Encl. 49A.

underground, built beneath an old ammunition store under the city walls, and the galleries ran into the side of a hill. It was of permanent design ; on the lower floor was the ground floor of the filter room with its plotters' table in the centre. The telephone system was housed in three small rooms—the main frame room, the telephone exchange and the accumulator room. The offices of the Commanding Officer, Adjutant, Scientific Analysis Officer and the Senior French Liaison Officer were also on the ground floor. Above this was a gallery surrounding the filter room, from which the Filter Officers controlled operations and the French Air Movements Liaison Section worked. The French Grid was used on the plotting table, so all plots passed from Stanmore had to be converted from their English Grid references. Immediately after the move of No. 1 Signals Centre to Arras, some twenty French officers and one hundred and fifty French airmen were attached for liaison and training in the British technique of running a filter room.

Dissatisfaction of French with lack of progress

On 12 March 1940 a further R.D.F. conference was held in Paris between the French and British representatives.[1] The French were keen to have some of their technicians and operators appointed immediately to R.D.F. stations then working. The lack of the large permanent C.O. stations was also causing them anxiety, particularly as no firm date for their supply was forthcoming from the British. General D'Harcourt stated that the programme of supply of R.D.F. equipment was considerably behind that promised him by Air Marshal Sir Philip Joubert during his visit to France in March.[2] Despite the British inability to meet the supply of R.D.F. sets for agreed installations in France about this time, the French increased their demands for equipment by requesting R.D.F. cover for the South of France to protect that coast in the event of hostilities with Italy.[3] The Air Ministry had no alternative but to inform the French that no further R.D.F. stations were available.[4]

In view of the French dissatisfaction with the failure of the British to supply them with R.D.F. sets, British co-operation was offered to undertake R.D.F. production in France. General Jullien, however, indicated that there was no such urgency. Mr. Watson Watt had been one of the British representatives at the R.D.F. conference in Paris in March 1940, and largely by chance he discovered that the French had taken independent action in the production of R.D.F. equipment. Mr. Watson Watt visited the laboratories of Messrs. L.M.T. (*Le Materiel Telephonique*), a subsidiary of the International Telephone and Telegraph Company corresponding to the British Standard Telephones and Cables. Here he had a discussion with the Director, Mr. E. M. Deloraine, and was informed that after these laboratories had been requisitioned on 2 September 1939, he had been ordered to construct and instal near Toulon for the French Navy an R.D.F. station working on a frequency of 48 megacycles per second. Mr. Watson Watt declared this was a breach of the conditions imposed by His Majesty's Government when R.D.F. was disclosed to the French, whereby all manufacture of R.D.F. was reserved to Britain.[5] It was later learnt that another firm, *Messrs. SADIR* (*Société Anonyme des Industries Radioélectriques*), had been given the task of producing a 150-megacycles frequency Coastal Defence set. Two other firms, *Messrs. Radio Industrie*, and *Messrs. Société des Compteurs*

[1] A.H.B./IIH2/177, " R.D.F. Organisation in France," Encl. 1A.
[2] Air Ministry File S.4746, Encl. 8A.
[3] *Ibid.*, Encl. 8A, and S.2538, Encls. 28A and B.
[4] Air Ministry File S.4746, Encl. 3A.
[5] C.I.D. 1546B, para. 3.

had also been brought into the field. A London associate of the latter firm, *Société de Compteurs*, later innocently offered to help Britain by supplying details of a system of aircraft location ! Dissatisfaction was expressed with the method, though not the aim, of the French Government in bringing French contractors into the secret of R.D.F. without prior consultation or even informing the British authorities of the breach of agreement.[1] General Jullien offered no explanation of the French failure to consult British authorities but at once countered with some heat, saying that he regretted he had not taken this action earlier, the British having failed to deliver a single one of the sets promised. He admitted the high value of the British original disclosure of R.D.F. information to the French, but was obviously expressing the general dissatisfaction of the French with British supply measures.

Of the independent action by the French in disclosing R.D.F. secrets to their own firms, Mr. Watson Watt effectively commented—" Having thus torpedoed secrecy on performance specification, our Allied Navy closed the water-tight doors between their chosen contractors and ourselves, maintaining the completest secrecy about how we had overcome difficulties which they left their new agents to face *de novo*. It would be difficult to find a more effective way of jettisoning all the good and retaining all the bad in secrecy." General Jullien agreed that complete interchange of technical information was essential, but did not propose a mechanism to bring this about.

Dissatisfaction with the mobile R.D.F. screen in operation

Early in May 1940, the Air Officer Commanding-in-Chief, British Air Forces in France, communicated with Air Ministry on the failure of the mobile R.D.F. screen in practice, and the slow progress being made in the extension of the chain beyond its very limited existing area.[2] He instanced a case where a German aircraft flew in from the coast at 20,000 feet, passed right over the R.D.F. area as far as Arras and Lille (where there were R.D.F. stations) and was not plotted by any of the R.D.F. stations in France, although plots of this aircraft were being received from the Filter Room at Stanmore in England from Home Chain stations on the south coast of England. Air Marshal A. S. Barratt stated that despite efforts under No. 5 Signals Wing to build up an effective R.D.F. screen between January and May 1940, the results from this screen could only be described as disappointing.[3]

The No. 1 Filter Centre itself was working, but on quite inadequate material. The information passed from this centre was regarded by both General D'Harcourt and Group Captain Fullard, Officer Commanding No. 14 Group, as of " nuisance value only."[4] The continuous parts of tracks given were too brief, there was a failure to obtain a good range on high-flying aircraft, and there was no identification of aircraft, friend from foe. These were not faults of the centre but of the raw material of the information supplied to the centre by individual R.D.F. stations. Group Captain Fullard complained with justification of complacency about these stations, and General Jullien's criticism that the Filter Centre at Arras—" a very expensive centre "—was useless, was true to the extent that no useful information was coming from it at the time.

[1] Air Ministry File S.4746, Encl. 3A.
[2] A.H.B./IIH2/189. Headquarters, British Air Forces in France File, " R.D.F. Policy," Encl. 8A.
[3] A.H.B./IIH2/414, para. 22.
[4] Air Ministry File S.4746, Encl. 13A, para. 11.

A picture of the actual performance of each R.D.F. station in the field during the major battles of France is given in an interim report on 17 May 1940, from Mr. Watson Watt to the Director of Signals, Air Ministry, after his visit to France on 13 May.[1] The details were as follows :—

No. 1 *Station* .. (M.B.) Calais. Good set on a poor site. Plots of aircraft at 60 kilometres distance agreed within 5 kilometres with plots taken by Dover C.H. station on the same aircraft.

No. 2 *Station* .. (G.M.) Le Treport. Set partly modified for one-way looking to the North. Very few plots, performance appeared poor.

No. 3 *Station* .. (G.M.) Escobecques (near Lille). Poor set on a poor site, plots local activity only but had no operational value whatsoever.

No. 4 *Station* .. (G.M.) Descres (near Boulogne). Bad set on an excellent site. No plots seen at all during the inspection.

No. 5 *Station* .. (G.M.) Ficheux (near Arras). A good site. The set was partly modified for one-way looking but was clearly ill-adjusted when seen. It was unserviceable due to electrical power failure of the Lister diesel engine on the night that Arras town was bombed.

No. 6 *Station* .. (G.M.) Le Cateau. This was the best G.M. set in use, most completely modified for one-way looking but the coverage diagram was unduly narrow. Plots of over 100 kilometres were obtained along the line of shoot to the North but the ranges were very short at 60° of this line.

Summarising, Mr. Watson Watt observed that none of these stations was of substantial operational use in its existing state, numbers 3, 4 and 5 having no operational value whatsoever. He recommended their withdrawal to No. 5 Signals Wing for modification.

The Reims Filter Centre was rapidly nearing completion in May 1940, work having been pushed ahead rapidly after the set-backs due to the severity of the previous winter.[2] The termination of the landline facilities and the internal wiring of filter room equipment was being done by British G.P.O. engineers. Filter room personnel intended for No. 2 Filter Centre had been trained at No. 5 Signals Wing Headquarters and were ready for drafting in to Reims when required. The French stopped work on the No. 2 Filter Centre early in the opening stages of the Battle of France. As a result, the six British G.P.O. engineers and all their terminating equipment were withdrawn on 15 May to No. 5 Signals Wing H.Q. The buildings were subsequently blown up. As no additional R.D.F. stations had been erected in the Reims area, the delay in the preparing No. 2 Filter Centre had had no material effect on the Mobile R.D.F. Chain. All R.D.F. units in the field had concise instructions from No. 5 Signals Wing Headquarters on the emergency action to be taken in event of having to abandon the station due to enemy action.[3] No. 6 Mobile R.D.F. Station was urgently recalled from Le Cateau, being in the path of the German advance, and the unit was evacuated to No. 5 Signals Wing Headquarters.

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[1] Air Ministry File S.4746, Encl. 13A, para. 1. [2] A.H.B./IIH2/178, Encl. 53A.
[3] A.H.B./IIH2/177, Encl. 10B, and No. 5 Signals Wing, O.R.B., May 1940.

The evacuation of No. 5 Signals Wing from France

On 17 May, the Officer Commanding No. 5 Signals Wing received instructions from the Headquarters, Air Component of the Field Force to evacuate his Headquarters, together with No. 1 Filter Centre, to Abbeville.[1] The Filter Centre at Arras, which had been in use for a month only, was destroyed before it was left. Instructions were issued to all mobile R.D.F. Units except No. 1 to join the Wing at Abbeville. No. 1 Unit was dismantled, part of the equipment salvaged, the remainder destroyed and the unit was evacuated through Calais. On 19 May orders were received to proceed to Le Havre. Here No. 1 Filter Centre and the remaining five R.D.F. units ceased to exist as separate units, being absorbed into No. 5 Signals Wing.[2] Two days later the Wing was instructed to retire to No. 2 Base Area, Nantes; the road party with technical vehicles spent two days and nights en route due to the traffic congestion on the roads. The rail party of personnel journeyed nearly five days in cattle trucks to reach Nantes.

The use of R.D.F. in its inadequately mobile form was impracticable for the fluid warfare which had developed, and Headquarters, British Air Forces in France recommended to Air Ministry that No. 5 Signals Wing should be evacuated to England with all its equipment.[3] On 2 June, orders were received by the Wing to entrain for Cherbourg, the main rail party sailing on the following day for Weymouth.[4] The prime movers and technical equipment were embarked for Southampton on 6 June.

Causes of Failure of R.D.F. in France

In view of the strong opinions voiced by Senior Officers in the French Campaign and by Mr. Watson Watt, the application of R.D.F. in the form of modified G.L. sets must be regarded as an almost complete failure. The limitations of the technical equipment supplied to the mobile R.D.F. units was the largest single contributory factor. These R.D.F. sets, produced under emergency conditions, were inadequately tested for use in the field. The technique of an R.D.F. watch over land was previously untried. The chief limitations of the equipment when functioning normally were :—[5]

(*a*) Short range due to low height of towers (70 feet).

(*b*) Low transmitter power, also reducing the range.

(*c*) Blind patches in a vertical plane, often resulting in an aircraft not being observed.

(*d*) Uneven range in various directions in the horizontal plane due to the configuration of the ground.

(*e*) The available information for observed aircraft was inadequate for operational use because :—

  (i) there was no satisfactory height estimation;

  (ii) there was no identification of enemy and friendly aircraft.

Even within the range restrictions imposed by the equipment, these sets were not always sited to best advantage by the experts responsible for the selection of locations well in advance.[6] As a result, the station then had no operational value whatsoever although the personnel manning it were working quite satisfactorily.

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[1] No. 5 Signals Wing, O.R.B., and A.H.B./IIH2/414, Appendix " S," page 5.
[2] *Ibid.* [3] Air Ministry File S.1796, Encl. 73A. [4] No. 5 Signals Wing, O.R.B.
[5] Air Ministry File S.1796, Folder 1, Encl. 18A.
[6] Air Ministry File S.4746, Encl. 3A, para. 1, and S.2973, Encl. 20A.

The officers in charge of these R.D.F. units in France were very keen and were mainly Volunteer Reservists of good technical knowledge. They submitted helpful ideas and suggestions to Air Ministry for improving the performance of their R.D.F. equipment.[1] They were, however, lacking in experience and knowledge of Service methods.[2] For the first four months in France the units were neglected by the higher formations and, as a result, they were permitted too much laxity to experiment with their equipment, making unofficial modifications in an attempt to overcome the defects in their apparatus. Aerial systems were changed and even frequencies were altered on occasions to improve the performance figures of the station. Although these are healthy signs of initiative and enterprise, technical development by experiment is not the work of units in forward areas during a campaign.

The stations were seriously hampered throughout the whole period by lack of spare parts for replacement and repair purposes. During the initial months there was no source from which technical supplies could be obtained quickly.[3] Up to the end of 1939 there were not even stores references in the Royal Air Force vocabulary or secret equipment lists for ordering these components. The parts themselves were in extremely short supply. Arrangements had to be made for delivery from the manufacturers to be flown directly to France. There was undoubtedly a lack of organisation in the supply of spare parts for these G.M. sets. Even towards the end of the campaign, spares were arriving very slowly; demands raised in March had not been met in May.[4] This is not a reflection on the equipment organisation; many of the parts demanded were unavailable for the simple reason that they were not even manufactured. With no complete spare R.D.F. transmitter and receiver available on each unit, a station would be off the air for varying periods for routine servicing or for breakdowns. The infrequent availability of aircraft to make runs over the stations for calibration and performance checking was a serious drawback to the operational efficiency of stations.[5] No. 5 Signals Wing made strong attempts to remedy this state of affairs.

The reliability of any radio equipment is never greater than the reliability of its electrical power supply. Each station had one Lister Diesel-Electric Generator only. Spare Listers were not available and were not expected to be available until May 1940.[6] As a result, R.D.F. stations were off the air owing to power supply failure at times when they were most urgently required. No. 5 Station at Ficheux, near Arras, was unserviceable for this reason when Arras town was bombed during May 1940.[7]

The timely evacuation of R.D.F. units from France effectually prevented the capture of equipment of considerable security value. Concern was felt however regarding the extent of any compromise which might occur as a result of the disclosures of R.D.F. information which had been made to the French. A note on this aspect appears at Appendix 57.

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[1] Air Ministry File S.1796, Encl. 59A.

[2] A.H.B./IIH/147, Encl. 6A, and Air Ministry File S.1796, Folder 2, Encl. 6E, and Folder 6, Encl. 6A.

[3] Air Ministry File S.1796, Folder 5, Encl. 6B, and Air Ministry File S.2937, Encls. 1A and 4A.

[4] Air Ministry File S.1796, Encls. 18A (Folder 1) and 67A.

[5] A.H.B./IIH2/178, Encl. 28A.

[6] Air Ministry File S.2937, Encl. 5A and Minute 19.

[7] Air Ministry File S.4746, Encl. 3A, para. 1.

CHAPTER 8

PROPOSALS FOR EXPANSION AND PROGRESS OF R.D.F. ABROAD, SEPTEMBER 1939–JULY 1940

At the outbreak of war the Joint Oversea and Home Defence Committee, which had considered R.D.F. requirements prior to the War,[1] had lapsed and in consequence no central record was available of the progress in the provision of R.D.F. for ports abroad, though material changes had taken place in the general situation. The Port Defence Committee of the Chiefs of Staff Committee, War Cabinet, therefore reviewed the position in December 1939 in the light of the effect of the War on the relative importance of ports. Special consideration was given Rangoon and the Indian ports[2] The situation regarding the supply of R.D.F. was, however, so obscure that further consideration of the order of priority of supply for ports overseas was deemed unprofitable. The Air Ministry was therefore invited to circulate the required information to the Committee and include details regarding siting reconnaissance and the works services for installations of sets already approved.

The Director of Plans, Air Ministry, prepared a note for circulation to the Port Defence Committee on 18 January 1940 stating that it was not possible to give a definite rate of production, because as the production of one type was advanced the others were retarded, and the completion of the home emergency programme was the first consideration in this respect. Subject to unforeseen emergencies it was estimated that M.B.2 sets would be available by May 1940, C.H.L. equipment would be available by June 1940, and C.D. sets could not be produced while they were only in the development stage. The note was considered immediately by the Port Defence Committee. It was thought worth while to provide the maximum possible scale of R.D.F. at ports where fighter aircraft would be operating defensively, but at ports where only A.A. guns were installed a C.H.L. set would suffice. It was agreed that Alexandria, Aden, Malta, Port Said and Singapore should be equipped with both C.O. and C.H.L. sets, in that order of priority, and that Gibraltar, Haifa, Freetown, Trinidad, Trincomalee and Hong Kong should next be equipped with C.H.L. sets only.[3] Port Sudan, Rangoon, Colombo, Penang, Bombay, Calcutta and Karachi were to be included in the order of priority at a later date, and it was also suggested that Canada and South Africa would find it desirable to order R.D.F. equipment for Halifax, Vancouver and the Cape.

At this same meeting of the Ports Defence Committee there was a discussion on the inadequacy of the machinery for allotting R.D.F. equipment. It was suggested that the best means of securing a reasoned order of priority would be for the Deputy Chiefs of Staff to deal with this matter in a similar manner to that in which they had already dealt with the allotment of A.A. guns. The Air Ministry, as the responsible department for supplying R.D.F., would be able to prepare a statement every month showing authorised demands, the probable production, and the proposed allocation.[4] The approval of the Deputy Chiefs of Staff Sub-Committee was invited to this proposal.

[1] *See* Chapter 5—R.D.F. Overseas—Pre-War.
[2] Air Ministry File S.40952, Encls. 121A, 123A, 124A and 127A.
[3] *Ibid.*, Encl. 131B.
[4] *Ibid.*

The Inter-Services R.D.F. Committee met on 9 February 1940, to consider how the requirements of the first five important ports could be satisfied. The provisional programme agreed upon was :—[1]

Alexandria	M.B.1 (already there)	C.H.L. in May	M.B.2 in mid-March.
Aden	M.B.1 (already there)	C.H.L. in May	M.B.2 at end of March.
Malta	M.B.1 (already there)		
Malta	M.B.2 in April	C.H.L. in May	M.B.2 at end of March.
Port Said	M.B.2 in April	C.H.L. in May	
Singapore	M.B.2 in April	C.H.L. in May	

Instructions were also given by the Committee for the preparation of a statement to show proposed production, authorised requirements and suggested allocation of the various types of R.D.F. stations for submission to the Deputy Chiefs of Staff for their approval. In this manner the Committee was to receive guidance on the strategical aspect of the allotment of the principal types of R.D.F. sets.

Pressure from the Middle East for more R.D.F. installations

In January 1940, three sites had been selected for R.D.F. stations in Egypt at Alexandria, El D'Aba, and 20 miles West of Helwan. The Air Officer Commanding-in-Chief, Middle East, concurred with the suitability of these sites to guard against attacks from Libya, but urged that the allocation was insufficient as he desired to prepare for the threat of German bombers from Bulgaria.[2] He also wanted a further two mobile (M.B.) sets to be provided as potential cover for a proposed air contingent proceeding to Turkey. Air Ministry was unable to meet this request. The scientific officer, Flight Lieutenant Atherton, attached to Headquarters, Middle East, had by March 1940 completed his report giving siting recommendations for C.O. and C.O.L. stations.[3] These were as follows :—

C.O. Stations	Ikingi Maryut
	Wadi Natrun
	Cairo
	Damietta
	Ismailia
C.O.L. Stations	Aboukir
	Port Said
	Cairo

Although in complete agreement with these proposals, the Air Officer Commanding-in-Chief, Middle East, realising the time taken to site and erect R.D.F. stations of these types, was not satisfied with the actual provision of R.D.F. cover for the Middle East, and pressed in a personal signal to Air Ministry in July 1940 for the supply of :—[4]

6 further M.B. stations for Egypt.
1 (additional) station for Aden.
At least one, preferably two, for each of Mombasa, Khartoum and Port Said.
1 or 2 (additional) for Malta.

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[1] Air Ministry File S.40952, Encl. 136A.
The term "C.H.L." ceased to be used for overseas low cover sets in February 1940 ; they were then called "C.O.L." stations. The chief difference between C.O.L. and C.H.L. equipments was that the former were semi-tropicalised.
[2] Air Ministry File S.5734, Encls. 13A, 16A and Air Ministry File S.47125, Encl. 90A.
[3] Air Ministry File S.47125, Encl. 128A.
[4] *Ibid.*, Encl. 172B.

The representations of the Air Officer Commanding-in-Chief, Middle East, could not be ignored. There has been some delay in implementing the decisions of the Port Defence Committee meeting of January 1940, as this committee had been acting on information which later proved to be inaccurate.[1] At a further meeting on 22 May 1940, a decision was taken that R.D.F. cover against high-flying and low-flying air attack was to be provided at all the ports for which C.O. sets were to be supplied and also at Kilindini. In addition, on 2 July 1940, the Air Ministry wished Port Sudan to be added to the list. The following revised order of priority for the provision was recommended by the Inter-Services R.D.F. Committee (upon which the Port Defence Committee was then represented) :—

1 Alexandria (Ikingi Maryut)
2 Cairo (Gebel Qatrani)
3 Wadi Natrun, Egypt
4 Damietta
5 Suez (Ismailia)
6 Additional station in Egypt
7 Malta[2]
8 Aden
9 Gibraltar
10 Haifa
11 Singapore
12 Khartoum
13 Port Sudan
14 Kilindini
15 Freetown
16 Trinidad
17 Hong Kong
18 Trincomalee }
19 Rangoon } Deferred
20 Colombo }
21 Penang }

This proposal, approved by the Treasury Inter-Service Committee, was the stage reached at the time of the emergency at home occasioned by the fall of France.

Egypt

The mobile R.D.F. station, situated at El D'Aba on the Egyptian coast midway between Alexandria and Mersa Matruh, had been working for six months by November 1939 when Air Chief Marshal W. P. Mitchell, the Air Officer Commanding-in-Chief, Middle East, rendered a report on the performance of this station to the Under-Secretary of State for Air.[3] He explained that the original intention to use this R.D.F. station in its mobile form to test the suitability of various sites in Egypt for R.D.F. working had not been carried out, since the political situation in Egypt at the time and the necessary provision of R.D.F. cover against air attack for the Fleet in Alexandria harbour

[1] Air Ministry File S.44211, Encl. 69A. These decisions of the Port Defence Committee were given earlier in this chapter.
[2] Malta. The plans for the C.O. station were temporarily suspended owing to enemy bombing, but there was no suspension of the C.O.L. provision.
[3] Air Ministry File S.47125, Encl. 80A.

had precluded such site-testing. The Air Chief Marshal expressed his grave concern at the limited range of this mobile station and its inability to determine the height of aircraft. He pressed strongly for a C.H. station to be provided as soon as possible. Replying at the end of November 1939 the Air Ministry informed the Middle East Command that the priority for the provision of R.D.F. stations in Egypt had been reduced owing to increased commitments in the United Kingdom and France under the initial condition of war.[1] However, in order to improve the performance of the mobile R.D.F. equipment already in use, 250-foot high special timber masts already promised for the aerial system of the mobile R.D.F. set were provided. These were rushed out in January 1940 by the Navy at " emergency speed."

Meanwhile in anticipation of the arrival of a further two M.B. sets, plans were made for their installation on sites at Aboukir and Ikingi Maryut, near Alexandria. Consequently it was decided to erect the 250-foot masts at Ikingi Maryut immediately they arrived.[2] The mobile M.B. station at El D'Aba was withdrawn for overhaul and re-erected near Aboukir for the purpose of giving warning to the A.A. guns against possible long-range German aircraft attack. The selection of sites for R.D.F. stations had not been easy. It was essential that firm foundations for buildings and the erection of towers should be available and although many sites were found which were satisfactory with regard to height above sea level, the presence of shifting sand dunes, sand quarries, antiquity excavations and the like enforced a renewed search for other sites with firm foundations.[3]

Another difficulty was the absence in the Command of technical officers who were experienced in the operation and maintenance of R.D.F. installations. Knowledge of the behaviour of radio components under Middle East conditions was scanty even with the experts who were eventually sent out. Humidity played havoc with the installations until tropicalisation of all sets was effected.[4] Considerable assistance was, however, afforded to the Command when R.D.F. technical officers from England arrived. Flight Lieutenant Weakes, of the Air Ministry Research Establishment, was sent to Egypt to assist with the erection of the aerial arrays on the new 250-foot masts, and early in February 1940, two officers, Flight Lieutenant J. F. Atherton and Flying Officer Cotten of the Directorate of Communications Development, Air Ministry, also arrived to give technical assistance with the existing equipment and to make recommendations for future development and siting of R.D.F. stations throughout the Command.[5] Flight Lieutenant Atherton paid a visit to the mobile A.M.E. station at Aboukir at the end of February 1940. His technical report, submitted to the Director of Signals, Air Ministry, gives a detailed account of the performance of this M.B. station[6]. He found that the equipment gave a slightly reduced range estimation, and that some indication, rough only, of the height of an aircraft was being obtained.

By May 1940 the work at Ikingi Maryut was proceeding rapidly ; transmitter and receiver huts and a power house had been built.[7] The 250-foot aerial towers were in the last stages of erection. In order to improve the power supplies, two 25-KVA 3-phase Diesel-electric generators were being sent from England. The two expected M.B. sets had also arrived, one of which was to be located on

[1] Air Ministry File S.47125, Encls. 87A and E, 94A, and Air Ministry File S.5734, Encl. 8A.
[2] Air Ministry File S.47125, Encls. 47A, 48A, and Air Ministry File S.5734, Encl. 19A.
[3] *Ibid.*, Encl. 47A. [4] *Ibid.*, Encl. 94A. [5] *Ibid.*, Encl. 100C.
[6] Air Ministry File S.47129, Encl. 122A and B. [7] *Ibid.*, Encl. 147A.

the old site at El D'Aba. There was a temporary set-back on this site, however, the transmitting aerial tower being completely destroyed by gales.[1] Early in June the R.D.F. cover was vastly improved, although still far from perfect. The two new M.B. sets were now in operation and, with the original M.B. set formerly installed at El D'Aba, formed a three-station chain,[2] Ikingi Maryut–Aboukir–El D'Aba. Ikingi Maryut had 250-foot masts and the other two had 70-foot masts.

As has already been stated the Air Officer Commanding-in-Chief, Middle East, was still not satisfied with the existing R.D.F. cover or the plans for the future. He requested a further six M.B. stations for Egypt by personal signal to Air Ministry.[3] Air Ministry pointed out that additional supplies were governed by availability of radio gear and trained crews to man it, but two further M.B. sets and crews were diverted to the Middle East at the beginning of July 1940. The higher power M.B.2 transmitter and the R.F.7 receiver were in fact ready in the United Kingdom for despatch to Ikingi Maryut.

The 250-foot high aerial towers at Ikingi Maryut must have attracted the attention of the enemy Intelligence, for the station was bombed twice on 16 July 1940.[4] Fortunately no damage was done to the M.B. equipment or the masts, but the technical stores were damaged. The transmitter and receiver were removed from their huts and placed below ground and urgent demands for replacement valves were sent to the United Kingdom. Thus, at the time when Britain was facing its most critical hour after the Dunkirk evacuation, R.D.F. stations in Egypt were also receiving the enemy's attentions.

Malta

At the outbreak of war the only R.D.F. installation working in Malta was the M.B. set situated at Dingli at a height of 800 feet.[5] Technically the equipment was giving a good performance. The transmitting aerials were arranged to " illuminate " over a full 360° so that all round R.D.F. cover was obtained. The aerial system was mounted on four wooden telescopic towers 70 feet high. In order to improve working conditions and mitigate the effects of high temperature on the set, the equipment was housed in stone buildings. The results obtained were good for the equipment in use. Single aircraft were detected at 70 miles at 10,000 feet and at 30 miles at 2,000 feet. No height measurements were possible with this equipment. Unfortunately, with only one set, the necessary servicing limited the watch to approximately 12–16 hours per day.[6] In order to give the full 24 hours daily R.D.F. cover to the Island, a second M.B. set was sent to Malta early in July 1940. This was sited at Dingli also, and thus continuous watch coverage was achieved. In consequence of hostile bombing it was necessary to defer part of the proposed installation of the permanent C.O. sets at Dingli.[7]

Aden

Considerable delays occurred before the mobile R.D.F. station was operational at the site at Aman Khal Fort, although the equipment had arrived at Aden just before the outbreak of war.[8] The original difficulties were due to labour

[1] Air Ministry File S.47129, Encl. 145A. [2] Air Ministry File S.47125, Encl. 166A.
[3] *Ibid.*, Encls. 172B, 173A, 176A. [4] Air Ministry File S.5734, Encl. 43A.
[5] Air Ministry File S.47124, Encl. 106C. [6] *Ibid.*, Encl. 106B.
[7] Air Ministry File S.44211, Encl. 67A.
[8] Air Ministry File S.1056, Encls. 29A, 30A, 34A, and A.H.B./IIE/70, R.D.F. Overseas Folder, Minute 19.

troubles and lack of knowledge of tower erection. The completion of the Works Services did not end the delay, and the Air Officer Commanding, Aden, asked for assistance from Air Ministry. A technical officer was despatched to investigate the trouble.[1] The packing case containing the receiver had been flooded by a cloud-burst during installation, necessitating some re-wiring which was done incorrectly owing to the absence of blue-prints. In addition persistent breakdowns of technical components occurred and the tropical, humid climate was affecting the soldered joints.[2] The officer observed in his report that much of the initial inefficiency of this station had been due to the personnel not being experienced enough to use the equipment, and that a more thorough testing of the radio gear sent overseas should have occurred in the United Kingdom prior to despatch. Lack of stores and other facilities made experimental work on site a very difficult and haphazard proceeding.

By March 1940, the station was operating but only on the seaward quadrant. Further investigation showed that lack of performance on the landward side was due to a long range of hills in the hinterland causing permanent echoes. After continued experience, R.D.F. operators became sufficiently skilled to distinguish aircraft indications among the permanent echoes. By the time Italy declared war the station was working satisfactorily. One Army G.L. set was installed by the garrison, and H.M.S. "Carlisle," which periodically visited Aden, was also equipped with a G.L. set. Continuous R.D.F. cover was thus maintained, despite periodical overhauls or temporary breakdowns, by amicable inter-Service co-operation.[3]

By July 1940, Malta, Egypt and Aden all had some measure of R.D.F. cover. Fortunately, the R.D.F. equipment on Malta was functioning best, and it was there that efficient raid reporting was required most of all. Progress in the installation of R.D.F. equipment overseas had been slow. The non-availability of apparatus, shipping delays in wartime, and the lack of experience in the operation of R.D.F. equipment in hot climates, all contributed a delaying effect on the overseas R.D.F. programme.

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[1] Air Ministry File S.1056, Encls. 38A and 58E. [2] *Ibid.*, Encls. 52A and 58E.
[3] *Ibid.*, Encl. 61A.

CHAPTER 9

THE HOME CHAIN UNDER THE THREAT OF INVASION (MAY–JULY 1940)

When the Germans moved into Denmark and simultaneously launched their invasion of Norway on the night of 8 April 1940, the Air Component of the British Expeditionary Force for Norway was already assembled at the Royal Air Force Station, Uxbridge. This included four Transportable Radio Units destined to give R.D.F. cover for the ground forces after landing. An R.D.F. reconnaissance party of two officers visited the Narvik area immediately after the Expeditionary Force had landed, and toured the district. They reported that M.B. and G.M. transportable R.D.F. stations would be valueless there because of the extremely mountainous nature of the terrain.[1] Only C.H.L. stations would have had any real value. The Officer Commanding the Air Component of the North-West European Force therefore decided on 29 May that there was no immediate need for R.D.F. facilities in North Norway, and the Transportable Radio Units did not embark.

After the evacuation of the Expeditionary Forces from Norway the Germans held an extended coastline facing the north-eastern coast of Britain. Some improvement in R.D.F. cover in this area was necessary and three further C.H. stations were proposed immediately for the north-east of the British Isles, at North Unst, Sumburgh and Sanday.[2] The Inter-Services R.D.F. Committee also approved C.H.L. stations commensurate with the above commitments, in order to cover the Orkneys and Shetlands area.

The Fall of France and Emergency Extension of the Home Chain

As the enemy advanced towards the Channel during May 1940, not only was additional R.D.F. cover required in Britain along its north-eastern coast, but also for the western districts. On 25 May, at a meeting at Air Ministry, the Director of Home Operations laid down the priority of requirements as :—[3]

(*a*) Defence of London from the Channel Approaches.

(*b*) Strait of Dover to the Humber.

(*c*) Lizard to Bristol Channel.

(*d*) Liverpool to Clyde.

(*e*) Humber to Shetlands.

To meet the demand for increased cover, the following R.D.F. stations were required :—C.H.L. stations at Rye, Pevensey, Poling, Rowe Head, Black Head, Dunkirk, Hopton, Skendleby, Flamborough Head ; C.H. stations at Hawks Tor and Lizard ; both C.H. and C.H.L. stations at Swanage, West Prawle, Newquay, Tenby, Stranraer, Antrim. A pool of twelve M.B.2 mobile stations was to be formed for Advance stations or to replace stations knocked out by enemy action.

[1] Air Staff Folder, *Component Field Force No. 2—Observer Sites and Wireless Screens*, A.H.B./IIH5/1/61, Encl. 12A.

[2] Minutes of the Inter-Services R.D.F. Committee, 11th Meeting, 6 June 1940, A.H.B./IIE/68.

[3] Headquarters, No. 60 Group File 60G/S.400/AIR, "C.H. Policy—New Stations," Encl. 9B.

No. 60 Group undertook the task of co-ordinating this programme of eight C.H. stations and fifteen C.H.L. stations. The target date for the C.H.L. " crash " programme was 8 July 1940.[1] No specific date was fixed for the completion of the C.H. installations. To assist in temporary cover, the Group had already available some six mobile M.B.2 stations. During May it was decided to increase the reserve pools. Two pools of twelve mobiles each were formed for the north and south areas of the Chain.[2] In order to facilitate No. 60 Group's effort in meeting this emergency expansion, No. 2 Installation Unit was handed over to the Group on 7 June 1940, and later in the month its establishment was raised from 343 to 508 personnel. Experienced personnel to fill this increase were difficult to find, however, and the Unit had to continue working below strength. It was made responsible for :—[3]

(*a*) Completion of the East Coast C.H. stations to four-frequency working and the West Coast Chain to two frequencies.

(*b*) Completion of the mobile stations programme.

(*c*) Modification to C.H.L. stations of eight mobile G.M. stations.

(*d*) Assembly, testing and despatch of all R.D.F. equipment for stations overseas.

(*e*) All heavy maintenance work at home beyond the capacity of the Radio Maintenance Units.

(*f*) The fabrication of all parts to cover replacements not normally available through contractors.

(*g*) Installation of any additional stations in the Home Chain.

(*h*) Assembling, testing and installation of mobile C.H.L.s then being initially introduced into service.

(*i*) Any necessary modifications of all types of Ground Home R.D.F., both fixed and mobile.

(*j*) The " cleaning-up " of existing C.H.L. stations and installation of duplicate transmitters and receivers at those stations.

Technical Modifications to C.H.L. Stations

The last item was a heavy commitment, as major improvements to C.H.L. equipment were being made.[4] At the end of May 1940, the Air Ministry Research Establishment had experimented with a motor-driven C.H.L. aerial array at Douglas Wood Station capable of sweeping through 180° in 65 seconds. In May a turntable and mast had been evolved which carried both the transmitter and receiving aerial arrays on one gantry. Previously, all aerial rotation on C.H.L. stations had been done by hand turning ; the minimum rate of sweep allowed being eight minutes for a coverage of about 180°.

In June a cathode ray tube display using a radial time base, called the Plan Position Indicator (P.P.I.), was suggested as a means of increasing the speed of plotting.[5] In this tube the time base, normally horizontal and stationary in cathode ray tubes in other R.D.F. stations, rotated in conformity with the rotation of the aerials, giving a plan picture of the aircraft's position, doing

[1] No. 60 Group File 60G/S.400/AIR, Encl. 9B.
[2] A.H.B./IIE/68, R.D.F. Inter-Services Committee, 9th Meeting, 11 May 1940.
[3] A.H.B./IIE/64, Folder, " Organisation of No. 60 Group," Encl. 19A.
[4] Air Ministry File S.55153, Part II, Encl. 38B and 79A, O.R.S./4/1/2.
[5] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee.

away with the need for direction finding by the goniometer method. It covered up to 60, and later 90-mile ranges. The new tube was installed at the C.H.L. station at Foreness for testing.[1]

By the second week of July 1940, the date of the first large-scale day attack by enemy aircraft on shipping in the English Channel, the Chain had been enlarged by C.H.L. stations at Gaitnip (Orkneys), Poling, Worth Matravers (28 May), West Prawle (15 June), Beachy Head (16 June) and Carnanton (26 June).[2] C.H. stations were ready for operations at Worth Matravers, Hawks Tor (29 May), West Prawle (15 June), Goon Hilly Down (later Dry Tree) (20 June), Carnanton and Warren (24 June). A new Filter Room was opened at No. 10 Group Headquarters near Bath to which stations from West Prawle westwards all reported. To keep pace with these new installations, the training of personnel to man them had been stepped up. On 12 June 1940 Yatesbury Radio School opened a training centre for W.A.A.F. R.D.F. Operators.[3]

During May and June 1940, the Germans increased their use of aircraft for mine-laying operation in British port areas. Although the approach of the hostile aircraft was usually observed by the Chain, when the enemy adopted diversionary tactics of mixing mine-laying aircraft with bombers proceeding inland or high-flying decoy aircraft, difficulties were experienced in identifying the mine-layers. The mine-laying aircraft usually dived, with its engine throttled back, to the low altitude necessary to lay the mines safely. Experiments were conducted to determine if C.H.L. stations could observe the mine after it had been released from the enemy aircraft. The actual location of the mines was of great importance: since their presence resulted in the closing of harbours to all shipping until the laborious process of sweeping the entire navigational channels had been completed. The experiments were not successful, although the C.H.L. station reports on the exact location of the enemy aircraft's dive position were of some help.

With the fall of France the danger of invasion across the English Channel became imminent. The Admiralty asked the Royal Air Force, through the medium of the Inter-Service Committee on R.D.F., whether warning of the approach of troop-carrying craft, mine-sweepers, coastal motor boats, mine-layers and other surface craft could be given by the C.H.L. stations at Dover, Foreness, Walton, Dunwich, Walcott and Swanage.[4] The Air Officer Commanding-in-Chief, Fighter Command, was reluctant to accept the commitment because of the difficulties involved. The stations were in any case pre-occupied with watching for aircraft and would undoubtedly be fully engaged during raid periods. There would be no means of identification as our own surface vessels were not fitted with I.F.F. equipment. Moreover some means of passing the information was necessary, and probably a special plotting organisation would have to set up at a Naval headquarters, with direct telephone lines. The Inter-Service Committee recommended the erection of a new C.H.L. station in the Foreness area, manned by Royal Air Force personnel, solely for the purpose of locating surface craft. Stations at Dover and Bawdsey were made more capable of reporting surface craft at the same time as they

[1] This was typical of the way in which operational R.D.F. stations were the subjects of research and development at that time.

[2] No. 11 (Fighter) Group, O.R.B., May/June 1940. These locations are shown on Map No. 1.

[3] No. 2 Radio School, O.R.B., June 1940.

[4] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee, 11th Meeting, 6 June 1940.

searched for aircraft, by the installation of long after-glow type cathode ray tubes. This device caused indications of aircraft or ships to persist on the tube for a period of some seconds after it first appeared, thus making the work of reporting a number of simultaneous indications much easier.

At the beginning of July the Air Ministry agreed to allow watching for surface craft to be undertaken, provided that previous warning to expect hostile surface craft was given to the station, or in weather conditions which were adverse to air reconnaissance, or in cases of the concentration of ten or more ships; and otherwise, whenever possible.[1] Land-line communications from C.H.L. stations to appropriate regional Naval headquarters were provided, and the Admiralty published a memorandum showing which C.H.L. stations were required to do this work, the stations lying along the south-east coast being the most important.

If invasion were to occur, it was anticipated that simultaneously with the approach of sea-borne forces, enemy troops would probably be landed in this country from gliders. How much information C.H. and C.H.L. stations would be able to give, or even whether they could detect non-metal gliders, was not known.[2] It was thought that such gliders would be released from the German towing aircraft some distance from our shores. Investigations were therefore undertaken as a matter of urgency by Fighter Command. During the next four weeks Air Ministry Research Establishment conducted experiments and issued a report on the R.D.F. observation of non-metallic gliders. An isolated aircraft with a glider in tow produced a characteristic echo which, by a splittng effect, indicated the release of the glider. The latter could then be observed as a separate and distinct echo, but of smaller magnitude than the echo of a power-driven aircraft at a similar range. The maximum range at which a glider could be observed by a C.H. station was of the order of 30 miles. It was apparent, however, that the complex echo concentration to be expected in the case of a substantial number of aircraft with gliders would render positive identification of gliders unlikely. Mr. Watson Watt expressed the view that the common-sense way to identify an echo from a glider was by noting its relatively low speed over the ground.

Since the Home Chain was designed to give R.D.F. cover to seaward only, it was clear that once the gliders had passed the coast R.D.F. information on them would cease. The need for inland-looking or alternatively inland-sited R.D.F. stations now arose to cover the South-East of England. One mobile G.M. station from the reserve mobile pool was therefore sited inland in Kent and three existing C.H. stations on the Norfolk and Suffolk coasts were to keep an inland-looking watch in addition to their normal one by bringing their second receivers into operation. These were the stations at Canewdon, High Street and West Beckham.[3]

During May 1940 Headquarters No. 60 (Signals) Group foresaw new R.D.F. difficulties if the enemy resorted to mass raids.[4] C.H. stations could not present a clear picture of more than about twelve tracks at a time. Their rate of plotting was hardly fast enough to allow a minimum rate of one plot on each of these tracks every two minutes. In addition, tracks of aircraft which merged close together became easily confused. To alleviate difficulties when large numbers

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[1] A.H.B./IIE/68, Minutes of Inter-Service R.D.F. Committee, 13th Meeting, 4 July 1940, the Admiralty Memo.

[2] *Ibid.*, 11th Meeting, 6 June 1940, para. 6, sub-para. (iv). [3] *Ibid.*, para. 2, sub-para. (*c*).

[4] Headquarters, No. 60 Group File 60G/S.1/4/AIR, "Filter Room Procedure," Encl. 5A.

of aircraft might have to be plotted, Headquarters, No. 60 Group submitted to Fighter Command that a second cathode ray tube should be added to work in parallel with the existing tube as a " sorter." It was evident that in conditions of heavy activity, stations would be unable to plot all the aircraft showing on the tube ; nor would filter room plotters be able to make use of them.

The Research Section at Headquarters Fighter Command took up this suggestion and passed it to the Telecommunications Research Establishment. There, elaborations on a simple tube in parallel were visualised as a matter of future policy, eventually emerging in 1942 in the " Console ". It was unfortunate that the original suggestion was not acted upon, as mass raids had to be reported during the Battle of Britain on C.H. stations using the single tube. The idea was ultimately tried out during September 1940 when the stand-by receiver, R.F.5, was manned as a " sorter tube " at Pevensey and proved very helpful. C.H.L. stations were even more quickly saturated by large raids than C.H. stations. Their rate of sweep and plotting were slow, so that to follow more than two tracks was almost impossible.[1] There were some allegations of lack of conscientiousness in sweeping on the part of C.H.L. Operators. These were hardly justified. The hand operated aerial turning gear gave endless trouble and, in a wind of 35 m.p.h., it was often impossible to control the rotation. Scanning in these circumstances became exhausting and often gave good reason for pauses in the normal rotation procedure. Furthermore, in periods of fairly heavy aerial activity the cathode ray tube was so full that often nothing could be gained by turning the aerial.

Although remarkable progress had been made with the extensions to the Home Chain of C.H. and C.H.L. stations during May and June 1940, the R.D.F. raid reporting system was by no means perfect when the assault of the *Luftwaffe* began in July. The C.H. stations had not reached their planned " Final " stage and the C.H.L. stations were all of an emergency non-prototyped form. A compromise had been made between the desire for technical perfection and the necessity to have the fullest possible R.D.F. raid reporting system functioning as quickly as possible.

[1] Headquarters, No. 60 Group File 60G/S.51/6/Ops., " Ops. Procedure—C.H.L. Searching," Encl. 1A.

CHAPTER 10

R.D.F. RAID REPORTING DURING THE BATTLE OF BRITAIN

The Battle of Britain is taken as beginning on 10 July with the attacks on British shipping in the English Channel and continuing until October when, after the bombing of London, the assault gradually declined as a daylight operation. The offensive was an essential preliminary to the invasion of England by the Germans and was planned to take place in stages during which shipping, ports, docks and coastal towns, Royal Air Force airfields and installations, and finally the city of London were successively the targets for attack.

As far as the R.D.F. Home Chain was concerned the performance and organisation of the equipment were to be thoroughly tested, as were also the skill and endurance of the operating and maintenance personnel. Jamming and bombing of R.D.F. stations were experienced. It was to be shown whether the results of the scientific research and technical organisation built up in the previous five years could provide the Air Defence organisation with the early detection and continuous recording of movements of hostile aircraft, information which was essential to enable the Fighter Squadrons to defeat them.

The R.D.F. Chain at this time was by no means in the fully developed and highly trained state which it attained in the later stages of the War. Technically there was still much to be desired. The transmitters and receivers were fairly reliable and effective, but the aerial systems had not been developed to the stage of a satisfactory prototype. The search for the best type of aerial to suit all stations was still going on at the time of the Battle of Britain and did, in point of fact, continue until a much later date. Scientists who could have been concentrating on the solution of aerial problems had continually been called away from their laboratories, from the time of the Munich crisis onwards, to assist in the setting up of aerials on stations being brought into operation at emergency priority.[1]

Careful calibration was necessary before reliable height finding could be expected from the aerials in use. The task of calibration entailed the flying of helicopters and balloons in the English Channel and was only permissible in certain conditions of weather to give some measure of safety from hostile interference. Moreover, although Fighter Command was sometimes critical of the accuracy of height finding, they were naturally reluctant to allow stations to spend time on anything but the primary task of watching for hostile raids. The stations were capable, after calibration and in the hands of an experienced operator, of giving accurate heights. Even so, there was always a source of height error, in that the only method of calculation then available contained a chance of ambiguity, which could not be resolved at the R.D.F. station save by virtue of the experience of the operator.[2]

[1] Constant work on aerial arrays and feeder lines was necessary in any case during the Battle of Britain period because a satisfactory method of weather-proofing had not been found, and the entry of water into the feeder lines caused performance to deteriorate gradually to the point where replacement was unavoidable.

[2] There was also another source of error in height finding. Height reading was a cumbersome process, especially for inexperienced operators, during which it was possible to lose the broad picture in plan position of the raid or raids being reported. It was the practice, therefore, to read only one height for every four plots or so. Enemy formations were frequently reported while many miles from the coast and still engaged in gaining additional height. The result was that British fighter aircraft sent to intercept them found them noticeably higher than had been reported.

Estimation of the number of aircraft present in an observed formation was also dependent on the skill and experience of the individual operator. The difference between the indications given by one, two or three aircraft was easily distinguishable, but formations of twenty, sixty or a hundred and fifty gave responses of varied shape, size and characteristics which could only be "counted" by an operator who had seen similar indications previously, and had learnt what they represented.

There was therefore an urgent need for operators who had considerable experience, in addition to a normal facility for accurate perception and quick thinking. The need, moreover, was rapidly increasing, and the supply lagged behind, causing an acute shortage of trained personnel. Successive extensions of the Chain had been made to give increased cover, and the decision on 25 April to instal an additional eight C.H. and fifteen C.H.L. stations had seriously overloaded the training facilities available. The operators' course had to be shortened to three weeks duration, in which young men and women who had just been called up were hurriedly instructed in the elements of the new trade, before being posted straight to operational R.D.F. stations. An effort was made to offset the rawness of the newly fledged operators by careful selection of the best possible material before training.

First Phase of the Battle of Britain, 10 July–7 August

Although 8 August 1940 is the day popularly known as the beginning of the Battle of Britain because it was then that air fighting over England began, the real commencement of air attacks was on 10 July when the German Air Force started a series of raids on British shipping convoys in the English Channel and to a less degree in the Thames estuary.[1] The German policy during this period was towards the establishment of superiority over the waters of the English Channel and the exhaustion of our Metropolitan Fighter Force.

Between 10 and 19 July, German air operations were of one type. A force of bomber aircraft would form up over the French coast, fly directly to a shipping convoy, bomb and retire quickly, leaving a fighter escort to act as rearguard and fend off the attacks of British fighters.[2] R.D.F. Chain stations on the south coast were able to observe the German bombers forming up in the air at their rendezvous, usually in the Pas de Calais or Cherbourg areas. These activities were reported to filter rooms and operations rooms, and Controllers despatched fighters to intercept. The target being in the English Channel, however, and the Germans having the advantage of a slight start added to that of height, the bombing was usually over before the British fighters could intercept. Later there were occasions, as for example off Selsey Bill on 21 July, when warning was sufficient to allow defensive fighters to appear over the convoy, and the enemy retired without attacking.[3]

The increase in aerial activity during the opening phase of the battle presented a new air picture on the cathode ray tubes of the south coast R.D.F. stations; the number of indications showing on the tubes was so large in comparison with previous experiences that the work of the R.D.F. operators became much more exacting. However, the raid reporting system stood up well to these new stresses. Operating personnel quickly became adept at reporting the increased activity and, as the air battle approached more nearly to the

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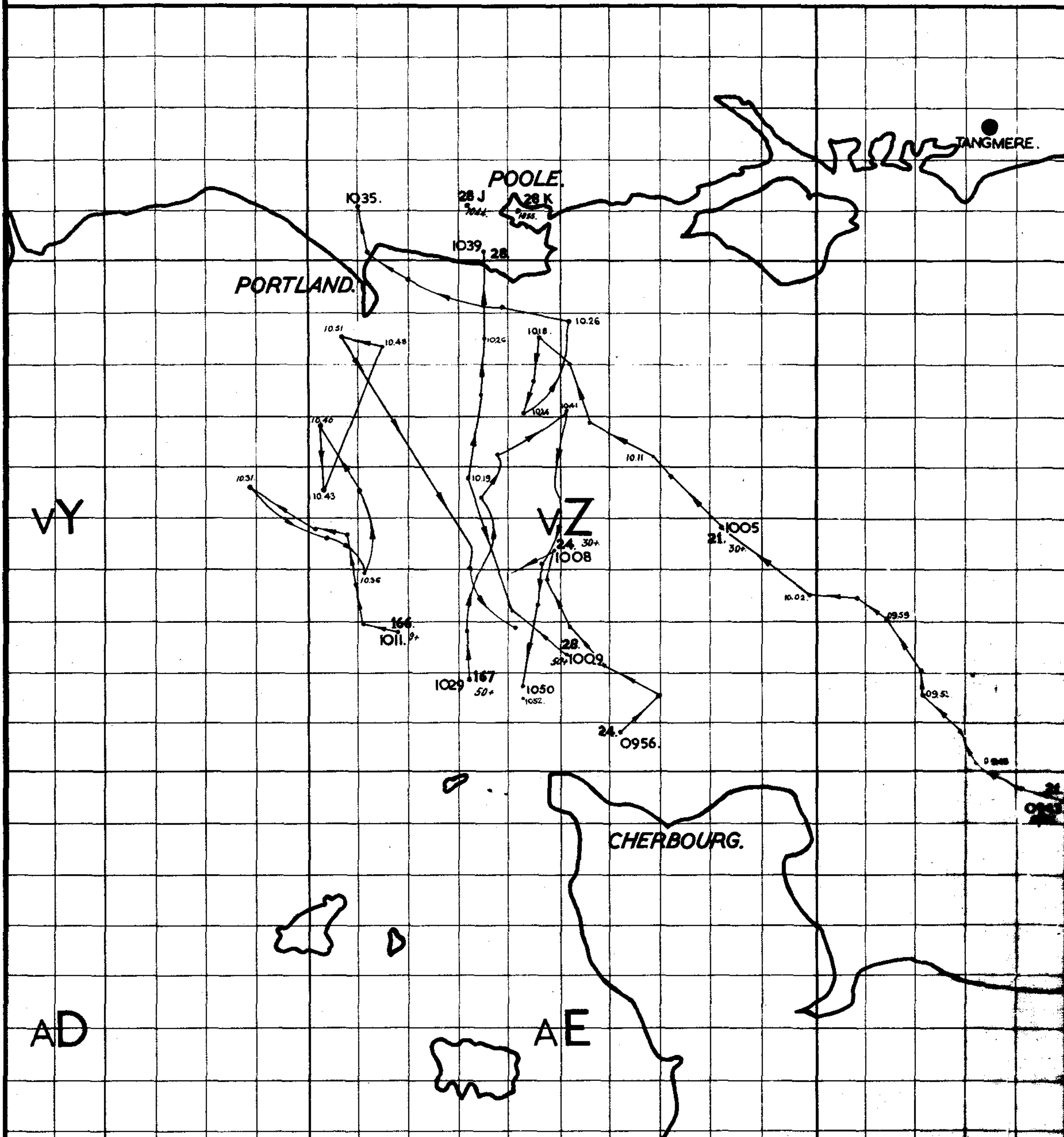
[1] Daily summary of Naval Events, 10–17 July 1940.
[2] R.A.F. Narrative *The Battle of Britain*, pp. 59 and 60.
[3] *Ibid.*, p. 64.

MAP No. 2

HOSTILE AIRCRAFT TRACKS IN BATTLE OF PORTLAND - POOLE 11 AUGUST 1940 - 10.12 HRS. 11.12 HRS.



A.H.B.1. MAP No 463.

coastal locations of the R.D.F. stations themselves, a marked stiffening of the already high morale and keenness of the stations' personnel became most apparent.

Of the technical performance of the R.D.F. stations themselves, the ranges attained were satisfactory and the bearings well within the standard of accuracy required in practice. Generally the C.H. stations attained a radius of nearly 200 miles in the most favourable circumstances and had an average effective range of about 80 miles.[1] Their limitations against low-flying aircraft below 1,000 feet had been countered by the C.H.L. stations introduced in the earlier "crash" programme. These C.H.L. stations had a restricted effective range of 30 miles but were fairly accurate in azimuth or bearing readings.[2]

Second Phase of the Battle of Britain, 8–18 August

During this period of the German air onslaught, the attacks were pressed against the Fighter Command organisation, including the bombing of coastal airfields and some south coast R.D.F. stations. Coastal towns were also bombed. The enemy during this period resorted to great variety in his attacks. His methods included (*a*) casting about over the Channel to make tracking difficult, (*b*) the extensive use of decoy flights to distract the Controller from the main attack, (*c*) two- and three-pronged heavy attacks from bases as far apart as Calais and the Cherbourg area, and (*d*) the quick-mounting of direct attacks; such rush tactics reducing the period of R.D.F. warning to the Controller.

The following example of R.D.F. plotting gives an idea of the scale of activity in one area at that time.[3] On 11 August 1940, between 1005 and 1009, the following German formations were plotted in the central Channel, all of them on a course to Portland and Swanage :—

"(*a*) The force was originally plotted as it emerged from the Baie de la Seine thirty or more aircraft strong; at 1005 hours this was 30 miles south of St. Catherine's Point.

(*b*) A force of fifty or more aircraft was about 15 miles north of Cherbourg at 1005 hours.

(*c*) A smaller force, plotted as 'nine plus,' was 26 miles north-west of Cherbourg at 1009 hours."[4]

These reports were made during the German attack on Portland which was only one of the three main operations on 11 August. The other two were attacks on convoys off Orfordness between 1200 and 1100 hours, and a series of attacks in the Strait of Dover which continued during the whole of the morning.

Attacks on R.D.F. Stations

R.D.F. stations were usually regarded as secondary targets for air attack during war. C.H. stations, with their 350-foot transmitter steel towers and 240-foot aerial array wooden towers, were unavoidably conspicuous but it was not until 12 August that the enemy showed any attention to the Home Chain stations on the south coast. The nature of his attack on that date, however, indicates that these stations were primary targets for attack, though there

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[1] A.H.B./IIHI/18, *The Battle of Britain*. Despatch by Air Chief Marshal Sir Hugh C. T. Dowding, A.O.C.-in-C., Fighter Command, para. 54. [2] *Ibid.*, para. 56.
[3] Fighter Command "Y" Form, 11 August 1940. [4] See Map No. 2.

is no direct evidence that the enemy fully appreciated the paramount importance of the stations.[1] The following attacks were suffered by Chain stations on 12 August :—

Pevensey.—At 0932 hours on 12 August three German aircraft attacked Pevensey successfully. Casualties were caused amongst the Army ground defence detachment and consternation was caused amongst station personnel by a direct hit on the N.A.A.F.I. The R.D.F. equipment escaped damage. Power cables were cut but repairs were effected and the station was functioning again during the afternoon of the same day.

Rye.—A quarter of an hour after the Pevensey attack the Chain station at Rye was attacked by six *Me.110s.* All huts were destroyed with the exception of the transmitter and receiver blocks. The normal working of the station was restored within three hours. The diary of a German Lieutenant taking part in this attack was recovered from his body when he was killed on 15 August. This revealed that the R.D.F. station was the primary target. Although not interfered with by A.A. or fighters, their bomb-aiming was affected by a strong wind from starboard and all the bombs fell wide of the main buildings.[2]

Dover.—At the same time as the attack on Rye, Dover was also attacked. Considerable damage was done to the huts inside the compound and slight damage to the aerial towers but no vital damage was done and the station continued to function on emergency equipment.

Ventnor.—At 1140 hours two large German forces over the Cherbourg peninsula began to move across the Channel. These were plotted at "150 plus" and "30 plus." The larger force headed for Portsmouth and subsequently bombed it, the smaller force attacked the R.D.F. station at Ventnor. Just as the enemy bombers commenced to dive on the station from a height of about 10,000 feet our Fighters, Nos. 152 and 609 Squadrons, intercepted them. No. 152 Squadron got to some of the bombers before they released their bombs while No. 609 Squadron engaged their German fighter escort.[3] Ventnor R.D.F. station was nevertheless heavily and accurately dive-bombed by about fifteen *Junkers 88s.* Casualties were fortunately extremely light, one soldier on station defence duties being wounded. The majority of the surface buildings on the station were destroyed, despite assistance from the local fire brigade—lack of water on the site hampered their efforts. Repair work was not immediately possible, the site having to be evacuated owing to the presence of delayed-action bombs.

Dunkirk.—On the same day this station also was lightly attacked. A 1,000-lb. bomb dropped near the transmitter block, two huts were destroyed but there was no vital damage and the station continued to operate.[4]

Pevensey.—A single aircraft, which had been plotted the whole way across the Channel, passed over the station, turned, and bombed from a low altitude on the way back during the afternoon of 14 August. Although the bombs fell within the C.H. station compound and the receiver block was hit, the station remained operational throughout.

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[1] Headquarters, Fighter Command Signals Branch, O.R.B., 12 August 1940.
[2] Royal Air Force Narrative *The Battle of Britain*, p. 113.
[3] Consolidated Combat Reports, No. 152 and No. 609 Squadrons, 12 August 1940.
[4] Royal Air Force Narrative *The Battle of Britain*, Appendix III.

On 16 and 18 August raids were made on Ventnor and Poling R.D.F. Stations :—

Ventnor.—This station was still inoperative from the previous bombing on 12 August, and efforts were being made to repair it, when on 16 August, at 1315 hours, it was again subjected to attack. Although good R.D.F. warning had been given of the approach of enemy aircraft, two other raids were proceeding simultaneously on airfields at Gosport and Lee-on-Solent and heavy fighter engagements were occurring in mid-Channel, so the German aircraft reached their objective before they were intercepted.[1] Five *Junkers 87s* dive-bombed the station, seven H.E. bombs being placed successfully in the target area. After this latest attack all buildings except two above ground and those below ground were unusable and the aerial towers had suffered damage. This gap in the Home Chain was not replaced until 23 August, when a reserve mobile station was then functioning at Bembridge on the Isle of Wight.[2]

Poling.—On 18 August at 1400 hours the C.H. stations reported three enemy formations : "80 plus" north of Cherbourg, "20 plus" east of Cherbourg and "10 plus" north-west of Le Havre. These formations reached the coast at 1425 hours and were then two formations of dive-bombers ultimately responsible for the bombing of airfields at Thorney Island, Ford and Gosport and the R.D.F. station at Poling. These formations were intercepted five times by our fighters but pressed home their attacks despite heavy losses. Approximately 90 bombs were dropped at Poling and the station was badly damaged. Emergency mobile equipment was installed but it could not give as comprehensive information of enemy movements as the permanent station had done. Air Vice-Marshal Park warned his Operations Controllers to this effect on 25 August. The actual situation at Poling is a little obscure at this time as the records of the Signals Branch at Fighter Command Headquarters imply that this station was out of action for the remainder of the month.[3]

On 12 August the Air Officer Commanding-in-Chief, Fighter Command signalled the C.H. stations at Dover, Rye, Pevensey and Ventnor expressing his satisfaction and pride in the behaviour of the W.A.A.F. personnel in the face of enemy attack.[4] In his Despatch on the Battle of Britain, Air Chief Marshal Sir Hugh C. T. Dowding comments that the operating personnel of these C.H. stations which were attacked, and particularly the women, behaved with great courage under threat of attack and actual bombardment.

Immediately after the attacks on the south coast R.D.F. stations on 12 August, the Air Officer Commanding No. 60 Group inspected the stations and was delighted with the spirit of the personnel under attack.[5] On his way back to Headquarters No. 60 Group he called at Headquarters Fighter Command to report to the Air Officer Commanding-in-Chief. The latter showed great insight into German psychology when he stressed that in view of the fact that the R.D.F. stations were kept on the air, the enemy would cease his attacks. On the question of more A.A. protection, Air Chief Marshal Sir Hugh Dowding

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[1] Royal Air Force Narrative *The Battle of Britain*, p. 188.
[2] Headquarters, Fighter Command Signals Branch, O.R.B., 23 August 1940.
[3] *Ibid.*, 18 August 1940. [4] *Ibid.*, 12 August 1940, and A.H.B./IIHI/18, p. 134.
[5] Personal Diary of Air Commodore A. L. Gregory, A.O.C., No. 60 Group.

was firm in his decision that no more guns would be sent to A.M.E. stations for this would have been at the expense of the A.A. defence of aircraft factories. He amplified this by adding that if five R.D.F. stations were wiped out he could carry on using the mobile reserve, but not if he were robbed of a single aircraft from the factories.

These heavy attacks on the Home Chain stations coupled with sustained attacks on No. 11 Group airfields which occurred during the same period were part of the German plan of an offensive against Fighter Command. Why these attacks were not maintained just as they were seriously affecting the south-east portion of the Chain is not known. After the war a questionnaire on the Battle of Britain was addressed to *Generalfeldmarschall* Milch, former Inspector-General of the *Luftwaffe* and Secretary of State for Air and *Generalleutnant* Galland, who commanded the German *Jagdgeschwader* 26 (about twelve enemy fighter squadrons) during the Battle of Britain. They agreed that they thought that serious damage had been done to one or two R.D.F. stations but that, in general, they considered them to be difficult targets to damage effectively.[1] Neither seemed to realise fully how vitally important were the R.D.F. stations to the Fighter Command technique of interception or how embarrassing sustained attacks on them would have been.

The pool of M.B.2 Mobile R.D.F. stations which was formed as a result of the meeting on 11 May 1940 of the Inter-Services R.D.F. Committee had proved its value in filling the breach made in the Home Chain at Ventnor.[2] The buried Intermediate equipment had acted as a replacement at Poling also.

The damage done to R.D.F. equipment and aerial masts as a result of enemy attacks was studied carefully by Signals staff officers to decide whether any change in policy with regard to dispersal of technical equipment was necessary.[3] In view of the probability of an increasing scale of attack in the future, the Assistant Chief of Air Staff (Radio), Air Marshal Sir Philip Joubert, decided that no more C.H.L. stations were to be erected within half a mile of C.H. station compounds and that the 40 foot gantries used for supporting aerial arrays should only be used in places where there was no high ground available, thus making the majority of C.H.L. stations less conspicuous.

All future C.H.L. stations were to be erected so that they could also cover both high and low-flying aircraft.[4] It will be remembered that they were originally used only for low-flying aircraft. This decision was taken so that the C.H.L. stations might provide some measure of cover against aircraft at all heights in the event of C.H. stations being rendered unserviceable.

Attacks on the North-East Coast

So far, apart from small numbers of night raiders and enemy minelaying aircraft, the Battle of Britain had been fought out entirely in the south of England. On 15 August the enemy tried a change of tactics by attacks on north-eastern districts. The Commander-in-Chief, Fighter Command, believed this new course was taken by the Germans on the assumption that our fighter strength had been withdrawn from the north to meet attacks in the south.[5]

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[1] Royal Air Force Narrative *The Battle of Britain*, Appendix No. 37.

[2] A.H.B./IIE/68, Minutes of R.D.F. Inter-Service Committee, 9th Meeting.

[3] Air Ministry File S.3522, Encl. 35A. [4] *Ibid.*, Encl. 43A.

[5] A.H.B./IIHI/18, *The Battle of Britain.* Despatch by the Air Officer Commanding-in-Chief, Fighter Command, para. 195.

A raid of " 20 plus " from Norway was plotted many miles out to sea opposite the Firth of Forth at 1208 hours on 15 August. A second raid of " 10 plus " was observed 20 minutes later and a third of " three plus " was also in evidence, all heading for the Tyne area. Meanwhile a new threat was also detected by R.D.F., some " 30 plus " enemy aircraft making for the coastline 100 miles south, near Scarborough. This latter estimate of numbers proved very low, as the force was subsequently found to be one hundred enemy aircraft approximately. The early warning from the north-eastern Chain stations was ample for successful interceptions to be made. Our pilots claimed over thirty enemy aircraft without loss. A.A. guns also accounted for six hostile aircraft This was the first, and the last, attack on targets in the north-east to be made in daylight during the Battle of Britain. The enemy bombers and *Me. 110* received such a drubbing that the experiment was never repeated. The defences there were on the alert and the Chain stations in that area had made no small contribution to the outstanding successes of our Fighter organisation.

Third Phase of the Battle of Britain, 24 August–6 September

During this phase the German air attack continued. The targets were almost all airfields in the No. 11 Group area, but the more important inland Royal Air Force stations were included in these heavy attacks. Because of the greater distance the enemy aircraft had to fly, the R.D.F. stations were normally capable of giving a longer warning and therefore were generally of even more value to the Controller.[1] The ratio of the number of successful day interceptions by our fighter aircraft to the number of sorties flown was therefore good during this period.

The Germans adhered to their plan of maintaining formations over the Strait of Dover in such strength that the Controller was unable to decide whether or not an attack was imminent despite the R.D.F. information. This difficulty was increased as occasional feint attacks were made by their fighter formations, thus tending to reduce the effectiveness of R.D.F. warnings from the operational point of view.

There was a failure by the R.D.F. to give warning during this period. A small enemy force which crossed the Norfolk coast at 0750 hours on 24 August was completely undetected by R.D.F. and bombed Great Yarmouth. The probable explanation of this failure was the use of the three East Anglian C.H. stations at Canewdon, High Street and West Beckham for an inland-looking watch in addition to their normal watch to seaward.[2] The additional responsibility was cancelled some four weeks later.

Generally, the standard of R.D.F. warning was high. The new C.H. stations on the south-west coast were giving excellent range results, detecting all German formations over the Cherbourg peninsula and giving ample warning to the Controllers of No. 10 Group.[3] Estimation of the numbers in enemy formations continued to be on the low side throughout the whole of this phase of the battle for the reason already given. The heights given by R.D.F. were usually reasonably accurate, and attempts by Controllers and Squadron Commanders to improve on information supplied to them were discountenanced by No. 11 Group Instructions to Controllers Nos. 10 and 12.

[1] Royal Air Force Narrative *The Battle of Britain*, p. 283.
[2] A.H.B./IIE/68, R.D.F. Inter-Service Sub-Committee, 13th Meeting, para 2, sub-para.(*c*).
[3] R.A.F. Narrative *The Battle of Britain*, p. 270.

Fourth Phase of the Battle of Britain, 7–30 September

Instead of continued attack on No. 11 Group airfields and R.D.F. stations which had been anticipated, the enemy changed his tactics on 7 September and began his mass attacks on London. It was on this date that the "Alert No. 1" —invasion imminent and likely to occur within the next 12 hours—was given. The large numbers of aircraft used by the enemy and the numbers of formations employed simultaneously from different directions made detailed R.D.F. reporting very difficult. On 9 September 1940, a comprehensive operational instruction was issued by No. 60 Group to all R.D.F. stations. It required a regular watch to be kept on the vertical gap filler to avoid missing raids; in future, height was to be passed with each plan position in order that the Controller would have more accurate height information, and "Mass Plotting" was to be introduced.[1] "Mass Plotting" was a system of reporting raids by batches or waves instead of by individual aircraft and gave a better picture of enemy bulk activity. It was also called "Macroscopic" reporting, and had been evolved locally and used unofficially by several C.H. stations prior to the No. 60 Group Instruction.[2] Before the official introduction much of the value of this effective "macroscopic" reporting from R.D.F. stations was lost as Filter Room was still trying to filter individual tracks.

On 7 September, 380 enemy aircraft broke through to London to attack the docks area and a series of heavy night raids on London began. The number of aircraft appearing on the R.D.F. tubes was at times too great to be reported by the operator accurately enough to give a clear picture. On occasions the amount of information passed was sufficient to swamp the Filter Room. Fair warning of the approach of raids was being given by R.D.F. stations, however, rarely giving less than 10 minutes' notice before the Germans crossed the coast.[3] More often the warnings were some 20 minutes in advance. But the R.D.F. stations, so at least both the Commander-in-Chief and Air Vice Marshal Park complained, were not giving sufficiently precise information either of plan position, numbers, or height for interception to be certain at this time. Nor was it possible to distinguish between fighter and bomber aircraft. Once the raids crossed the coast the tracking of the raids was bad, for the Observer Corps could not be expected to plot through thick cloud to the 20,000–30,000 ft. at which the Germans were flying.

The use of high flying aircraft put the R.D.F. stations also at a disadvantage. At high altitude the gaps between the lobes of transmission were wider than at medium heights, and continuous tracks of aircraft and formations became impossible to obtain. By the second week in September No. 11 Group attempted to counteract the enemy's high-flying tactics and to supplement R.D.F. information by despatching single reconnaissance aircraft from a Spitfire squadron to patrol at maximum height the usual enemy routes across the coast. Having located advancing hostile aircraft they reported to the Sector Controller by R/T the numbers, composition, route and altitude of the German force. Towards the end of the month No. 421 Flight was formed, fitted with V.H.F. R/T and in direct communication with Group Operations Room, especially for these reconnaissance duties.

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[1] No. 60 Group File 60G/S.1/11/OPS., "R.D.F. Operational Instructions."
[2] No. 60 Group File 60G/S.1/AIR/OPS., "Procedure, A.M.E. Stations," Encl. 27A.
[3] R.A.F. Narrative *The Battle of Britain*, p. 481.

Jamming of R.D.F. Stations

Throughout this fourth phase of the battle it is interesting to note that although active reconnaissance of R.D.F. stations was carried out by enemy aircraft, there was no attempt to interfere with the function of the R.D.F. Chain by further bombing of important stations. The enemy now resorted to radio jamming in an effort to neutralise the early warning given by these stations. The first enemy jamming was experienced in September 1940 when Dover C.H. Station was jammed by Frequency Modulated Continuous Wave and Dover C.H.L. Station by short bursts of Continuous Wave transmissions.[1]

Fortunately such an enemy policy had been anticipated, and anti-jamming equipment fitted to the R.D.F. stations. This consisted of the Anti-Jamming Tube and Filters (invented March 1939), the Intermediate Frequency Rejector Unit (invented July 1939), the Intentional Jitter which was able to unlock pulses locked to the mains, and the Automatic Gain Control which cut down the gain at the beginning of the trace where aircraft "echoes" and ground reflections were very strong, leaving normal gain at far ranges where echoes were weak.[2] It was thus possible to plot through the jamming. The effect of the enemy counter-measures on the efficiency of the C.H. stations was very slight, but depended noticeably on the efficiency of individual operators. Canewdon, Dunkirk, Rye and Pevensey also experienced Continuous Wave interference, but continued to work through the jamming.[3] The jamming of C.H. stations was never expected to cause a total failure of the early warning system since it was estimated that the enemy would have to employ some 320 jammer transmitters to jam successfully the number of frequencies in use in the Home Chain. The C.H.L. stations were a more serious problem as only sixteen transmitters would be required to jam the C.H.L. frequencies successfully. At the end of September, the Air Ministry Research Establishment suggested the formation of a specialised body of experts to deal with anti-jamming, in case the enemy persevered with this form of radio attack on the Home Chain.

The Fifth Phase of the Battle of Britain, October 1940

The fifth and last phase of the battle occurred throughout the month of October. This phase saw the decline of the enemy's attacks on London and an increase in the night bombing of London and the arms-producing centres of the Midlands, the aircraft industry in particular being selected for attack.[4] Some idea can be gained of the falling off of the daylight attacks by the fact that of the estimated 9,000 tons of bombs dropped on this country during the month, only 1,000 tons, one-ninth of the total, was dropped by day. Although the German concentration on night bombing relieved the pressure on the day-fighter organisation of Fighter Command, there was little relief for the R.D.F. personnel and Operations Rooms staffs, who were rarely free from intensive work. Adequate warnings were given of hostile raids, but the night defence of London and the industrial centres devolved largely on Anti-Aircraft Command and the Civil Defence Services; Fighter Command operated night-fighter aircraft but had no efficient counter to the German night raider during this period.

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[1] Air Ministry File S.44413, Encl. 9B. [2] *Ibid.*, Encls 27B and 28B. [3] *Ibid.*, Encl. 42B.
[4] R.A.F. Narrative *The Battle of Britain*, p. 545.

The Problem of the Night Raider

During the Battle of Britain period the normal day-time methods of interception was used at night, with searchlights attempting to illuminate and hold the enemy bombers. In June, when the enemy attacked in some strength, six were shot down by our night-fighter aircraft. This attack was, however, made at comparatively low altitude (8,000–12,000 feet) and thereafter the Germans resorted to greater heights where the searchlights became practically ineffective.[1] A further handicap in the air defence system was that the " sound plot " track transmitted from the Observer Corps at night was too inaccurate to be of use for controlled interception by fighter aircraft ; height indications were little better than guesswork.

As the Home Chain stations gave no further information once the enemy had crossed the coast, some ten Army Gun Laying (G.L.) sets were borrowed for inland plotting. Within limited range (about 40,000 feet) this set gave accurate position plots and could read heights to within 1,000 feet at average ranges. These sets were installed in the Kenley Sector on the usual line of the enemy approach to London.[2] The plots were reported by telephone direct to Kenley Sector Operations Room and a much more accurate picture was given of the enemy bomber's position by half-minute plots. The track of the intercepting fighter was obtained from direction-finding by Sector Fixing stations. Unfortunately we had no aircraft really suitable for use as night fighters. Better R.D.F. methods of ground control of interception aids were under development at this time. The month of October saw a quickening of research and experiment in the problem of night defence and the creation of a number of reviewing bodies, notably a War Cabinet committee under the chairmanship of the Prime Minister.[3]

Expansion of the Home Chain during the Battle of Britain

While the Battle of Britain was in progress, the Home Chain was extended round the coast in low power form under the co-ordination of No. 60 Group. During July 1940 one C.H. station at Hayscastle Cross and eleven C.H.L. stations were put into operation at Whitstable, Hopton, Skendleby, Bempton, Carnanton, Tannach, Glenarm, Cregneish, Prestatyn, Strumble Head and St. Twynnels.[4] In August, School Hill C.H. Station and Foreness II, Anstruther, Cromarty and Deerness C.H.L. Stations were opened. In September, Hollingbury, Bride, Scarlet and Newin C.H. Stations and Dunwich, Shotton and Doonies Hill C.H.L. Stations were completed. Branscombe, Trerew and Castell Mawr C.H. Stations and Cresswell, Bamburg, St. Cyrus and Roschearty C.H.L. Stations all opened during October. A total of nine C.H. stations and twenty-two C.H.L. stations was thus erected during the Battle of Britain period. In order to avoid congestion on the filter room table through aircraft or formation from being told individually, it was arranged that these C.H.L. stations would tell to a local C.H. station, where available, which would tell a combined plot to the filter room. During September a new Fighter Group, No. 9, was formed in the north-west area at Preston. The Group had its own filter room to which R.D.F. stations north of Hayscastle Cross reported.

[1] A.H.B./IIH1/18, *The Battle of Britain.* Despatch by the Air Officer Commanding-in-Chief, Fighter Command, paras. 233/4.
[2] *Ibid.*, para. 240.
[3] The progress made by this Committee is given in Volume V of this narrative, together with a full account of all the R.D.F. aids to interception.
[4] No. 60 Group O.R.B., July–October 1940.

Value of the contribution of R.D.F.

The air struggle was fought out without any large deviation from the technique of raid reporting and fighter control organisation evolved for defence in air exercises before the war. The battle was unique in that it was the first occasion in the history of warfare on which this scientific and co-ordinated early warning and control system had been employed in a major air battle. The Royal Air Force, though inferior in numerical strength, had the tremendous advantage which this system gave. The *Luftwaffe* was flying without remote ground control during the battle and, as far as possible, flew according to pre-arranged plans. The Royal Air Force fighter aircraft under effective ground control thus had a much greater flexibility of attack than the German fighter screens had in defence of their bomber formations. Whereas the British system of raid reporting was designed to give an economical scale of effort in that it usually avoided the necessity of standing patrols, the German bombers required a constant escort of defensive fighter aircraft which rose as high as five fighters to each bomber aircraft.

The first link in the operational system of control was the R.D.F. stations. This source of information was vital to the defence, and it is one of the mysteries of the battle that the Germans made so few and relatively small efforts to disrupt the R.D.F. Home Chain in the south and south-east of England. The fact that the battle was brought to a successful conclusion is one reason for considering that the Home Chain reporting system fulfilled its function creditably. The performance was remarkable having regard to the short training and lack of experience of so many of the operating and maintenance personnel, and to the difficulties in handling and keeping serviceable equipment which was not, as a whole, in a finished state. A false impression would be created if the minor limitations of the R.D.F. cover were not appreciated, but although the R.D.F. stations occasionally failed to locate an enemy formation, they never failed on a single occasion to locate a major attack. The information they supplied was occasionally imprecise, especially their height-finding and estimations of numerical strength. Nevertheless, the performance of the Home Chain during the Battle of Britain may be assessed from the Despatch of the Air Officer Commanding-in-Chief, Fighter Command, Air Chief Marshal Sir Hugh C. T. Dowding, who said of R.D.F.—" The system operated effectively, and it is not too much to say that the warnings which it gave could have been obtained by no other means and constituted a vital factor in the Air Defence of Great Britain."[1]

[1] A.H.B./IIH1/18, *The Battle of Britain.* Despatch by the Air Officer Commanding-in-Chief, Fighter Command, para. 57.

CHAPTER 11

THE R.D.F. HOME CHAIN, AFTER THE BATTLE OF BRITAIN UNTIL DECEMBER 1941

The successful termination of the Battle of Britain in October 1940 brought considerable relief to the whole country and to the hard-pressed organisation of Fighter Command, of which the R.D.F. Home Chain formed part. The months which followed would not permit of complacency, however, as the initiative still rested in the hands of the enemy. Although the Germans had received a considerable military set-back in the stemming of the *Luftwaffe* during the Battle of Britain, they still had a supremacy in material. Their invasion forces and shipping were intact at the beginning of the winter of 1940. There were no signs that the expected invasion of Britain would not occur at the next favourable opportunity, the spring of 1941.

At the 39th Meeting of the War Cabinet Defence Committee on 31 October 1940, the Prime Minister stated "Our power of survival depends on the maintenance of the life of this island—this postulates continued superiority in air defence and the successful countering of night bombing. That we must keep our sea lanes open goes without saying."[1] The basic principles underlying the need for expansion of the R.D.F. Home Chain conform to Mr. Churchill's statement during the period covered by this chapter, for in broad outline these may be summarised as :—

(*a*) Counter-invasion.

(*b*) More efficient raid-warning ; assisting in superiority in air defence.

(*c*) Development of an adequate western R.D.F. Chain giving increased cover to our western sea approaches.

In common with other forms of Home Defence the R.D.F. Home Chain, as yet far from complete despite its valuable contribution during the Battle of Britain, entered into a phase of intensive preparation to counter possible invasion during 1941. During this vital period when Britain and her Empire alone stood against the might of the German forces, the changes in R.D.F. policy were not governed by the threat of invasion alone. The new experience of mass raids, the continual night raids over London and ranging over the western coasts and Northern Ireland, the wave-hopping low-level attacks against coastal objectives, and the beginning of the Battle of the Atlantic all called for a bold R.D.F. policy. Policy and planning may be bold but their fruition is dependent on production and trained man-power. During the period under consideration in this chapter the climax was reached when the R.D.F. installation programme, fraught with many practical difficulties, seriously lagged behind the policy, and the organisation was strained to the limit.

The Installation Programme, October 1940

Of the many plans which had been made for an increase in the R.D.F. cover consequent upon the fall of France and the occupation of Norway and Denmark, none had been completed by October 1940, although No. 60 Group had forged ahead with the extensions of the Home Chain as quickly as possible.

[1] War Cabinet Defence Committee (Operations), Minutes of 39th Meeting.

Towards the end of September the Group had requested guidance from Air Ministry as to the relative priorities of the outstanding work. Although the operational needs were constantly changing and the installation programme was almost entirely dependent on the progress of Works Services and the supply of technical information by the Experimental Establishments, the following order of priority was laid down :—[1]

(*a*) The completion of the East Coast Chain to two frequencies. It will be remembered that in its " Final " form, this portion of the Chain, including the northern stations, was to be fitted to four frequencies working.

(*b*) In view of the approach of winter and the requirement for improved coverage and height-finding in the west, the item of second priority was the completion of the " Advance " C.H. stage in :—

(i) the South-West

(ii) the West

(iii) North-West, including Castle Rock, Islay and Deerness—in Northern Ireland, the Outer Hebrides and the Orkneys respectively.

(*c*) The commissioning of the " Buried Reserve " which had been planned for the original 20-Station Chain, on stations between Ventnor and Stenigot. This should have been on very high priority but was placed third in order to allow for the supply of technical information and the completion of the Works Services.

(*d*) The fitting of second long wave aerials to the C.H. stations between Ventnor and Stenigot.

(*e*) The fitting of second long wave aerials to stations between Stenigot and Skaw.

(*f*) The fitting of the second short wave aerials of the East Coast Chain.

The C.H.L. stations working at this time had been installed at emergency speed earlier in the year and a technical " clean-up " was necessary in order to standardise and improve them. For example it was hoped to fit automatic turning gear to all of them in place of the hand-operated turning gear. The work on the mobile pool of R.D.F. stations could not be included in any priority list. This had always to contain eight such units which were dispersed at the Radio Maintenance Units. The number requiring building up at any particular time depended entirely on the extent of enemy action.

During October 1940, C.H. stations had been opened at Branscombe, Trerew and Castell Mawr and C.H.L. stations at Cresswell, Bamburgh, St. Cyrus and Rosehearty. In the following month Downderry, Trevescar and Castle Rock C.H. stations and Downhill C.H.L. station were put into operation.[2] Nevertheless, the installation programme was falling badly behind. The Air Officer Commanding, No. 60 Group attributed this to the complexity of the organisation, a large number of authorities being involved.[3] In addition to No. 60 Group there were the Director of Signals, the Director of Communications Development, Headquarters Fighter Command, the Director of Works, No. 2 Installation Unit, the Director of Equipment, the General Post Office,

[1] Air Ministry File S.41234, Part II, Encl. 72A.
[2] Headquarters, No. 60 Group, O.R.B., October/November 1940.
[3] A.H.B./IIE/66, Folder " R.D.F. Organisation—General."

and the civilian firms of Messrs. Pye and Messrs. Metropolitan Vickers. At the end of August an establishment had been made at No. 60 Group for a Chief Engineer of Group Captain rank to assist in the co-ordination of the installation programme but this post was not filled until the 14 December.[1] Shortage of personnel on No. 2 Installation Unit and the Radio Maintenance Units caused delay—unavoidable because of the acute shortage of trained R.D.F. personnel generally.[2]

On 21 December 1940 Air Ministry Signals Staff suggested that much delay in the R.D.F. installation programme was due to lack of co-ordination of the authorities involved.[3] It was suggested that an " R.D.F. Dictator " should be appointed and recommended that No. 60 Group should be made a Royal Air Force Command to give it the necessary powers for co-ordinating the installation programme and to be responsible for the many R.D.F. stations functioning all round the coasts of the British Isles.

Mr. R. A. Watson Watt, as Scientific Adviser on Telecommunications (S.A.T.), wrote a minute to the Secretary of State for Air during the same week calling for an immediate examination of the problem of delays in R.D.F. construction.[4] He pointed out that the effort in the installation of R.D.F. coastal stations had not yet been proportioned to the size and urgency of the programme. Large as the number of individual persons engaged might be, it was relatively small to the need. The six months lateness in the East Coast programme and the rudimentary state of the R.D.F. cover in the West indicated that a more powerful organisation was needed. Stressing that the partial failure in R.D.F. installation was due to planning on too small a scale and to dispersal of interest and effort, he summarised the work involved by stating, " We are attempting to build a radio network several times larger than any other in the world in a time several times smaller than that allowed for building earlier and smaller networks. . . . If we propose to set up all the stations of several B.B.C.s within a few months, would we put the contracts in the hands of a civil engineering firm primarily engaged on other work (as is the Directorate-General of Works), of a public utility company primarily engaged in the daily operation and maintenance of the existing undertaking (as is No. 60 Group), and of an electrical engineering drawing office with a total strength of twenty-six (as has the Royal Aircraft Establishment drawing office concerned) ? " The Scientific Adviser on Telecommunications (S.A.T.) urged that even so late in the installation programme a single engineering enterprise should be found or set up which would have the whole responsibility without division or distraction, of installing R.D.F. stations. The internal R.D.F. equipment—thanks largely to past delays in installation—was now available in quantity which would not limit the rate of completion. This single enterprise would thus feel that it had, with undivided responsibility, the undivided support of all who could implement the War Cabinet instruction for the highest priority for R.D.F.

As an afterthought, in a second Minute to the Secretary of State for Air, Mr. Watson Watt suggested that the Ministry of Aircraft Production be asked to undertake the provision of the complete R.D.F. stations, thus adding construction to their then existing responsibility for design, lay-out, and

[1] Headquarters, No. 60 Group, O.R.B., August 1940.
[2] Air Ministry File S.48327, Folder 123A. [3] A.H.B./IIE/66, Folder.
[4] A.H.B./IIE/74/2, Under-Secretary of State for Air's Committee on R.D.F. Construction, Minutes, Encl. 2A.

provision ; M.A.P. were to let the whole construction and installation contract, undivided, to a selected major civil engineering firm.[1] Such a revolutionary suggestion focussed considerable attention on the problem of delay in R.D.F. installation. All the authorities involved were in complete sympathy with the objective which the S.A.T. wished to achieve. The Under-Secretary of State for Air urged that any course to be followed should not be arrived at impetuously but should have due consideration and final certainty that it was the one most likely to give what was wanted in the shortest time.[2]

The Air Member for Supply and Organisation (A.M.S.O.) welcomed the relief that the Directorate-General of Works would have received if the proposal to put the R.D.F. installations in the hands of a firm of civil engineering contractors were feasible.[3] But he thought that no consulting engineer existed who could manage the difficulties of this problem and certainly no contractors who could handle all the work. Headquarters, No. 60 Group also pointed out that no firm could be found who were first-class experts in civil engineering, electrical engineering, high-frequency radio engineering and automatic telephone equipment, though large firms could be found who were first-class in one activity or another.[4] No. 60 Group therefore defended the existing organisation in that the best service was being obtained from the best sources. The Group outlined the fourteen stages in the process of producing an R.D.F. station and made suggestions for the improvement and speeding-up of R.D.F. construction.[5] It was stressed that another factor productive of delay was the embodiment in the programme of untried and experimental equipment. This tendency required rigid control.

At a conference on 1 January 1941, the Secretary of State for Air directed that a sub-committee should be formed under the chairmanship of the Under-Secretary of State for Air and including the Air Member for Supply and Organisation, the Assistant Chief of Air Staff (Radio), the Director-General of Works, the Director of Signals, the Scientific Adviser on Telecommunications and the Director of Communications Development, with the following terms of reference :—[6]

(*a*) To consider the best organisation for dealing with long-term problems on R.D.F. construction.

(*b*) To consider the exact nature of the bottle-necks which were checking the work then in hand and the best means of overcoming them.

This R.D.F. Construction Committee were required to report within one week, so urgent was the need for a decision on the speeding up of construction.

At a meeting of the Committee on 6 January the whole field of R.D.F. construction was surveyed thoroughly by the various authorities represented.[7] It was clear that the idea of single units to do R.D.F. work exclusively in the various departments was already taking shape, for this had already occurred in the Works Branch and in the Royal Aircraft Establishment Drawing Office. It was felt that this principle should motivate the whole organisation so that those working on the different aspects of R.D.F. construction would be freed from all other duties and given a single-minded purpose. After detailed discussion on all the causes of delay,[8] the Committee rejected the idea of making

[1] A.H.B./IIE/74/2, Encl. 2B. [2] *Ibid.*, Encl. 1A, para. 5. [3] *Ibid.*, Encl. 6A.
[4] *Ibid.*, Encl. 3A. [5] This outline is given at Appendix No. 5.
[6] A.H.B./IIE/74/2, Encls. 4A and 12B. [7] *Ibid.*, Encl. 12B.
[8] *See* Appendix No. 6 for Minutes of this meeting.

a civil engineering firm responsible for future construction of R.D.F. stations. In order to foster the idea of single responsibility within the authorities concerned, it was considered that the most effective way of speeding up R.D.F. work was by the formation of a special technical committee (subsequently known as the R.D.F. Chain Committee) formed from senior representatives of the different interested departments in the Air Ministry and the Ministry of Aircraft Production. Each representative on this committee had the responsibility of following up his particular speciality in relation to R.D.F. construction so that the committee was invested collectively with the powers previously held by many. The constructional programme provided for one hundred stations in the next fifteen months in England alone, so it was recommended to the Secretary of State for Air that this high-level standing R.D.F. committee should be formed and meet weekly.

The R.D.F. Chain Committee

The R.D.F. Chain Committee was formed on the instructions of the Secretary of State for Air and met first on 17 January 1941. Its broad terms of reference were to review the current position of R.D.F. construction work, to define objectives and agree programmes, to endeavour to stage out the work and arrive at target dates for its completion, and generally to watch progress and co-ordinate the work throughout the different stages.[1] The Chairman of the Committee was the Assistant Chief of Air Staff (Radio), Sir Philip Joubert, and included the Director General of Works, the Director of Signals, the Director of Communications Development, the Scientific Advisor on Telecommunications, a representative of Finance nominated by the Permanent Under-Secretary, Deputy Directors of Home Operations and Planning and a representative from Headquarters, Fighter Command. This committee had a common and collective responsibility for the speeding up of R.D.F. construction, but was not a committee which worked by vote because each representative had his own responsibility and could not be voted down. As a committee it had absolute power as far as the progressing of R.D.F. installation was concerned but it could not become involved in the discussion of radio techniques, which was the responsibility of the Inter-Services R.D.F. Committee.

In the course of the first meeting of this Chain Committee, the whole organisation then existing for the construction of R.D.F. stations was examined.[2] The re-organisation of Signals 4 (the Section of Air Ministry concerned with R.D.F.) was recommended, to form a Directorate of R.D.F. under the Director General of Signals. The strengthening of the Director of Communications Development's Directorate was also considered necessary. The mobilisation of outside firms was found to be possible, Messrs. Metro-Vickers, Marconi, Standard Telephones and Cables, Cossor, and the General Post Office —all were found to be in a position to render valuable assistance in drawings and erection work. Progress reports of the stations under construction were discussed and the supply position of the provision of equipment investigated. Altogether there appeared to have been formed a vigorous means of control which would provide the impetus and drive for accelerated R.D.F. construction. This was essential before April 1941 when the threat of invasion would again be imminent.

[1] A.H.B./IIE/74/2, Encl. 12B, para. 14, and Encl. 17A.
[2] *See* Appendix No. 7 for list of R.D.F. stations existing and projected, January 1941.

Although the drive for a speed-up in the R.D.F. constructional programme had to be produced by Air Ministry, No. 60 Group were to play a significant role in the actual work. Accordingly, in order to strengthen the Group, it was re-organised in January 1941.[1] The Radio Maintenance Units were made self-accounting Signals Wings which were to take over from the parent units the administration of the stations of the Chain. The eight Maintenance Units became Nos. 70 to 77 Wings and shortly afterwards a ninth Wing, split off from No. 76 Wing, came into being as No. 78 Wing. The Wings were based on a geographical division of the whole of the British Isles in much the same manner as the original Radio Servicing Sections had been responsible for C.H. and C.H.L. stations in set geographical areas of the country. No. 60 Group Headquarters and the Wings were given increased establishments to enable them to face the large programme of the completion of existing stations and their responsibilities in the new stations to be opened.

Difficulties in Manning R.D.F. Stations

The many problems which faced Air Ministry in the rapid expansion of the R.D.F. Chain were not only those of construction. It will be remembered that during the autumn of 1940 a shortage of trained R.D.F. personnel was becoming acute and that Air Ministry was giving close attention to the important question of selection and training of personnel for R.D.F. duties.[2] The personnel deficiencies were not only numerical. The Scientific Advisor on Telecommunications had expressed the view that the R.D.F. apparatus was capable of providing better information than the operational crews were obtaining. Both Mr. Watson Watt and the Air Officer Commanding No. 60 Group had suggested the formation of a corps of W.A.A.F. officers of advanced scientific education. At an Air Ministry meeting on 4 October 1940, it was decided to create an establishment on C.H. stations of one Flight Officer and three Assistant Section Officers (W.A.A.F.) per station.[3] The Flight Officers were to be women with University degrees and several years of experience in Physics, and were to act as scientific observers for the Scientific Research Section and to be responsible for the efficiency of operating personnel. The Assistant Section Officers, of less experience though still of graduate standard, some to be recruited from the best of the existing Radio Operators, were to work on a watch system in charge of operations. It was hoped that this latter establishment would check the rate of flow of expert operators into non-radar commissions and offer a career in their own trade. The first Supervisors' Course began in March 1941. This had the essential advantage of having A.M.R.E. Scientists to give part of the course. Personnel of the required educational standard were not always available, but officers of a lower standard were trained successfully.

During the latter part of 1940 such a large programme was envisaged for R.D.F. both at home and overseas that it was realised that the supply of skilled Radio Mechanics in the United Kingdom would be inadequate. R.D.F. Operators could be trained in a period of four weeks but efficient Radio Mechanics required several years of radio servicing experience behind them as a background to specialised work in R.D.F. Signals were therefore sent to the Dominions of Canada, South Africa, Australia and New Zealand to

[1] Headquarters, No. 60 Group, O.R.B., January 1941.
[2] Air Ministry File S.3523, Encl. 8A, and Air Ministry File S.48327, Encl. 13A.
[3] Air Ministry File C.S.14822, " Supervisory Officers—W.A.A.F."

try to recruit suitable candidates as technical officers and airmen mechanics.[1] A similar signal was sent to the British Ambassador in the United States attempting to get U.S. citizens of suitable qualifications to volunteer. On 18 June 1941 the existence of R.D.F. was made public in the House of Commons by the Leader of the House, and on the same day Lord Beaverbrook appealed to America for technicians to form a civilian Technical Corps.[2] The name given to the science of R.D.F. was " Radiolocation." [3] On 23 June, " Radiolocation " formed the subject of a W.A.A.F. recruiting poster in an effort to obtain more volunteers with a sufficiently high standard of education for these important duties.

The formation of a Radio School in Canada was proposed in August 1940 and its organisation was planned. However, at that time the transfer of the Air Training Schools from Britain under the Commonwealth Training Plan was taking place, and Canada had very heavy commitments under this scheme. After giving further consideration to this matter, Air Ministry felt that there was not sufficient justification in pressing the Canadian Government to establish a Radio School.[4] However, in July 1941 No. 31 Radio School opened at Clinton, Ontario, for training Canadian and American R.D.F. Mechanics, these latter being enrolled in the Civilian Technical Corps.

A second R.D.F. School in the United Kingdom was a necessity during the Autumn of 1940 if the expanding Home Chain were to be manned. The figures furnished by the Director of Organisation at the end of August give testimony to this urgent requirement :—[5]

(*a*) *Existing training facilities at No.* 1 *Radio School, Yatesbury, for Radio Operators.*

Airmen	126 every three weeks.
W.A.A.F.	54 every three weeks.

(*b*) *Present strength of Trained R.D.F. Operators.*

Airmen	402
W.A.A.F.	147
Total ..	549

(*c*) *Requirements of R.D.F. Operators to April* 1943.

Airmen	2,095
W.A.A.F.	1,205
Total ..	3,300

From the estimates available it appeared that by January 1941 there was a requirement for 800 trained personnel. This could not be met unless a second Radio School were formed.[6] There was some indecision about the location of the school, Northern Ireland and Prestwick being considered, but the Royal Air Force Station, Cranwell, was the final decision. The establishment for the school was settled at the beginning of December 1940. Some

[1] Air Ministry File S.48327, Enclosed Folder 123A, Encls. 3A–7A.
[2] *The Times*, 19 June 1941. [3] *Ibid.*, 23 June 1941.
[4] Air Ministry File S.48327, Folder 123A (Encl. 1A) and Encl. 124A.
[5] *Ibid.*, Folder 123A (Encl. 11A). [6] *Ibid.*, Folder 123A (Encl. 22A) and Encl. 126B.

Works Services were necessary and it was not until 10 March 1941 that No. 2 Radio School was formed under the control of No. 27 Group, Technical Training Command, and training commenced. By the end of 1941 it became evident that the output of Radio Operators and Radio Mechanics was exceeding the rate at which they could be absorbed into new R.D.F. stations being erected at home or despatched overseas.[1] Sufficient Radio Operators existed to cover all requirements up to 1 May 1942, and a reduction in intake of personnel into training schools was therefore arranged. For the first time the Home Chain was adequately manned numerically.

The Capacity of the R.D.F. System

Towards the end of 1940 additional attention was given to obtaining the maximum benefit from R.D.F. information derived from the Home Chain reporting system.[2] Examination showed that information was being lost not only at the source but also in subsequent passage through the Filter Room to the Operations Room table. The Stanmore Research Section at Headquarters, Fighter Command, which carried out the examination, was responsible for advising on the organisation and working of the R.D.F. Chain. Their responsibility covered the operation and technical performance of stations both as individual units and as a whole, including lay-out of equipment, procedure, and communication systems. Their field of investigation included filter rooms. They also advised on the selecting, training and efficiency of personnel, and on the general policy concerning the research and production of R.D.F. equipment. In order to enable the reader to appreciate fully the work of the Stanmore Research Section in connection with raid reporting, a brief explanation of the duties of the individual operators and others composing one watch at a typical R.D.F. station in early 1941 is attached at Appendix 58.

The investigations of the Stanmore Research Section were directed primarily towards finding the weakest links in the raid reporting system. It was discovered that the saturation limit, defined as the maximum number of tracks which could be reported in a given time, was reached in the process of telling, and of filtering, much more quickly than at any other point in the system.[3] In fact it was calculated that tellers and filterers could only handle about one-third of the number of tracks which the rest of the system could deal with in the same period of time. Secondly, it was shown that, provided each station had its own telephone line to the filter room, there was no slowing down of information at that link. If, however, one telephone line was shared by a C.H. and a C.H.L. station, a reduction in the flow of tracks became apparent ; moreover the hold-up was even greater where two C.H.L. stations shared a line with a C.H., as was sometimes the case. The attempt made at the time of the Battle of Britain to reduce congestion at the filter room by making two neighbouring stations share one line was thus shown to be harmful to the system as a whole. It caused even worse congestion at the reporting station. Arrangements were made, therefore, for every station, whether C.H. or C.H.L., to have a direct telephone line to the filter room with effect from 13 March 1941.

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[1] Air Ministry File C.S. 9742, Encl. 5A.

[2] Air Ministry File S.41234, Part II, Encl. 92A.

[3] *Ibid.*, Part II, Encl. 92A, p. 12.

Improvements at the Filter Rooms

The existing Filter Room at Stanmore was already crowded and incapable of accommodating further personnel around the plotting table. The Research Section had decided that the personnel there were already fully employed in the handling of the incoming R.D.F. information for the No. 11 Group area only, whereas they were attempting to attend to the areas covered by Nos. 11, 12 and 13 Fighter Groups.[1] With the introduction of other improvements recommended by the Research Section at the C.H. and C.H.L. stations themselves, it was anticipated that the output of R.D.F. information from these stations would be doubled in the near future. There appeared to be no escape from this difficulty other than the division of the Filter Room table into units covering smaller areas. It would then be possible to enlarge the scale and redesign the tables so that the required number of filterers could be seated round the enlarged perimeter of each new filtering unit. Since the new tables would each require a separate room, it was reasonable to make the new filtering units correspond to Group areas where these were also convenient from the standpoint of R.D.F. coverage, and to place the new Filter Rooms near their respective Group Headquarters, providing adequate telephone facilities for easy liaison between adjacent Filter Rooms. Other advantages which would attend this re-organisation were :—

(*a*) Closer liaison with the responsible Fighter Groups.

(*b*) Simplification of communications, as the R.D.F. stations would be connected to geographically proximate Filter Rooms instead of all being connected to Stanmore.

(*c*) Increased protection against disorganisation of the whole system by enemy action.

Filter Rooms were already working at Fighter Groups at Box (No. 10 Group), Preston (No. 9 Group) and Kirkwall (No. 14 Group) so there was every reason to anticipate that a similar organisation extended to Nos. 12 and 13 Groups would be successful. Headquarters, No. 60 Group had originally recommended that plotting should be decentralised from Fighter Command down to the Groups as early as June 1940. It was therefore decided in December 1940 to decentralise the Stanmore Filter Room and split it between the Fighter Groups throughout the country.[2] This was in accord also with a scheme to decentralise the Air Raid Warning control from Fighter Command Headquarters to the Headquarters of each Fighter Group.[3] Naturally such an undertaking required considerable time to complete the technical work, largely that of the G.P.O., in the installation of the many telephone lines required. It was not until September 1941 that the division was complete, the Stanmore Filter Room then being used solely for the No. 11 Group area, new Filter Rooms being opened for Nos. 12, 13 and 14 Groups, and another established at No. 82 Group for the Northern Ireland Area.

Improvements at C.H. Stations

Apart from some recommended improvements in the aerial systems by the Stanmore Research Section, the principal scope for increased efficiency in each station was an improvement in the conditions of working.[4] In particular the radio equipment controls required re-disposing to permit the most rapid

[1] Air Ministry File S.41234, Part II, Encl. 92A, Section IV, p. 15.

[2] Headquarters, Fighter Command Signals Branch, O.R.B., December 1940.

[3] Home Office File GEN.93/82, Peck Committee.

[4] Air Ministry File S.41234, Part II, Encl. 92A, p. 19.

and convenient manipulation. Another very important factor leading to slow observing was the time spent in attempting to correlate correctly echoes on the tube with their designated track. This difficulty in matching plots and tracks at the station end of the telephone line imposed a heavy burden on the whole reporting system. Not only did it distract the observer, but it also led to indecision, confusion and waste of valuable time in interrogations to and from the Filter Room. The major improvements required therefore at the C.H. station could be summarised as :—

(*a*) Some form of " Tracker," which would enable the Filter Room to designate a track on its first plot and to obtain all subsequent plots from the C.H. station with their correct track designation without the need of further interrogation.

(*b*) The reorganisation of the equipment controls to facilitate the work of the observer and supervisor.

The Tracker

A Tracker was installed in experimental form at Dunkirk during March 1941.[1] It required the addition of a second cathode ray tube installed near the one manned by the observer, and connected electrically to show the same indications. Close underneath the time-base or trace on the second tube, a long roll of paper passed over a thin roller and moved downwards at a slow but constant speed under the power of an electric motor. A range scale was given by equi-spaced vertical lines marked on the paper. Whenever a new echo appeared on the trace, its position was marked on the paper in the appropriate position, and labelled with the letters and numbers designating the particular track as soon as this was received from the filter room. Subsequent movements of the echo along the trace were thus marked at the tracker tube and by drawing a line through successive recordings of the same aircraft, a range-time curve for each track appeared. A movable range marker pointer on the observer's tube was coupled with a similar marker on the tracker tube in such a way that they moved together, and thus the tracker observer should never have been in doubt as to which particular track the reporting observer was working on.

The introduction of the tracker enabled the R.D.F. station to keep a check of all echoes appearing on the tube, together with the filter room designation of the track. Previously the observer had to rely on memory alone when making reports and when answering cross-questions from the filter room. A considerable clarification of work resulted and the track handling capacity of the stations increased. The additional equipment was soon approved for all C.H. stations and installation proceeded during the remainder of the year.

The Console

To facilitate the work of the observer and supervisor, the several pieces of equipment that they were required to manipulate were mounted together as a single unit called, for simplicity, the " Console ".[2] This development went far beyond No. 60 Group's original requirement from which it had arisen ; the proposal being for the addition of a second cathode ray tube as a " sorter " in parallel with the observer's tube. Although this elaboration deferred its introduction, the elaboration appears to have been worth while. The " Console "

[1] Air Ministry File S.41234, Part II, Encl. 92A, p. 21. [2] *Ibid.*, Part II, Encl. 92A, p. 22.

was introduced at Dunkirk R.D.F. station in experimental form in March 1941. So great were the advantages of this new layout of controls that it was immediately termed, unofficially, the " Wurlitzer " by R.D.F. station personnel —a compliment to the easy availability of the controls, suggestive of the cinema organ. The chief components of the Console were :—

(*a*) The second cathode ray tube unit together with its tracker.
(*b*) The plotting map.
(*c*) The horizontal polar diagram of the station on which was indicated the bearings at which the electrical calculator did not read heights.
(*d*) The vertical polar diagrams for various azimuths or bearings which also showed the upper and lower cut-off points on the electrical calculator for the height systems.
(*e*) An improved standby " Manual Convertor " for obtaining heights in case of unserviceability of the electrical calculator.
(*f*) A calculator display panel similar to that on the receiver.
(*g*) A master switch for the use of the supervisor, causing the display " No height " and informing the operator that height could not yet be obtained.

Improvements at C.H.L. Stations

For efficient working the rate of sweep of the rotating aerials had to be increased to a speed greatly exceeding that which was possible by the manual turning gear. Consequently a mechanical drive was required, the speed of which was variable at will to serve both the requirements of the C.H.L. stations with a linear time-base and also those with a radial one.[1] The mechanical drive needed a reserve of power sufficient to maintain operations during high winds. The development of this mechanical turning gear was not without its difficulties as the C.H.L. stations in use were not standard, having been erected during the earlier 1940 programme, the majority with separate transmitter and receiver aerials.[2] The change to mechanical turning of a common aerial for both the transmitter and receiver took place throughout 1941.

Those few C.H.L. stations which were fitted with the Plan Position Indicator (P.P.I.) were proving more efficient than the earlier stations with the normal cathode ray tube horizontal time-base display. The radial time-base of the P.P.I. enabled the operators to give good macroscopic reports and also to pass all other information with considerable thoroughness, since a plan picture of the aerial activity of the whole sector was continuously presented to the observer. The only disadvantage of the method of presentation was that the range was limited to about 60 miles. This was, however, no great drawback since the picture presented by C.H.L. stations was superimposed on the longer range raid reporting of the main C.H. Chain.

Triple-Service CD/CHL Stations

In a consideration of problems connected with defence against invasion, the War Cabinet Defence Committee on 31 October 1940 agreed to recommend that the provision of R.D.F. for detecting enemy surface craft and for coastal artillery should receive a higher priority than was being accorded at the time.[3] The three Services were all considering their separate requirements and it became obvious that a certain amount of overlapping of R.D.F. cover would

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[1] Details of this have been given in Chapter 9.
[2] Air Ministry File S.3522, Encls. 60B and 63A.
[3] War Cabinet Defence Committee (Operations), D.O. (40), 39th Meeting.

occur if each Service had its own chain of stations. A letter from the Admiralty to the Air Ministry on 8 January 1941 urged the necessity of co-ordination of the supply, erection and manning of C.H.L. stations since the three fighting Services employed, or intended to employ C.H.L. stations for the following purposes :—[1]

Air Ministry	..	For location of low-flying aircraft.
Admiralty	..	For locating enemy vessels approaching a harbour or passing through a channel.
War Office	..	For locating and ranging on enemy vessels approaching the coast or attempting an invasion.

Up to the beginning of 1941 Air Ministry had erected a large number of C.H.L. stations, some forty-four in all with sixteen more projected ; some of which afforded the Admiralty a part-time service. The Admiralty had erected six stations only and the War Office had not erected any, though a great deal of experimental work had been carried out in connection with siting and design. The Ministry of Aircraft Production had supplied all the radio equipment so far. The Admiralty pointed out the strong similarity between the Naval and Military requirements though there were some differences in detail ; both Army and Navy desired to prevent the enemy from approaching our shores. The Air Ministry had already proved that their C.H.L. stations could meet Naval requirements in the location of surface targets—demonstrated by the part-time service some of these stations were giving for the Admiralty. The Admiralty, therefore, recommended that the Air Ministry, by reason of experience and organisation, would be best suited to undertake all C.H.L. work for the three Services.

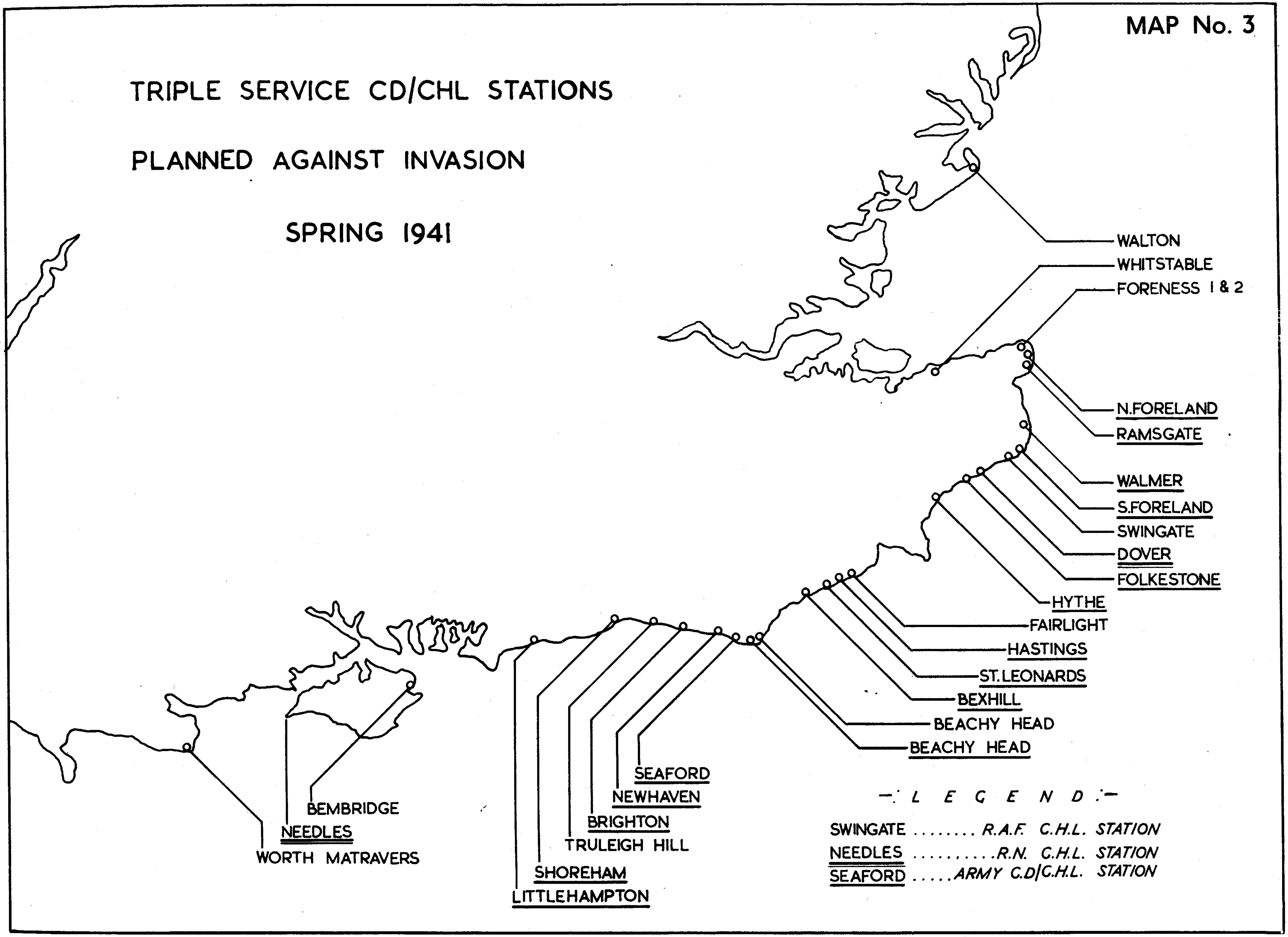
The Admiralty proposal was considered at the sixteenth meeting of the Inter-Services Committee on R.D.F. on 30 January 1941, and after a short preliminary discussion, it was decided to appoint a small sub-committee of six members, two from each Service, under a chairman, to consider the requirements of the three Services with respect to C.H.L. stations and to recommend to the main committee plans to meet these requirements. This C.H.L. Planning Sub-Committee met immediately and submitted an interim report within two weeks. A realistic view of the situation was taken, in that its recommendations were governed by the development which could be undertaken before 1 April 1941, by which date invasion might be imminent. It was the period until the 1 April which was covered by the interim report, thus excluding all considerations of an ideal or theoretical character. Some twenty-four C.H.L. stations were planned to be completed within this period.[2]

The value of the reports from these stations (termed C.D./C.H.L.—Coast Defence/Home Chain, low-looking) would have been rendered nugatory unless accurate and swift filtering was assured. It was considered that this could only be carried out in the nearest Naval Operations Room where it was necessary to maintain plots of all friendly ships, naval, merchant and fishing, round the South-East coast of England. To achieve this it was necessary to fit I.F.F. sets (Identification Friend and Foe) in all naval vessels operating in this area, and there had to be a great tightening up of the reporting and plotting organisation for merchant and fishing vessels.

[1] A.H.B./IIE/68, Inter-Services Committee on R.D.F., Minutes of 16th Meeting, Appendix " A."

[2] A.H.B./IIE/67, " C.H.L. Planning Sub-Committee " (Interim Report).

The locations of the twenty-four C.D./C.H.L. stations erected as a result of these plans are given on Map No. 3.



A.H.B.I MAP No. 407

In addition to the normal Royal Air Force telephone lines to the parent C.H. station, each C.D./C.H.L. station required lines to the nearest Naval Operations Room and separate military lines to the Local Defence Commander and the nearest coast battery.[1] At the station end of these lines it was recommended that two P.P.I.s should be fitted, one for the use of the Royal Air Force operator and the other one for the Army and Navy. This latter P.P.I. was to have a shorter range scale (0–25 miles). Since P.P.I.s were in short supply, a priority list of stations to be fitted was drawn up.

Prior to the proposal of Triple Service Stations, the Army were developing plans for their coast defence stations separately from the Royal Air Force. The total number of C.D./C.H.L. stations now required to cover the British coastline in the final form of a single warning chain comprised :—[2]

Royal Air Force	60 stations.
Army	60 stations.
Total	120 stations.

Despite the seemingly large number of C.D./C.H.L. stations involved, this would be a great economy over the originally projected Army and Royal Air Force separate chains.

The C.H.L. Planning Sub-Committee recommended that trials be carried out with a single suitably-equipped station serving the three Services to test the efficiency of the scheme, a CD/CHL station at the Needles being selected for this purpose. This station, the first of the War Office stations to operate, was ready on 10 June 1941 and was followed by 1 August with twelve more War Office constructed CD/CHL stations.[3] In view of the shortage of trained personnel, the CD/CHL Planning Sub-Committee agreed that initially these stations should be manned and maintained by the Army. When the CD/CHL station at Needles was inspected by two radiolocation specialist Royal Air Force officers it was found to be well below standard for aircraft detection.[4] They recommended that the Royal Air Force should not take over the station from the Army until it was installed to the operational standard required by Filter Room. This policy was adopted and it was the end of 1941 before the transfer of Army CD/CHL stations to the Royal Air Force began. Fortunately the Germans never mounted the threatened invasion, for this CD/CHL station programme was far behind its planned schedule and would not have been of much real assistance in the spring of 1941.

Detection of Very Low-Flying Aircraft

Early in 1941 it was apparent that the enemy appreciated that aircraft could evade detection by R.D.F. by flying very low on their approach to the coast. On the Eastern Scottish coast many attacks were made on convoys and targets near the coast by enemy aircraft flying at heights between 50 and 100 feet above the sea,[5] notably in the neighbourhood of Kinnaird's Head, Firth of Tay, Cromarty Firth and Scapa Flow. The Air Officer Commanding-in-Chief, Fighter Command, drew the attention of Air Ministry to this weakness, pointing out the necessity of developing suitable equipment. The Stanmore Research

[1] Air Ministry File S.45860, Encl. 79A, and Air Ministry File S.3522, Encl. 78A.
[2] A.H.B./IIE/67 (Final Report).
[3] Air Ministry File S.8696, Encls. 1A and 8A.
[4] *Ibid.*, Encls. 24A and 41A.
[5] Air Ministry File S.3522, Encl. 80A.

Section were asked to carry out a detailed investigation of each individual low-flying raid undetected by R.D.F. in order that information could be compiled on the important weaknesses in the existing Chain.[1] In March 1941 the Telecommunications Research Establishment at Worth Matravers was asked to examine all possible methods of improving the range performance on aircraft flying at 50 feet, a 50 mile range being desired, either by modification of the existing apparatus or by the design of new.

Several alternatives were possible to obtain low-angle coverage :—[2]

(*a*) Using the existing C.H.L. stations, four methods suggested were :—

(i) increasing the effective height of the aerials ;

(ii) increasing the output of the transmitter ;

(iii) using larger aerial arrays ;

(iv) increasing the receiver sensitivity.

(*b*) Using a much shorter wave-length (ultra high frequency)—requiring a major change in equipment.

Of these methods only one was possible to give immediate results, namely an increase in transmitter power, which was boosted to 200 kilowatts during March. The prospect of increasing the receiver sensitivity was not encouraging, and although it was being studied by various research groups, no satisfactory solution to this problem was expected in under six months. The size of aerial was considered to be ample for practical purposes. Some trouble had been experienced with rotating aerials in high winds, so that any increase in size could only aggravate the problem. The only alternatives were either to increase the height of the aerials or to change the equipment and work on a much higher frequency. Experiments were carried out simultaneously along both these lines.

To obtain increased aerial height, the C.H.L. station could be re-sited on higher ground. However, this normally meant moving further inland, and any increase in height gained would be subject to a loss of coverage due to moving further from the coastline. The only solution was to raise the height of the C.H.L. aerial by the use of a 200-foot tower near to the coast. Such stations became known as C.H.L.(T) stations.

The second method of obtaining low angle R.D.F. coverage by using a much higher frequency, also appeared to be a practical proposition for detecting the very low-flying raider. The development of a new type of valve, the cavity magnetron,[3] by a Birmingham University research group, Professors M. L. Oliphant, H. T. Randall and Mr. H. A. H. Boot, during 1940 had opened up the possibility of R.D.F. transmitters of sufficient power on a frequency of 3,000 megacycles per second.[4] The General Electric Company (G.E.C.) rapidly improved on this valve and went into production.[5] By November 1940 the Telecommunications Research Establishment demonstrated a somewhat primitive form of ultra-high frequency ground R.D.F. equipment capable of following a submarine to 7½ nautical miles from the equipment.[6] By April 1941 the Royal Navy had an improved set of this type, termed the Type 271, in production. This set worked on the very high frequency of

[1] Air Ministry File S.3522, Encls. 82A and 85A. [2] *Ibid.*, Encl. 86B.
[3] *See* Appendix No. 8, " The Development of the Magnetron Valve."
[4] C.V.D. Report, May 1941, " Magnetron Development in the University of Birmingham."
[5] G.E.C., Ltd., Lab. Report No. 8717.
[6] Air Ministry File C.S. 12138, Part I, Encl. 1A.

3,000 megacycles per second and it was considered possible to use it for the Home Chain requirements against very low-flying raiders. The Type 271 used a 4 feet 6 inches paraboloid reflector, giving a sharp beam of some six degrees angular width. In the original equipment, separate transmitter and receiver aerial systems were used and their turning gear was hand-driven. For the Air Ministry requirement it was necessary to develop this along similar lines to the C.H.L. station development, with common aerial working and the addition of mechanical turning gear. Both C.H.L. on high towers and the Naval Set Type 271 were proceeded with experimentally but tests were not carried out until 1942. The remainder of this programme for R.D.F. cover against the very low-flying raider is dealt with in Chapter 16.

Defence of R.D.F. Stations

The attacks on R.D.F. stations during the Battle of Britain had given first-hand experience of their weakness under bombing. There was every reason to expect more such bombings and under the threat of invasion, direct attack by enemy paratroops and saboteurs. As the Buried Reserve would not be available for some considerable time, it was essential for precautions to be taken on the existing stations. The aerial feeder lines were very vulnerable, so all receiver feeder lines had to be provided with earth traverses, and balks of wood and hurdles covered with sandbags or earth were placed across the top of the traverses to protect the feeder lines from rock falling as a result of nearby explosions.[1]

Increasing the height and thickness of blast walls round permanent receiving and transmitting blocks and an improvement in the camouflage of vital points were undertaken to give better protection. Such precautions were not considered adequate for the more exposed stations in the South-East.[2] Certain caves in the cliffs of Dover, at that time used for storing ammunition, were requested for R.D.F. equipment and personnel in order that the vital R.D.F. station at Dover could be maintained in the face of the heavy scale of air attack to which the area had been subjected. If this installation proved successful, further similar systems were contemplated at Beachy Head and Ventnor.[3] Such " Cliff C.H." stations were to have the aerials and reflectors mounted on the face of the cliff : no masts being necessary. After the August attacks on the South-Eastern R.D.F. stations during 1940 the enemy never attacked them again, so the " Cliff C.H." station was not constructed. There was a change in the standard lay-out of the C.H. station from the vulnerable East Coast type of station to the more dispersed type used in the West Coast Chain

R.D.F. for Northern Ireland and Eire

After the fall of France, although the most direct threat to this country was that of invasion of the South-East of England, there was the danger that the enemy might avoid a frontal attack and attempt to attack this country by a flank movement through Eire. At the 39th Meeting of the War Cabinet Defence Committee at the end of October 1940 the possible German invasion of Eire was discussed.[4] It was agreed that " although the threat of invasion generally was becoming more remote, it is possible that, during the winter months, Ireland might be invaded with the object of increasing the scale of

[1] A.H.B./IIE/168, Air Marshal Joubert's Folder " R.D.F. Station Defence," Encl. 30A.
[2] War Cabinet, Chiefs of Staff Committee, 280th Meeting, C.O.S. (40).
[3] A.H.B./IIE/168, Encls. 45A, 52A, 58A and 83A.
[4] War Cabinet Defence Committee (Operations), 39th Meeting, D.O. (40).

attack on our shipping and Western ports." Plans had therefore to be drawn up by the Chiefs of Staff for the defence of Eire as soon as political considerations permitted access to that country.[1] From the R.D.F. viewpoint the primary requirement was to give cover to the Irish Sea and its approaches, although by December 1940, the Chiefs of Staff had approved that the requirement was for range and height-finding facilities up to distances of 100–200 miles to seaward round the entire coast.[2]

A preliminary reconnaissance showed that to give adequate cover to vital points on the coast of Ireland fourteen C.H. and fourteen C.H.L., stations would be necessary in addition to those stations already operational in Northern Ireland. It was considered that the Observer Corps system as employed in Britain would be impracticable on account of the paucity of communications in Eire and in any event, the possibility of sabotage. Reliance had therefore to be placed on G.C.I. sets inland and a Wireless Intelligence Screen with W/T communications similar to that used during the French Campaign. Some eight G.C.I. sets were estimated to meet this requirement.[3] This project made a heavy call on available equipment, as it had to be operational by March 1941. It was obvious that there would have to be some drastic speed-up in production of equipment or the Middle East R.D.F. programme would have to be retarded. Air Staff had laid down the priority of R.D.F. cover required as :—

(*a*) North Channel.
(*b*) To fill gaps in R.D.F. coverage in St. George's Channel.
(*c*) To fill gaps in R.D.F. coverage in Irish Sea.
(*d*) To provide cover for possible fleet anchorages in the Shannon, Queenstown, Berehaven and Loch Swilly.

Between June and December 1940, some sixty new R.D.F. stations had been erected and manned either at home or overseas. The additional thirty-six R.D.F. stations now requested for Ireland were a commitment which could not possibly be met.[4] To cover the bare requirements laid down by Air Staff, Air Ministry Signals Staff could only offer four mobile R.D.F. units and seven C.H.L. stations with one spare set for each. No G.C.I. stations were available but six were being fabricated for use in Britain and it was suggested that two or three of these equipments would have to be released for Eire. These stations would have provided the minimum cover for the Air Staff plan. All stations were to report to the appropriate sector plotting table by R/T, these sectors having been planned to cover the various regions of Ireland. Each sector was to tell its tracks by broadcast so that the neighbouring sectors could intercept the information.

Meanwhile additional sitings of R.D.F. stations in Northern Ireland and the Isle of Islay were carried out.[5] Since the control of Fighter squadrons during the first phase of any invasion of Eire would be exercised from Northern Ireland, it was essential that this vital base area should have adequate R.D.F. warning. At this time there were two C.H.L. and two C.H. stations working in Northern Ireland. Surveys showed that it was necessary to instal three C.H. stations, four C.H.L. stations, four G.C.I. stations and one Mobile Radio Unit to complete the Northern Ireland R.D.F. cover. The Mobile Radio Units required for Eire were under construction, and the provision of personnel

[1] Air Ministry File S.4990, Encl. 2A.
[2] Air Ministry File S.7464, Minute 2.
[3] Air Ministry File S.4990, Encl. 16A.
[4] *Ibid.*, Encl. 17B.
[5] *Ibid.*, Encls. 20A, 21A, 81A.

to man them continued in February and March 1941.[1] Two M.R.U.s were shipped to Northern Ireland in April, Nos. 245 and 246 M.R.U.s, while Nos. 247 and 248 M.R.U.s also earmarked for this commitment were retained in a Maintenance Unit in England. The latter two M.R.U.s were subsequently released from the Eire programme for duties overseas. To control the development of R.D.F. stations in Northern Ireland, a new Wing, No. 79 Signals Wing, was established on 24 September 1941.

The circumstances which had required the planning of R.D.F. cover for Eire ameliorated towards the end of 1941. During November disbandment instructions were issued for the personnel and material then massed in Northern Ireland, but Nos. 246 and 247 M.R.U.s were retained there and sited to give R.D.F. cover on the N. Ireland/Eire border in February 1942. This period of the threatened invasion of Eire, of some sixteen months duration, had no adverse effect on the development of the Home Chain. It provided a certain small impetus to the rate of production of the equipment but had the disadvantage of deferring for some months the shipment of additional Mobile Radio Units to other overseas theatres.

Further Operational Considerations of R.D.F. during 1941

In addition to the danger from undetected very low-flying aircraft, enemy activity at night was the other most serious threat during the winter of 1940–41. The night attacks on London diminished towards the end of October but a series of raids on the provinces began.[2] Coventry (15 November), Southampton (18 November), Birmingham (12 December), Sheffield (13 and 16 December), Liverpool (21 and 22 December), Manchester (23 and 24 December), Cardiff (3 January 1941), and Swansea (18–22 January) were the chief targets. These towns were raided repeatedly throughout the first half of 1941. London was still a main target, notably on 31 December when there occurred a very damaging incendiary attack; and on 17 and 20 March 1941 when London was attacked by 500 and 400 aircraft respectively. The normal raid strengths varied between 100 and 400 enemy bombers.

The conditions of greatest stress on the R.D.F. system at night were essentially different from those by day during the Winter of 1940–41. Enemy aircraft flying by night crossed our coasts singly, moving in parallel tracks confined to a narrow belt often no more than 10 miles in breadth.[3] These so-called "crocodiles" of enemy aircraft were commonly encountered over the South-East coast and occasionally in the Thames Estuary, and the reporting of detailed and accurate information on them involved considerable difficulties. A typical "crocodile" had the following structure:—

Average speed of aircraft ..	180 miles per hour.
Influx strength	One aircraft crossed the coast every 4 minutes (*i.e.*, 15 per hour).
Typical width	15 miles.
Linear distribution along the "crocodile".	One aircraft every 12 miles on average.
Average superficial density ..	One aircraft per 180 square miles.
Average volume distribution ..	Since the aircraft flew between 10,000 and 20,000 feet, there was an average of one aircraft per 345 cubic miles.

[1] Air Ministry File S. 4990, Encls. 44A, 100A, 107A, 119A and 135A and B.
[2] Headquarters, No. 11 Group, O.R.B.
[3] Air Ministry File S.41234, Encl. 92A.

When a " crocodile " passed near or over a C.H. station the number of echoes on the cathode ray tube with a 100-mile range was 100/12 = 8·3. There were also echoes from enemy aircraft not in the main crocodile. The picture was complicated by echoes of aircraft behind the station and echoes from our own aircraft. Altogether the number of echoes to be examined was hardly ever less than 20 in these circumstances. Experiments had shown that the greatest number of plots, complete with heights, which could be passed under ideal conditions and competently placed on the Filter Room table was about six per minute. In practice the number was nearer three to four plots per minute. Thus to report 20 or more responses on the tube a period of some five minutes was needed. In such circumstances continuous and accurate filtering became difficult and the tracking of individual aircraft obscure.

From our own predicted scale of activity against the enemy it was anticipated that the enemy might propose to send some thousand planes to bomb a limited metropolitan industrial area. Under such conditions the one-dimensional display on a C.H. station cathode ray tube interpreted by microscopic reporting would have been useless.[1] In the spring of 1941 the new system of macroscopic reporting was ordered. This consisted of dealing not with single aircraft but the average properties of collections of aircraft by giving :—

(*a*) the mean plan position and superficial extent of one or more large formations together with their boundaries and progress, or

(*b*) the breadth, direction and strength of one or more " crocodiles ".

The microscopic method of reporting the full details of height, speed, number and direction was only retained for dealing with small enemy formations. The improvement of R.D.F. information as a result of macroscopic reporting played some small part in the general improvement of our night defences, though this was largely due to the maturing of the new G.C.I./A.I. technique. G.C.I. stations were in operation early in 1941 and A.I., Mark IV—the first successful form of A.I. aircraft equipment—was in use in British night fighter aircraft.[2] On the night of 11 May 1941 three hundred and sixty enemy aircraft attacked London and a record number was shot down.[3] After that night, attacks were made in much less strength, and died away at the beginning of July, with the transfer of the major portion of the enemy bomber strength to the Russian front.

Proposals to use C.H.L. Stations offensively

By the middle of 1941 offensive sweeps were being carried out as normal routine by Fighter Command over the French coast. The bombing of selected targets in the occupied countries was also part of Air Staff policy. The possible use of C.H.L. stations for " offensive " operational requirements was under consideration. In such circumstances it was necessary to keep the C.H.L. beam directed on to a " friendly " target rather than to search continuously for hostile aircraft. The aerial turning gear then being introduced was particularly suited to this use. The system suggested was that our attacking

[1] With the introduction of "macroscopic" reporting, the old method of giving information of each aircraft individually began to be known, for the sake of distinction, as microscopic reporting. The literal meaning of the word microscopic has no application in this sense.

[2] The G.C.I./A.I. technique of night interception is described fully in Volume V.

[3] Headquarters, No. 11 Group, O.R.B.

aircraft should fly on a C.H.L. beam which could be locked to pass right over the desired target. The aircraft was to be controlled by R/T and, when its range was the correct distance from the C.H.L. station to the target, bombing instructions could be given. This proposal, made by Mr. Edmund Dixon of the Directorate of Communications Development, was received with interest by the Signals Branch at Air Ministry. A written report of these proposals was requested together with any actual data available, to be laid before Air Staff with a view to obtaining the allocation of some four C.H.L. stations forthwith for this work.[1] This suggestion must be regarded as the forerunner of " Oboe ", radio aid to bombing, which is described in Volume III.

Termination of the " Buried Reserve " Chain Programme

It will be remembered that in September 1939 the Chief of the Air Staff had directed that the Intermediate R.D.F. sets of the original twenty-station Home Chain, when replaced by the Main Chain " Final " sets, were to be used for stand-by purposes and housed in buildings which were to be sunk to ground level and turfed over for concealment.[2] This was a long-term policy for the maintenance of serviceability of the Chain stations in face of air attacks which might render their " Final " R.D.F. sets unserviceable. In such circumstances, the personnel would have been transferred to this " Buried Reserve " equipment, situated some 300 yards from the main buildings.

This reserve programme could only be put into effect as each station in the Chain received its final equipment. Even then the amount of work involved in excavations and buildings was enormous, as damp-proof, force-ventilated buildings below ground level were necessary. None had been completed at the time of the Battle of Britain. As a result of the enemy attacks on the south coast Chain stations, No. 60 Group was instructed to proceed with the installation and commissioning of the " Buried Reserve " stations between Ventnor and Netherbutton on high priority.[3] The Chain station at Stenigot was selected as a prototype by No. 60 Group and work began during October 1940. By the end of November the " Buried Reserve " programme had been sanctioned for thirty-seven C.H. stations. In addition 100 per cent. reserves in mobile form for all C.H. stations to be assembled in two pools, one at Sealand and the other at Halton, had been approved by the Treasury.[4] The Air Ministry R.D.F. Panel decided that, without prejudice to the right to provide 100 per cent. reserve mobile installations for the future, this last line of mobile reserves was to be limited to 50 per cent. of the total number of C.H. stations.

By December 1940 the twelve south-west stations between Ventnor and Warren (South Wales) had been included in the " Buried Reserve " programme. Some of the difficulties of implementing it were causing concern. The construction required a very large contractor's effort. The labour available at this stage in the war was only just sufficient to proceed rapidly with the main R.D.F. stations. All the authorities concerned were agreed that effort was not to be diverted from the main stations, so this meant that the " Buried Reserves " were not to be completed until well into 1942.[5] Excavation

[1] Air Ministry File S.8143, Encl. 61A.
[2] This was given in Chapter 6 of this volume. Air Ministry File S.47412, Encl. 168A, also refers.
[3] Air Ministry File S.3859, Encls. 5A, 7B and 21A.
[4] A.H.B./IIE/69, Air Ministry R.D.F. Panel, Minutes of Meetings, July–September 1940, Encls. 5C and 6A.
[5] Air Ministry File S.3859, Encls. 23A and 26A.

difficulties arose, associated with unexpected rock formations requiring blasting, and on some sites the waterlogged ground caused the abandoning of the construction. It soon became apparent that reserve cover could be supplied more cheaply and more quickly by methods other than burying the reserve equipment.

Partial abandonment of the programme began in March 1941 when the decision was taken not to continue with the twelve stations west of Ventnor.[1] Air Staff considered the matter further and on 6 March a decision was taken to abandon the burying of the Reserve equipment of those C.H. stations upon which excavation had not been started, reducing the number by seventeen and leaving the original twenty-station Chain Reserve to be completed. The reserves for the stations not to have a " Buried Reserve " were to be built above ground in a ferro-concrete building and termed " Remote Reserves ". Later, even the " Remote Reserve " programme was cancelled for south-western stations in June 1941.

The prototype " Buried Reserve " station at Stenigot was ready for operation in August 1941 and was put on a one month test to collect operational data.[2] This station had 110-foot towers and generally its operational performance was below that of the main station. Dampness was a constant source of loss of power. The Deputy Director of Radio, Air Ministry, after a visit to the Buried Reserve station at Dunkirk, wrote that he " was very forcibly impressed with the futility of this type of station. It is only just buried and therefore vulnerable to anything approaching a direct hit . . . I cannot see how the Buried Reserve can ever be made dry, and therefore can only assume that they will require considerable maintenance ".[3] The Deputy Director, continuing, recommended that the " Buried Reserve " situation should be reviewed, feeling that with the exception of Dover there was no justification in completing or maintaining a " Buried Reserve " at any other station on the south or east coast.

There was little enthusiasm for the " Buried Reserve " programme by autumn 1941. Most of the original twenty-station Chain had, by this time, their Buried Reserves either completely finished or well on their way to completion. It would have been an act of doubtful wisdom completely to have ignored the thousands of pounds and man-hours spent on these stations as well as the equipment—Post Office, electrical and radio—which had been manufactured especially for them and which could not be put to any other use.[4] To have abandoned the programme altogether at this stage would not have been cutting losses but, rather, a serious waste. As a result, the programme continued into 1942 before completion ; the work was not allowed to compete or interfere with other installation work of the Chain. Throughout 1941 there was a tendency to regard the " Buried Reserve " programme as both extravagant and unnecessary. There are many such references in correspondence on the subject, leading one to query whether the original Air Staff decision on the " Buried Reserve " taken in September 1939 was ill-advised.[5] But the position in 1941 was vastly different from that in 1939. Originally, when the decision was taken, no satisfactory mobile R.D.F. station had been developed whereby gaps in the Chain could have been filled after enemy action. Moreover, it will be recalled that the " Buried Reserve " stations were to be equipped with

[1] Air Ministry File S.3859, Encls. 30A, 33A and 42A.
[2] *Ibid.*, Encl. 87A.
[3] *Ibid.*, Encl. 81B.
[4] *Ibid.*, Encl. 81A.
[5] Narrator's comment.

apparatus thrown up on the conversion from the "Intermediate" to the "Final" state of the Home Chain—a sound and economical proposition. The partial abandonment of the scheme is not an admission that the scheme was ill-advised, rather was it a wise precaution in view of the circumstances at the time.

The Calibration of R.D.F. Stations

In previous chapters on the development of the Home Chain the problem of calibration of C.H. stations has been discussed. Although every effort was made to adjust the rate of calibration by No. 60 Group from the outset, the non-availability of suitable aircraft and crews and the shortage of calibration equipment had slowed down the work. During the autumn of 1940 Air Ministry expressed the opinion that the calibration situation could not be considered satisfactory and, with a view to investigating the reason for this lack of progress, a special conference was called at Air Ministry.[1] Representatives of Air Ministry Signals Staff, the Scientific Adviser on Telecommunications, No. 60 Group, and the Research Establishment met under the chairmanship of the Assistant Chief of Air Staff (Radio). An appreciation of the difficulties of calibration was taken and the necessary action commenced to obtain better-equipped aircraft for the task and the provision of height calibration and other test equipment. The technical aspects of calibration were re-examined by the Director of Communications Development Staff because some of the results were not attaining the standard of accuracy desired.[2] It was pointed out that the cost of calibration was high—approximately £800 per frequency for each station—but that the R.D.F. receiver was not merely an aircraft detection device; when properly calibrated and in the hands of a skilled operator it was a measuring instrument capable of giving results of considerable accuracy. Full technical details of the necessary steps in calibration were laid down and circulated to No. 60 Group.

The production of the height calibration gear and special oscillators to be carried on the calibrating aircraft was a slow process, and the rate of calibration of stations was falling behind the constructional programme for new stations.[3] The strain on the calibration resources of No. 60 Group became acute during the spring of 1941, and by May 1941 the calibration position had deteriorated. The Scientific Adviser on Telecommunications, Mr. R. A. Watson Watt, pointed out to the R.D.F. Chain Committee that notwithstanding increases in personnel, apparatus and aircraft for the calibration of C.H. stations the position was far from satisfactory.[4] He instanced three particular cases of inefficient calibration and commented that during March, April and May of 1941 it had been necessary to comment very adversely on eleven sets of calibration results. He summarised the causes of inefficiency as—

(*a*) use of low-grade labour in calibrating parties;

(*b*) lack of supervision by H.Q. No. 60 Group and Wings;

(*c*) ever-recurring unserviceability of aircraft;

(*d*) unsuitable methods of calibration;

(*e*) slackness and irresponsibility of some calibrating parties.

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[1] Air Ministry File S.42719, Encls. 55A and 60A. [2] *Ibid.*, Encl. 64B.

[3] Air Ministry File S.B. 11888, Encl. 26B.

[4] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes of Meetings, May/June 1941, Encl. 7A.

He pressed for the appointment of a technically qualified officer to visit all parties while at work and that expert instruction be given to calibration parties, who should not be allowed to introduce new calibration methods without prior approval of the Research Establishment.

Headquarters, No. 60 Group defended their position with regard to calibration, pointing out that an increase in calibration of 142 per cent. had occurred between autumn 1940 and spring 1941 and that such calibrations had been carried out under the Group authority as accurately and far more speedily than by the previous authority, despite the fact that adequate resources in aircraft, in equipment and in personnel were not available.[1] It must be borne in mind, in fairness to No. 60 Group's effort, that in no sphere of R.D.F. at No. 60 Group or elsewhere, had the art of calibration reached a stage where errors were not made. Headquarters, No. 60 Group, also emphasised how difficult it was to keep a station at its calibrated performance in face of frequent feeder-line trouble,[2] for which a solution had not been found. Much of the calibration trouble centred in the design of the aerial systems.

A further conference to improve the speed and efficiency of the calibration of C.H. stations took place at Headquarters, No. 60 Group, in July 1941, when the Scientific Adviser on Telecommunications, members of his Department, No. 60 Group representatives and two members of Headquarters, Fighter Command Operational Research Section, discussed calibration difficulties.[3] The autogyro was the most successful aircraft for this calibration but no further supply of this aircraft from America was anticipated, so alternative methods of calibration had to be explored. Other types of aircraft were listed for examination for this task and Mr. Watson Watt undertook to set in train, at the Telecommunications Research Establishment, experiments to try calibration with the aid of A.I. Beacons. The establishment, at Headquarters No. 60 Group, of a special checking section of some ten officers was also recommended to improve the efficiency of this calibration work. Towards the end of 1941 comprehensive and detailed instructions for both calibration and test flights for R.D.F. stations were issued by Headquarters, No. 60 Group and by Headquarters, Fighter Command.[4] Examination of these orders gives some impression of the magnitude of the effort, a minimum of fifty hours flying per station. A system of calibration reports on a weekly basis from Headquarters, No 60 Group, was agreed upon to keep all interested authorities informed of progress. By the end of 1941 the calibration programme, though lagging behind immediate requirements, was at last on a sound basis and could be regarded as satisfactory. The only delays at this period were those due to weather and enemy action.

The Home Chain and Identification Friend and Foe (I.F.F.)

The increased range of frequencies covered by R.D.F. since the outbreak of war extended the problem of identification. Originally the twenty-station Chain had worked on frequencies in the 22–30 megacycles per second band and the airborne equipment called the I.F.F. set had responded to this

[1] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes of Meetings, May/June 1941, Encl. 9A.

[2] Even insulation defects due to a deposit of copper dust on the insulators caused by the aerial wire rubbing on them in windy weather was sufficient to upset the calibration.

[3] Air Ministry File S.42719, Encl. 102C. [4] *Ibid.*, Encls. 105A and B, 106A and 111A.

frequency band. The Advance C.H. stations which had been rushed into operation in 1940 worked on the 38–52 megacycles per second frequency band and the Army G.L. sets from 54–82 megacycles per second, to which the original Mark I I.F.F. signal did not respond. Accordingly a Mark II I.F.F. set was introduced, the response of which swept through the 22–82 megacycles per second frequency band and thus showed on C.H., A.C.H., and Army G.L. stations. By November 1940 Mark II I.F.F. had been fitted to "a large proportion of bomber and coastal aircraft" and to four hundred fighter aircraft.[1] The C.H.L. stations and the newly developing G.C.I. (Ground Control of Interception) stations worked on a frequency band of 180–210 megacycles per second and so Mark II I.F.F. did not respond for aircraft observed by such stations. Accordingly a set responding to G.L., G.C.I., and C.H.L. station frequencies, known as the Mark IIG, was made for use chiefly in night fighter aircraft, to distinguish them quickly during night interceptions of enemy bombers, and by the end of 1940 had been installed in a few fighter aircraft.

The need for an I.F.F. set with universal responses whatever the ground R.D.F. frequencies in use became apparent, and on 20 November 1940 the Inter-Services R.D.F. Committee agreed to adopt I.F.F. Mark III, a set operating on a separate frequency band which would respond to all types of ground R.D.F. sets as an identification if they were fitted with suitable interrogator/responsers. Separate transmitter and receiver aerial arrays were to be installed for the new I.F.F. displays on the ground stations, and an interrogator and responser had to be fitted at each station. The interrogator was a small transmitter of 1 kilowatt power only and the responser connected to the additional receiver arrays caused the I.F.F. to be shown on the cathode ray tube. The changes in the I.F.F. equipment in aircraft are mentioned here because the ground Home Chain stations were the controlling factor in these requirements. The story of the development of I.F.F. is recounted fully in another volume.

R.D.F. Construction—Failure of the R.D.F. Chain Committee

With the formation of the R.D.F. Chain Committee in January 1941 (described previously in this chapter) it was anticipated that a speeding up in R.D.F. construction would occur. Under its terms of reference the Committee possessed very wide powers; its composition gave representation to all the interested Departments and it was arranged that it should meet weekly to maintain close control on the progressing of the large constructional programmes. All possibilities of accelerating progress on the R.D.F. Chain were to be explored and the preferred means put into practice. The installation programme which it had to examine comprised some fifty C.H. stations, ninety C.H.L. stations and thirty G.C.I. stations. During the six months up to June 1941, the Committee, instead of meeting weekly, had met only on four occasions; it had appointed no sub-committees and heard no evidence from non-members save for a brief statement from No. 60 Group, and made no detailed examination of specific causes of delay. Twenty-one of the C.H. stations were due for completion on a two-frequency basis before July 1940 but none was yet operational on this basis: all were operating on one frequency only though the importance of this second frequency for C.H.

[1] Headquarters, Fighter Command Signals Branch, O.R.B., November 1940.

stations ranked highly as one of the safeguards against enemy jamming. The C.H.L. programme had certainly made better progress but large-scale modifications were still required before the most effective operational working would be attained.

With so many masters to serve in the matter of installation and maintenance of R.D.F. stations, the Air Officer Commanding, Headquarters No. 60 Group, felt the problem getting increasingly difficult and protested for help. The Scientific Adviser on Telecommunications, Mr. R. A. Watson Watt, who, it will be remembered, in December 1940 had drawn the attention of the Secretary of State for Air to the lack of progress at that time in the R.D.F. Chain, returned to the attack with considerable vigour in June 1941, submitting a Note on the R.D.F. Chain Committee drawing attention to its shortcomings.[1] Of the effective co-operation between the Directorate of Works, the Directorate of Communications Development and No. 60 Group which it was hoped this Committee would bring about, he wrote :—

> "None is authorised to give instructions to the other. None is responsible, even on the individual site, for trouble-finding and trouble-clearing. This is pseudo-democracy run mad ; each constituent element is an autocracy ; it has not even a chairman of Soviet. . . . No one of them insisted on having facilities adequate for the programme. Each has with gallant folly attempted the impossible ; accepting responsibility without power ; using junior amateurs where he might have demanded professionals of high status ; knowing the War Cabinet instructions on the priority of R.D.F., yet submitting to conditions which are ludicrously incompatible with that priority. Each has, less gallantly and with greater folly, assured the committee of the substantial perfection of his own contribution (within the limits of his facilities) and emphasised the imperfections of all the other co-equal partners."

The Scientific Adviser on Telecommunications then proceeded to advocate :—

(*a*) That an engineer organiser of high status, who had himself been in charge of a major engineering enterprise, be requested to examine and report on the provision required in the Directorate of Works, the Directorate of Communications Development and No. 60 Group, or in any combination of parts of them, and on the best means of engineering organisation and co-ordination towards speedy execution of the R.D.F. Construction programme.

(*b*) That this investigator be specially requested to consider the means for reducing to a minimum the proportion of experienced radio engineers required in the undertaking.

(*c*) That War Cabinet authority be sought for implementing his recommendations on staffing and co-ordination, without regard to normal service practice, gradings, remuneration and relativities.

(*d*) That the recommended co-ordinating authority be given access to high authority on material and personnel priority.

Finally Mr. Watson Watt recommended that if the proposal (*a*) above were not approved, the authority of the War Cabinet should be sought for a reduction in the priority of the R.D.F. Chain to accord realistically with the limited effort being applied to its completion.

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[1] A.H.B./IIE/7/1, R.D.F. Chain Committee, Minutes, Encl. 13A.

This devastating but belated attack on the existing R.D.F. construction co-ordinating organisation by the Scientific Adviser on Telecommunications at last focussed attention on the necessity for immediate action. His suggestion for an examination of the whole problem of speeding up the Home Chain construction programme by an engineer organiser of high status was accepted. The Secretary of State for Air invited Sir Robert Renwick of the County of London Electric Supply Company to exercise a general supervision of the progress of the R.D.F. Chain and to co-ordinate the various interests in order to ensure that all needless delays were avoided.[1] The last meeting of the R.D.F. Chain Committee, its 6th meeting, took place on 18 June 1941. The proceedings were largely formal and the Committee were notified of Sir Robert Renwick's appointment.

The R.D.F. Chain Executive Committee—Formation

Within one week Sir Robert Renwick had made a superficial examination of the R.D.F. construction position.[2] He proposed vesting his authority in a committee comprising himself as chairman, Mr. R. A. Watson Watt, the Director of Radio, and, when necessary, the Director of Communications Development, the Director General of Works and the Air Officer Commanding, No. 60 Group. This committee, termed the R.D.F. Chain Executive Committee, superseded the R.D.F. Chain Committee. Sir Robert Renwick arranged for the employment of certain specialist individuals, some ten in number, who were engineers and progressing experts of great experience.[3] They were quickly given rank appropriate to their work. It was at this time that Air Ministry announced a 20 per cent. establishment cut in all Home Establishments in order to economise in manpower. The Secretary of State for Air ruled that this cut would not apply to No. 60 Group but that its establishment would be increased to what was required to enable the Group to carry out its commitments. In view of the enormous expansion of the Chain and also a large G.C.I. station programme it was necessary to economise on the installation effort to the greatest degree. Air Staff therefore decided not to continue with the provision of the third and fourth frequencies at the east coast C.H. stations.[4] Three sub-committees were formed to advise the Chain Executive Committee. These were the C.H. Working Sub-Committee, the C.H.L./G.C.I. Working Sub-Committee and the Ground Modifications Sub-Committee.[5] With these sub-committees providing the impetus in their respective specialised portions of the Chain, the R.D.F. Executive Committee remained effective as the driving force behind R.D.F. construction throughout the subsequent development of the Home Chain. At last an organisation had emerged capable of coping with the very difficult programme.

R.D.F. and the Battle of the Atlantic

Mr. Churchill, in his capacity as Minister of Defence, issued a Directive to the Chiefs of Staff on 6 March 1941.[6] In it he stated : " In view of various German statements we must assume the Battle of the Atlantic has begun. The next four months should enable us to defeat the attempt to strangle our food supplies and our connection with the United States. For this purpose

[1] A.H.B./IIE/74/2, R.D.F. Construction—Under-Secretary of State for Air's Committee, Encl. 36A.
[2] A.H.B./IIE/75, R.D.F. Chain Executive Committee, Minutes and Papers, Encl. 1A.
[3] *Ibid.*, Encl. 3A.
[4] Air Ministry File S.41234, Part II, Minute 104.
[5] Air Ministry Files S.10379 and S.10380.
[6] Chief of Air Staff Folder No. 637, " Battle of the Atlantic."

we must take the offensive against the U-boat and the *Focke-Wulf* wherever we can and whenever we can . . ." The Prime Minister went on to give the highest priority to all efforts to provide improved defensive coverage for shipping. In the view of the Inspector General of the Royal Air Force, the German *Focke-Wulf* aircraft was to be regarded as a greater menace to our convoys at that time than the U-boat.[1] In addition, intelligence information led to the belief that the Germans were transferring some 200 to 250 long-range bombers (*Ju. 88* and *He. 111*) from night bombing of this country to the attack on our shipping in the Atlantic.[2] Our shipping had been harassed by U-boats throughout the war, but the addition of a heavy air attack on the convoys increased the seriousness of the threat. Although the major counters to these tactics were an increase of armament of our convoys, the increasing use of our own aircraft to provide defensive cover, and attacks on the *Focke-Wulf* and the U-boat at their bases, R.D.F. had a part to play in giving greater cover to the convoys nearing our shores.

The problem was largely one for the C.H.L. Chain. As a short-term measure the improvement of aerial systems and the fitting of a new valve (V.T.98) to replace the old V.T.58 valve, were put in hand immediately.[3] The V.T.98 valve gave C.H.L. stations an increase of four times the V.T.58 power and of 1·4 times the old range. A priority for the C.H.L. stations covering our Western Approaches was given and instructions were issued to fit Plan Position Indicators (P.P.I.) and power turning gear for the aerials. This would inevitably take longer, being dependent on the supply of the equipment direct from production.[4] The efficiency of the new C.H. stations in the South-West and West was also to be improved as speedily as possible. The whole short-term R.D.F. programme to assist in the implementation of the Prime Minister's directive involved :—[5]

(*a*) Installation of 12 new C.H.L. stations.

(*b*) Modifications to 17 existing C.H.L. stations.

(*c*) Speeding up of work of installation or modification of 32 C.H. stations.

The orders of priority were based on careful operational study of requirements made by the Air Officer Commanding-in-Chief, Fighter Command, in relation to the R.D.F. contribution to the Battle of the Atlantic.

Simultaneously with the extension of R.D.F. cover on our south-west and west coasts in Northern Ireland, there was a big extension in the number of airfields in Northern Ireland and the Hebrides.[6] The Prime Minister sent a message to the Chief of the Air Staff from Chequers on 1 March 1941 giving absolute priority to this work. The combined effect of this policy was to increase the effective area over the North Atlantic sea route where long-range fighter cover could be given to convoys. The entire region where *Focke-Wulf* aircraft could operate, from our western ports out through the Northern Atlantic route, was thus protected except for certain regions directly west of Ireland. With characteristic thoroughness, Mr. Churchill wanted a further extension of R.D.F. cover. On 21 March in a minute (Serial No. M.331/1) to the Secretary of State for Air on the subject of the destruction of *Focke-Wulf* aircraft he wrote : " If we could employ R.D.F. methods to find their positions and to

[1] C.A.S. Folder No. 637, I.G. Report No. 145.

[2] War Cabinet Chiefs of Staff Committee, C.O.S. (41) 130 of 3 March 1941.

[3] Air Ministry File C.S. 8143, Encl. 6A, and O.R.S./4/1/2, Encl. 62A.

[4] Air Ministry File C.S. 8143, Encls. 7A, 8B, 9A.

[5] This programme is given in detail at Appendix No. 9. Also in Air Ministry File S.41234, Part II, Encls. 103A-C.

[6] C.A.S. Folder No. 637, " Battle of the Atlantic."

direct long-range fighters or ship-borne aircraft to the attack we ought to be able to inflict serious casualties." The Prime Minister recommended R.D.F. stations on isolated islands in the Atlantic such as Tory Island and Rockall, and on Lough Erne. As R.D.F. ground stations have their maximum value when part of a chain, and as the sites suggested were very inaccessible from the Works Services aspect, the Secretary of State for Air, in his reply, said he thought the most promising line of approach was the provision of R.D.F. ships to control either their own catapult aircraft or long-range shore based fighters. Such ships, fitted with Naval R.D.F. sets giving a range of 30 miles, were already available but investigations were being carried out to fit them with C.H.L. equipment which would increase their range to 50 miles for aircraft flying at 2,500 feet. The provision of ship-borne aircraft was embarked upon almost immediately. The Merchant Ship Fighter Unit was formed at Speke in No. 9 Group for the training and supply of pilots and catapulting of Hurricane aircraft. These were carried on ships known as escort carriers, fitted with R.D.F., and could be employed against enemy aircraft when a convoy had passed beyond the range of shore-based fighter aircraft and R.D.F. cover.[1]

These measures all contributed to the opening phases of the Battle of the Atlantic. In May 1941 we lost 57 ships during the month, whereas 22 were lost during August. In the latter month, indeed, imports continued to come in at a rate of nearly one million tons a week.[2] There was no complacency because of this early success in combating the enemy's attempt to cut our supply lines from America. To increase the range of R.D.F. cover over the Northern Atlantic sea route, C.H.L. sites were selected by R.D.F. reconnaissance parties during December 1941 on the Faroe Islands and Iceland.[3] The provision of these stations, giving cover to the Denmark Straits, and an improvement in the R.D.F. facilities in the Orkneys and Shetlands during 1942 completed the programme of R.D.F. ground stations employed in support of the Battle of the Atlantic. Although we were to face a resurgence of the U-boat menace later, we had, by the end of the summer of 1941, checked it temporarily. In this important success, the ground R.D.F. stations had played a small but not insignificant part.

The development of the Home Chain during 1941, dealt with in this chapter, may be regarded as the most difficult year in the story of R.D.F. during the War. During 1940, there was some tolerance for minor weaknesses which had shown up in this raid reporting system. This may have been due to the relative novelty of R.D.F. warning and the incomplete state of the Chain, but the toleration for shortcomings in the system did not extend into 1941. Those responsible for its development were its most severe critics; there was no complacency. Criticism invariably produced action and out of it the organisation for control, construction, and development of the Chain was overhauled. Alongside this reorganisation of control, there had been equivalent technical progress, not only with regard to the actual equipment but also in the handling and filtering of R.D.F. information. The training of personnel to man the Chain was at last commensurate with requirements and R.D.F. equipment production was, in the main, satisfactory. All these were the outcome of the year 1941 which may be regarded as the turbulent and decisive year in the Home Chain story. By the end of 1941 the effort was proportioned to the size of the R.D.F. undertaking, and was in keeping with the War Cabinet priority allotted.

[1] C.A.S. Folder No. 637.
[2] Air Ministry File C.27924/45.
[3] Air Ministry File S.14124, Part I, Encl. 5A.

CHAPTER 12

R.D.F. IN THE MIDDLE EAST COMMAND, JULY 1940 – FEBRUARY 1943

When Italy declared war in July 1940 the Middle East Command—always important because of its position in relation to our sea communications with the East, became of even greater consequence, having a common front with the enemy in the Western Desert. The defence of the Suez Canal and the Egyptian Delta area was of great importance. This area, together with Palestine, formed a base against enemy hopes of moving eastwards towards the oilfields of Iraq and Iran. The compact nature of the Delta area had suggested a parallelism with the defensive methods used in the United Kingdom, and plans were already in existence for an Egyptian Chain of R.D.F. stations. Four mobile stations were already in operation at El Dhaba, Aboukir, Port Said, and Ikingi Mariut, near Alexandria. This chapter deals with the development of R.D.F. cover and its operational performance in the Middle East Command from the entry of Italy into the war until the defeat of the Axis forces at El Alamein and the advance of well over a thousand miles into Tunisia.

Increase of R.D.F. Cover—Middle East Command

Royal Air Force Headquarters, Middle East, was fully aware of the urgent need to strengthen the R.D.F. facilities of the Command. Urgent signals were sent to Air Ministry during July 1940 requesting additional R.D.F. equipment to be sent out on highest priority.[1] The Mediterranean Fleet anchorages at Alexandria and Haifa gave additional emphasis to the urgent requirement of adequate R.D.F. cover. Alexandria had some measure of R.D.F. early warning from the four Mobile Radio Units operating on the Egyptian coast. There were urgent representations from the Admiralty for protection for the Palestine area, Haifa in particular.[2]

Partly as a result of the various requests for assistance and also in implementation of Air Staff policy, the Assistant Chief of Air Staff (Radio), Sir Philip Joubert, ordered that the following R.D.F. sets were to be despatched with utmost speed, with a request that he should be kept informed of the progress of this programme :—[3]

(*a*) One M.B.2 Transportable Radio Unit for Haifa to arrive by 14 August 1940.
(*b*) Four M.B.2 Mobile Radio Units for the Middle East to arrive by 31 August 1940.
(*c*) One C.O.L. station for Aden, for Bir Fukum.
(*d*) One C.O.L. station for Egypt, for Alexandria.
(*e*) One C.O.L. station for Malta, for Valetta.

At least six month's supply of spares was to be sent with each unit. Thirty-two sets of I.F.F., Mark II, for use in aircraft in the Middle East, were also to be sent and eight sets of A.S.V.—R.D.F. used in aircraft against surface vessels —were included for use in Sunderland flying boats. Special high-speed transport was to take the accompanying party, including R.D.F. staff officers, experienced installation officers and technical personnel.

[1] Air Ministry File S.5734, Encl. 44A. [2] *Ibid.*, Encl. 53A.
[3] *Ibid.*, Encl. 47A. The nomenclature of the various types of R.D.F. station for use overseas, together with their purpose and range, is given in Appendix No. 10.

R.D.F. Low Cover in the Middle East Command

No date for the supply of the C.O.L. stations due for despatch could be fixed, as a fully tropicalised C.O.L. equipment had not yet been prototyped. Although the function of the C.O.L. station overseas was exactly the same as that of a C.H.L. station at home, namely the observation of low-flying enemy aircraft, the radio components of the C.H.L. stations in production at home would only stand up to temperate climates. Experiments on the tropicalisation of the C.H.L. station (thus converting it to a C.O.L. station) had been carried out at the Royal Aircraft Establishment, Farnborough.[1] Tropical-type condensers were introduced, internal wiring was modified, and a cooling system of air blowing was used to prevent formation of hot pockets of air inside the set which might cause consequent breakdown of the components. Six C.H.L. sets were partially modified and made ready for despatch in the hope that they would give satisfactory results temporarily until the fully-modified sets were available.[2] The C.O.L. stations were to be placed on sites at least 200 feet high, and there was a scheme afoot for designing C.O.L. aerial arrays on towers for use on flat terrain, but this was not yet practical due to the difficulties in evolving aerial turning gear. Of these six C.O.L. stations, two were to be sent to Aden for use at Bir Fukum and Ras Marshag, one to Haifa for Mount Carmel, and three to Malta for Dingli, Fort Ta Silch and Fort Madelena.

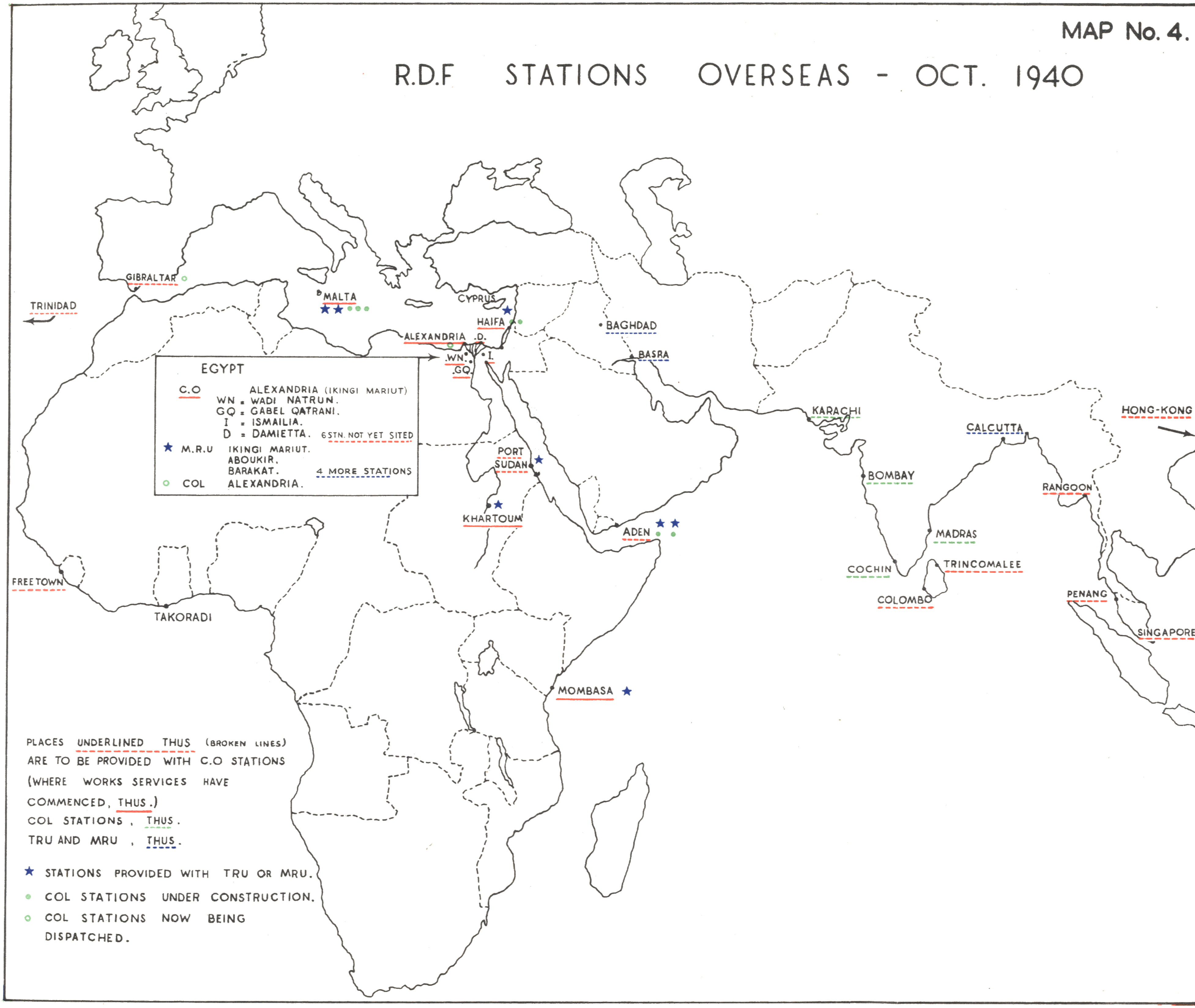
The general policy agreed by Air Ministry was that each C.O. station should be provided with complementary C.O.L. stations. An all-round looking C.O. station required the backing of three C.O.L. stations on an average, in order to give both high and low R.D.F. cover adequately throughout the full 360°.[3] It was for this reason that Malta required three C.O.L. stations as soon as possible.

R.D.F. Stations Planned for Middle East Command—August 1940

The Middle East Command covered a vast area at that time—approximately twice that of the United States of America. In order to present a clearer picture of the progress made in R.D.F. planning within the Command its territories must be considered under geographical sub-divisions :—

(*a*) *Egypt and the Sudan*.—Permanent installations had been approved by Air Ministry in the form of C.O. stations for Ikingi Mariut, Damietta, Wadi Natrun, a site 25 miles South-West of Cairo, and a site south of Ismailia, to be supplemented by C.O.L. stations at Alexandria and Port Said.[4] An M.B.1 station was earmarked for the defence of Mersa Matruh, to be sited within the defended area on security grounds. Although C.O. stations had been allocated provisionally for both Khartoum and Port Sudan, it was decided that in the case of the latter site a C.O. station would be unlikely to give good results owing to the proximity of the Red Sea Hills, which rise to 7,000 feet. It was therefore recommended that a C.O.L. station with 200-foot towers should be placed on the north side of the harbour where it would have the additional advantage of giving warning of approaching shipping. As little inland cover would be available, it was considered essential to have observer screens in the vicinity.

[1] Air Ministry File S.55153, Encl. 278B.
[2] Air Ministry File S.5734, Encl. 53A.
[3] *Ibid.*, Encl. 105A.
[4] *See* Map No. 4 for locations.



MAP No. 4.
R.D.F STATIONS OVERSEAS - OCT. 1940
GIBRALTAR
TRINIDAD
MALTA
CYPRUS
HAIFA
ALEXANDRIA
.D.
WN
GQ
I.
BAGHDAD
BASRA
EGYPT
C.O ALEXANDRIA (IKINGI MARIUT)
WN = WADI NATRUN.
GQ = GABEL QATRANI.
I = ISMAILIA.
D = DAMIETTA. 6 STN. NOT YET SITED
M.R.U IKINGI MARIUT.
ABOUKIR.
BARAKAT. 4 MORE STATIONS
COL ALEXANDRIA.
PORT SUDAN
KHARTOUM
ADEN
KARACHI
BOMBAY
CALCUTTA
HONG-KONG
RANGOON
MADRAS
COCHIN
TRINCOMALEE
COLOMBO
PENANG
SINGAPORE
FREETOWN
TAKORADI
MOMBASA
PLACES UNDERLINED THUS (BROKEN LINES) ARE TO BE PROVIDED WITH C.O STATIONS (WHERE WORKS SERVICES HAVE COMMENCED, THUS.)
COL STATIONS, THUS.
TRU AND MRU, THUS.
STATIONS PROVIDED WITH TRU OR MRU.
COL STATIONS UNDER CONSTRUCTION.
COL STATIONS NOW BEING DISPATCHED.
MAP 153 A.H.B.I.

(*b*) *Palestine.*—Subsequent to the allocation of a C.O. station for Haifa, a site had been chosen on Mount Carmel. This would have given good ranges and an all-round coverage but would not have been suitable for determining heights. Since Air Defence for Haifa was now under consideration, it was decided that height indication was essential and therefore the C.O. station should be resited on the flat ground to the south of Mount Carmel. As R.D.F. vision would thus be limited to an arc of 180°–360° it was recommended that a C.O.L. station should also be erected on Mount Carmel to provide satisfactory warning along the coast northwards.

(*c*) *Iraq.*—A plan for two MB stations at Basra and Abadan had been submitted to the Air Officer Commanding-in-Chief, Iraq. One station was to provide accurate air information during the last 30 miles of the approach of enemy aircraft and the second station was to fill the gap in the observer post layout, which was caused by the swampy nature of the country. An MB set was also proposed for Khan Bani Saad, about 30 miles from Baghdad, but the Kirkuk and Mosul areas were considered unsuitable for R.D.F.

(*d*) *Aden.*—The non-standard station in operation at Aman Khal in Aden was proving very unreliable. The equipment, which it will be recalled was rushed out just before the outbreak of war, was makeshift and non-tropically finished and replacements were needed urgently. The plan for a C.O. station was changed to two C.O.L. stations and an observer screen, as it was considered that these would give more satisfactory results in view of the nature of the terrain.

(*e*) *East Africa.*—Tentative proposals were made concerning a C.O. station for Mombasa. It was feared that permanent echoes from the coastal hills might prove too great an obstacle and a C.O.L. station might give better results due to its narrow beam. It was recommended that a reconnaissance party should be sent to inspect the area, and if in the meantime an emergency arose, there would be no serious difficulty in setting up an MB station to the north, with an associated observer screen for immediate early warning of the approach of aircraft. Flight Lieutenant J. F. Atherton, a scientific officer well versed in the siting of R.D.F. stations at home and overseas, eventually made a survey of the surrounding country and in his report suggested that a C.O. station should be sited at the disused Bamburi aerodrome, 40–50 feet above sea-level, with two C.O.L. stations, one at Nyali estate to give cover north-east—south—south-west, and the other at Kilifi, 38 miles north of Mombasa.[1] It is interesting to note that the South African Army were providing elementary home-made R.D.F. in this area, giving a range of some 35 miles but with no reliable height estimation for aircraft flying at normal heights.[2]

(*f*) *Malta.*—Although the R.D.F. cover for Malta was more advanced than in any other part of the Command, having two transportable Radio Units, Nos. 241 and 242 T.R.U., giving continuous cover for 24 hours, and with the work on the permanent C.O. station well in hand, the low cover was inadequate and three C.O.L. stations were to be erected as soon as the equipment could be made available.

[1] Air Ministry File S.5734, Encl. 50A. [2] *Ibid.*, Encl. 51A.

Delay in Implementing Plans for R.D.F. Cover in the Middle East

The R.D.F. Chain for Egypt had been planned originally before the end of 1939. Before an efficient air raid warning system could be developed there, the installation programme had to be completed. This was held up due to the non-arrival of equipment from the United Kingdom. In a letter dated 3 August 1940, to the Deputy Director of Signals, Air Ministry, Group Captain W. E. G. Mann, Chief Signals Officer, Middle East Command, expressed the gravest concern over the delay in the receipt of equipment from the date of its despatch.[1] He feared that R.D.F. and radio communications generally might collapse altogether unless equipment arrived forthwith and, in his opinion, the Air Ministry plan to complete the main R.D.F. chain layout in Egypt by December 1940 was impossible. There was no sign of equipment arriving, and shipment of towers and masts was not possible for at least four months. Part of this delay was due to the long route of the convoys via South Africa. He considered that it was fair to estimate that the organisation would not be functioning for at least another year and that even this was an optimistic guess.

It was difficult to attach blame to any particular person or section for the disorganisation and delay in carrying out overseas commitments. Official comment decreed that R.D.F. reinforcements would be sent "as soon as adequate supplies were available." The time-lag seemed to occur between the proposed date of despatch and the actual date of arrival, and could be anything up to several months. Lack of supervision probably accounted for minor set-backs, for example, the T.R.U. for Haifa was sent deficient of any power supply, as the Navy found it impossible to accommodate two Lister generators. The two C.O.L. stations for Malta and the Mobile Radio Unit for Khartoum were delayed due to shipping breakdown and the personnel were conveyed separately from their equipment, either arriving months ahead as in the case of the personnel for Aden's Transportable Radio Unit No. 304 or becoming lost in transit as did the Officers of this unit.[2] In addition, it was not always possible for a large convoy to stop in order to disembark one R.D.F. set. Every effort was being made to improve this state of affairs, but the United Kingdom at that time was being subjected to the strong enemy air attacks during the Battle of Britain and was making urgent preparations to counter possible invasion, so it could hardly be expected that a rapid improvement in the supply position of R.D.F. equipment for overseas would occur.

The Threat of Vichy French Attack in West Africa and Syria

The attitude of the Vichy Government in France towards Britain was an unknown factor in September 1940. There was every indication that this Government was pro-German. Their forces flanked ours in West Africa and Syria and were therefore a potential threat, not only in themselves alone, for the French colonies had to be regarded as possible enemy bases. Although West Africa did not come under the Middle East Command, being controlled direct from Air Ministry at this time, it is included here because the policy for its defence is so closely allied to our grand strategy for the Middle East generally.

[1] Air Ministry File S.5734, Encl. 58A.
[2] *Ibid.*, Encls. 73B, 88A and 119A. Also File S.1056.

West Africa.—French planes had been sighted over Freetown and Bathurst and the general situation in this area was giving rise to some anxiety over the lack of R.D.F. cover. Pressure of work and heavy responsibilities elsewhere had absorbed the attentions of the few radar experts engaged in siting and installation and no one could be spared for the reconnaissance of the West African sites.[1] Appeals had been made to Air Ministry for four more R.D.F. technical officers and three assistants to be sent out to the Middle East by the most rapid means possible, and these had been promised for the end of September 1940. Meanwhile it was found necessary for an officer, who was being invalided home, to travel via Freetown in order to make a report upon the site there. It was considered difficult country due to its mountainous surroundings and would probably need a combination of C.O., C.O.L. and T.R.U. or M.R.U. stations to ensure all-round cover.

An R.D.F. reconnaissance of the Freetown area, carried out during October 1940, led to the following scheme being drawn up :—[2]

(*a*) Immediate cover was to be provided by two M.R.U.s or T.R.U.s, together with three C.O.L. sets for the detection of low-flying aircraft and ships.

(*b*) Final cover was to be provided by two C.O. stations giving warning and height measurement over 360 degrees, together with the above three C.O.L. stations.

(*c*) An Operations Room was to be provided to utilise the information of aircraft and ship movements obtained from R.D.F. stations and enable counter-measures to be taken.

Further south, on the West African Gold Coast, Takoradi was becoming a port of considerable importance in view of its position as a base for the assembly and delivery of aircraft to the Middle East via the Sudan.[3] This Air Reinforcement Route port required an adequate air raid warning system. Consequently a survey was made during September 1940 in order to investigate the possibility of providing R.D.F. cover and to site the necessary stations. The hilly nature of the district severely restricted the choice of the C.O. station sites, particularly as all-round height measurement was required, whilst the low height of the hills made it necessary for C.O.L. stations to be erected on as high gantries as possible. As a result of this survey the following scheme for R.D.F. provision was proposed :—

(*a*) One T.R.U. and one C.O.L. station for immediate cover.

(*b*) One C.O. station, together with the above C.O.L. station, for final all-round detection and height measurement.

(*c*) An additional C.O.L. station on a 200-foot gantry, when this type of station had been developed.

There were no A.A. or coastal defence guns at Takoradi and the defence would rest solely with fighter aircraft operating from the new airfield north-west of the town. It was therefore considered that a very simple form of plotting table was necessary, to be installed in the Receiving Block of the C.O. station until the arrival of other defences made a more complicated system necessary.

[1] Air Ministry File S.5734, Encls. 83A, 85A, 87A.

[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder "R.D.F. Overseas," March 1938–March 1942, Encl. 78A.

[3] Air Ministry File S.6691, Encl. 11A.

Syria.—The defence of the Syrian border was of much importance. It was decided that if two more C.H.L./C.O.L. stations could be made available, one should be placed on the low site east of Mount Carmel, and one should be kept in reserve.[1] Approval was given for these to be despatched in November 1940.

Amended Policy for R.D.F. Overseas, October 1940

The full implications of the threat of the Vichy French territories and the Italian colonies as bases for enemy offensives were quickly realised after the fall of France. Japan, though neutral, was so pro-German that it was necessary to give special attention to the supply of R.D.F. equipment to India and the Far East. The acute shortage of R.D.F. equipment and trained personnel to man it called for frequent reviews of the priority of installation at the various overseas sites already selected. The Inter-Service Committee on R.D.F., in a memorandum to the agenda of its fourteenth meeting on 3 October 1940, had to make further amendments to the order of priority of C.O. stations.[2] Takoradi was added to the list as a result of recommendations of the Port Defence Committee but it was considered that a T.R.U. or a C.O.L. station would suffice for the time being. The amended list was as follows :—

Inter-Service Revised Priority List

1. Alexandria (Ikingi Mariut).
2. Damietta.
3. Gebel Qatrani.
4. Wadi Natrun.
5. Ismailia.
6. 6th Egyptian station.
7. Malta.
8. Aden.
9. Freetown.
10. Gibraltar.
11. Haifa.
12. Kilindini (Mombasa).
13. Khartoum.
14. Port Sudan.
15. Singapore.
16. Takoradi.
17. Trinidad.
18. Hong Kong.
19. Trincomalee.
20. Rangoon.
21. Colombo.
22. Penang.

Although Works Services had not yet been commenced at Stations 6–10 despite the fact that Stations 11, 12 and 13 were well under way, it was decided that Stations 6–10 should retain their present order in view of their importance.

The urgent need for C.O.L. aerial arrays on towers was discussed and a request made to the Director of Communications Development that research on this equipment should be speeded up considerably as good low coverage was lacking in the low-lying coastal areas of Egypt.[3] The type of C.O.L. set in use gave a very poor performance if erected on a 40-foot site such as El Sab Fort, Aboukir.

Nine C.O. stations, five for Egypt and the remaining four for Haifa, Khartoum, Port Sudan and Mombasa, were scheduled to be completed within the next six months. In the interim it was intended that R.D.F. cover should be improved within Middle East Command by an increase in the number of mobile R.D.F. stations.[4] Four M.B.2 stations were in the process of being despatched from the United Kingdom to Mersa Matruh, Aden, Mombasa and Khartoum. Four more M.B.2 mobile stations and three C.O.L. stations were

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[1] Air Ministry File S.5734, Encls. 93A, 95A.
[2] A.H.B./IIE/68, Minutes of Inter-Service Committee on R.D.F.
[3] Air Ministry File S.5734, Encl. 74A. [4] *Ibid.*, Encl. 103A.

in the course of preparation and were to be ready for despatch by the end of November. Building had already commenced to house the C.O.L. stations at Malta, Haifa and Aden.

Meanwhile the islands in the Eastern Mediterranean were not being overlooked. Middle East Headquarters was proposing to carry out an R.D.F. reconnaissance of Cyprus with a view to placing a mobile station on the south-west part of the island, in order to obtain better early warning of Italian air attacks from the Dodecanese islands. Mobile equipment was also being considered for Crete.

Review of R.D.F. in the Middle East Command—October 1940

From the Inter-Service R.D.F. priority list for R.D.F. stations, in which Middle East Command took absolute priority, and from the flow of mobile R.D.F. equipment to this theatre straight from production in the United Kingdom, it can be seen that there was every indication of a great increase in the R.D.F. facilities within the Command. It is difficult, within this welter of proposals and policy, to appreciate the actual R.D.F. cover available at that time without recapitulation.[1] Installed in buildings as a preliminary provision for the fixed C.O. stations, the equipment of which was not anticipated to be available before May 1941, there were mobile sets at :—

	Type.
(*a*) Alexandria (Ikingi Mariut)	M.B. 1.
(*b*) Aden	M.B. 1.
(*c*) Malta	Two M.B. 1.
(*d*) Haifa	M.B. 2.

In addition, fully mobile equipment in vehicles was in operation at :—

(*e*) Ikingi Mariut (supplementary to the original M.B. 1 in order to give 24 hours daily operation)	M.B. 1a.
(*f*) El Dhaba	M.B. 1a.
(*g*) Aboukir	M.B. 1a.
(*h*) Port Sudan	M.B. 1a.

With so few stations in such a vast territory it was inevitable that from the operational view point the outlook was very parochial. Each area under R.D.F. cover was relatively small and was run according to the views of the local commander. Controlled interception, either by Sector controlling or directly from R.D.F. stations, was little practiced. Too much reliance on R.D.F. cover, which was necessarily limited by the paucity of equipment, might indeed have been unwise. In some cases recourse was had to patrolling as the safer method.[2]

Operations Rooms, as in use in the United Kingdom, did not exist and the question of mobility for operations in the Western Desert at first proved a stumbling block to any permanent organisation. Filtering of R.D.F. information could not be compared with the system in use at home, as the plots of the Middle East stations rarely overlapped, making it impossible to obtain range cuts. A Filter Room was in operation at No. 256 Wing Headquarters in Egypt, but it was regarded more as an Information Centre. Communications were difficult and insecure so that complicated codes were in use, and consequently there was an appreciable time-lag on information. Height estimations

[1] Locations and details of R.D.F. stations operating and under construction overseas in October 1940 are given in Appendix No. 11 and Map No. 4.

[2] Air Ministry File S.5734, Encl. 101c.

from the R.D.F. stations were both rare and inaccurate and the Controllers were untrained and inexperienced. The maximum of R.D.F. information was not being obtained from the stations themselves as many of the R.D.F. operators being posted overseas were poorly trained—despite the fact that they had been given a refresher course before they embarked from England. A scheme of local training had to be evolved in the Middle East. Thus the stinted time allotment for basic training in the U.K., designed to speed up the manning of operational stations, failed to achieve its aim and, furthermore, loaded Headquarters, Middle East, with a big commitment which it was not designed to accept.

The Formation of a Separate Radio Branch at Headquarters, Middle East

The establishment for Headquarters, Middle East, had been increased to provide for a Wing Commander to act in an advisory capacity on R.D.F. to the Air Officer Commanding-in-Chief.[1] Wing Commander J. A. Tester was appointed to this post and immediately commenced a vigorous drive to improve the R.D.F. facilities. For the first year of the war all R.D.F. matters came within the province of the Signals Branch in the Middle East. Owing to the growth of the R.D.F. organisation, the special nature of this work, and the rapid expansion which was envisaged with the impending flow of equipment from Britain, it was considered essential to establish a completely separate Radio Branch—though this move was not accomplished without opposition and was without official approval of the Air Ministry. Once convinced of the advantages of such an arrangement, the Chief Signals Officer himself gave weight to this argument, and the Radio Branch came into being in October 1940—in good time to face the heavy programme of R.D.F. expansion in the Middle East.[2]

Establishment of a Branch of D.C.D. in the Middle East

A branch of the Directorate of Communications Development, Air Ministry, was established in the Middle East, in December 1940, attached to the Radio Branch at Headquarters. It was to deal purely with technical matters and in particular with the supply of spares which was causing great concern.[3] It was anticipated that this addition of experienced D.C.D. technicians to the Headquarters would lead to greater co-ordination in the development of R.D.F. facilities in the Middle East. This was certainly borne out in practice when the Middle East D.C.D. staff were working in conjunction with the Radio Installation and Maintenance Unit; the portable R.D.F. pack sets and the increased mobility of the C.O.L. stations resulted from this co-operation during 1941 and were subsequently used with success on operations.

Formation of the Radio Installation and Maintenance Unit (R.I.M.U.)

Following on the re-organisation of the Radio Branch in the Middle East, a Radio Installation and Maintenance Unit was formed on 14 December 1940.[4] With an establishment of 13 officers and 99 airmen (reduced to two officers and 15 airmen on its formation) its object was the installation of A.M.E. Stations and maintenance of R.D.F. equipment (both airborne and ground) in the

[1] Air Ministry File S.5734, Encl. 101c.
[2] Headquarters, Middle East, O.R.B., 10 October 1940.
[3] Air Ministry File S.44211, Encl. 105A, Headquarters, Middle East, File S.50530/R (now A.H.B./IIE/188/13), and Air Ministry File S.5734, Encl. 153A.
[4] No. 1 R.I.M.U. O.R.B., 14 December 1940.

Middle East Command. Its first concern, however, became the collecting and sorting out of missing technical equipment. Supplies had been arriving from the United Kingdom unchecked and badly labelled, so that parts were lost and mislaid. Cases had been known of equipment being unloaded at the wrong ports. With the acute shortage of every type of technical apparatus in this theatre, it was vital that wastage through such causes should be eradicated as soon as possible.

Personnel were arriving to man the A.M.E. Stations—many of which were still in transit. It was therefore suggested that the R.I.M.U. could be utilised as a pool for these surplus operators and it soon became a reception depot.[1] Here the men were reformed into units as the equipment became available. Many of them still had several months to wait before they were sent out to an operational site, but at least there was some sort of attempt by the R.I.M.U. to organise the flow of man-power. It was also under the aegis of this unit that a school was set up to train the airmen, newly arrived from the United Kingdom, on the mobile and transportable types of equipment they would be using. Some idea of local conditions was given to impress upon the men the need for a change in mental outlook from their previous experience in the relative comfort of Home Chain stations.

War Cabinet's Concern over Greece

On 1 November 1940 the Secretary of State for Air, who was visiting the Middle East at that time, sent a signal to the Prime Minister emphasising the imperative need for reinforcement in that area.[2] The Air Officer Commanding-in-Chief, Headquarters, Middle East, had informed the Secretary of State for Air that, in the event of serious military operations developing, the Royal Air Force was not in a position to give the Army any really effective help. Although up to that time the Italian bombing had been singularly ineffective, there was a real danger of heavy attacks becoming imminent over the crowded cities. The Secretary of State for Air paid tribute to the brilliant tactical skill of the small groups of Fighters and Bombers in operations against the Italians, but pointed out that the weakness of the Royal Air Force in the Middle East would become a major issue which might have the gravest consequence.

Between October and November 1940 the defence of the Middle East became a subject for discussion at several meetings of the War Cabinet Defence Committee, particularly with regard to affording assistance to Greece.[3] On 17 October 1940 the Committee requested the Air Staff to review the position of R.D.F. in the Middle East and on 5 November 1940 a report was approved containing proposals for establishing a fleet refuelling base in Suda Bay and advanced landing grounds in Crete.[4] A scale of reinforcements needed to carry out this scheme was outlined, and included R.D.F. equipment. On 6 November 1940 the Air Staff were again invited to examine the possibilities of providing R.D.F. equipment for Crete at the earliest possible moment. Although extremely short of supplies, Headquarters Middle East, was preparing a plan for operating R.D.F. at Athens and in Crete, using sets now existing in the Middle East plus those which it was hoped would be sent in the Greek reinforcements convoy if space in the ships could be made available.

[1] No. 1 R.I.M.U. O.R.B., 12 January 1941. [2] Air Ministry File S.5734, Encl. 108A.

[3] Confidential Annex to D.O. (40), 39th Meeting of the War Cabinet Defence Committee.

[4] Chiefs of Staff Papers, C.O.S. (40) 352, revised copy of C.O.S. (40) 903 of 11 November 1940, and C.O.S. (40) 26th Meeting (Operations).

Practical Aid for Greece from Headquarters, Middle East

A siting party was sent immediately to Greece and Crete and instructions were issued to divert M.R.U. No. 221, which had arrived by this time for installation at Khartoum.[1] Reinforcements in the shape of one Hurricane Squadron, two Wellington Squadrons and two Mobile R.D.F. Units were promised by Air Ministry as replacements for any forces sent to Greece from the Middle East. In the light of future developments, the reinforcements thus allocated seem somewhat inadequate, but it must be remembered that our industrial effort at home had by no means reached its peak and there were many demands on the small amount of equipment and transport available.

In view of the immediate urgency, it was decided to transfer the M.R.U. No. 252 from its operational site at Sidi Barakat to either Port Said or Crete and to replace it by a C.O.L. station as the site was particularly suited for this type of equipment.[2] A number of C.O.L. stations had finally reached the Middle East and were about to be despatched to Aden, supplemented by an M.R.U. and full crew. A suggestion was made to recall this latter equipment, for use at Khartoum and to dispense with the idea of a C.O. station at Aden until further research had been carried out on a new type of aerial array.[3] The question of a siting reconnaissance for Cyprus was still outstanding and as soon as this could be arranged an M.R.U. station was to be erected on the island and was to report information straight to Haifa.

Siting Difficulties Encountered in Crete

By the middle of December 1940 the Admiralty were making anxious enquiries as to the existence of R.D.F. in Suda Bay. The reply received from the reconnaissance party in Crete was not, on the whole, very reassuring.[4] M.R.U. No. 252 had been placed temporarily at Aroni on the north side of Suda Bay, its final location to be Maleme ; and a second M.R.U. was expected for use at Heraklion. There were very few possible sites in the area and out of these there was no site really suitable for an M.R.U. or a C.O.L. station. They were either too low or surrounded by hills which would cause large permanent echoes, and all suffered from extreme difficulty of access. Complete protection of Suda Bay was therefore impossible, and short-range warning only could be given. There were no suitable R.D.F. sites on the western end of the Island, but an efficient observer system was in operation. It was pointed out that even in the event of fighter aircraft being available, interception would be very unlikely with the type of R.D.F. gear then in use.

Development of a Small Portable R.D.F. Set in the Middle East

The Mobile Radio Units (M.R.U.s) were mobile only in the sense that they could be moved from one site to another on their appropriate motor transport. The degree of mobility of such stations during a campaign was really insufficient, as they took some four days to erect. In addition, on difficult terrain such as the mountainous regions in Greece and Crete, where the roads were particularly bad, many suitable sites were inaccessible to the heavy motor transport of these M.R.U.s. Finally, when a suitable site had been selected and the M.R.U. was set up there, no cover was given against low-flying enemy aircraft.

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[1] Air Ministry File S.5734, Encl. 115A.
[2] *Ibid.*, Encl. 112A.
[3] *Ibid.*, Encls. 117A and 118A.
[4] *Ibid.*, Encls. 132A and 138A.

These disadvantages of the M.R.U.s under campaign conditions stimulated the Radio Branch at Middle East Headquarters to develop a small portable R.D.F. set, quite independently of any technical developments at home.[1] This equipment consisted of an aircraft A.S.V. set used on the ground with a locally-designed aerial system. In its preliminary stage it gave ranges of 18 miles on an aircraft flying at 2,000 feet and 24 miles at 6,000 feet using an effective aerial height of only 15 feet. The whole equipment was designed for mule transport in the event of good motor roads not being available. By March 1941 two such sets were in use in Crete as satellite stations to the Mobile Radio Units in order to give adequate low cover. Sited on hills, they were surprisingly successful, giving 25-mile ranges on low-flying aircraft. Plans of the design of these sets were sent back to the United Kingdom to be prototyped for general production. Subsequently the first models of this equipment produced at home were unsuccessful, having inadequate range, though ultimately this apparatus was developed into the satisfactory Type 6 Station.

The Axis Bid for Supremacy in the Central Mediterranean

Towards the end of 1940 the enemy decided to make an effort to establish supremacy in the Central Mediterranean. During January 1941 German aircraft arrived in Sicily and began to operate against Malta and our Mediterranean convoys in support of increased enemy submarine activity.[2] Serious toll was taken of Naval convoys and the passage of shipping through the Western Mediterranean from Gibraltar was so dangerous that it became obvious that the Admiralty would be unable to ship any further R.D.F. equipment direct from the United Kingdom to Malta.

Appreciation of R.D.F. Cover in Malta

To safeguard their lines of communications from Italy to North Africa, the enemy undertook a steady aerial offensive against Malta. Radio-location could play a decisive role in the defence of such a compact target as that which Malta presented to enemy aircraft operating from Sicilian airfields. In order to appreciate the R.D.F. cover available in Malta it is necessary to recapitulate briefly the facilities which had been installed there. Until December 1940 the Island was protected solely by Transportable Radio Units Nos. 241 and 242 at Fort Dingli, working alternately throughout each 24-hours period and receiving some assistance from one G.L. set which came on the air when tracks were picked-up by these A.M.E. Stations.[3] The object of the G.L. set was to cover that area within the permanent echoes of the A.M.E. Stations. Although sited within 3,000 yards of each other T.R.U.s Nos. 241 and 242 had slight but important differences in performance resulting in varying gaps in the R.D.F. screen. Enemy formations flying at approximately 20,000 ft. were normally detected at 65–75 miles. On No. 241 T.R.U. these raids faded between 35–28 miles but this caused no serious operational drawback. On No. 242, however, the fading area was between 50–39 miles, a most inconvenient distance since it

[1] Air Ministry File S.5734, Encl. 182A.
The M.R.U. had a very unwieldy establishment of "specialist" personnel involving equally unwieldy impedimenta. The Middle East Command developed the policy of having the minimum number of men, each trained to do almost all field jobs—driving, cooking, defence, and operating—for the manning of its improved small portable R.D.F. That, as much as the facilities offered by the new stations, accounted for their remarkable mobility.

[2] *Ibid.*, Encl. 114A, and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder "R.D.F. Overseas", Encl. 63A.

[3] Air Ministry File S.47124, Encl. 131A.

covered the period during which fighters had to be flown off if interceptions were to be made. The addition of another receiving aerial to No. 242 T.R.U. did much to fill up this gap.

The first C.O.L. station became operational to provide low cover at Fort Ta Silch on 28 December 1940, followed by a second on 19 January 1941 at Fort Maddalena, while the third station commenced testing and calibration in February at Fort Dingli. Although these stations were able to plot aircraft at their extreme range (approximately 70 miles), the operational height of the enemy aircraft had been such that they had so far provided only a little extra coverage over Nos. 241 and 242 Transportable Radio Units.

Until mid-January 1941, when the *Luftwaffe* arrived in Sicily, the Italian daylight raids usually consisted of formations of bombers escorted by fighter aircraft and flying at an average height of 20,000 feet.[1] Similarly, reconnaissances were carried out by formations of fighter aircraft and no difficulty was experienced in detecting any of these raids. Single aircraft rarely approached the Island by day. Night raids usually consisted of single aircraft or a succession of single aircraft flying at approximately 10,000 feet. These were normally detected at about 40–50 miles, and were followed in by R.D.F. observation with some, but not serious fading.

With the arrival of the Germans, tactics underwent a noticeable change. Frequent reconnaissances were made by single high-flying aircraft (usually *JU.88*) and these were seldom picked up beyond 25 miles and, on two or three occasions, were only detected when within visual range of the Island. Fighter interception was impossible. On one occasion a *JU.88* slipped through the R.D.F. defence and caused casualties and damage before any alarm could be given. As a result of this attack the Army provided a 24-hour watch with a G.L. set in order to give warning of aircraft which evaded the R.D.F. screen.

At the beginning of February 1941, Wing Commander Tester, Chief Radio Officer from Headquarters Middle East, visited Malta at the request of the Air Officer Commanding, who was seriously perturbed at the number of single aircraft attacking the Island undetected.[2] Several technical faults were found in the newly-erected stations, and the chief trouble in the operation of the stations was found to be the method of sweeping of the C.O.L. stations, so that if the T.R.U. did not pick up a raid there was a great danger of its getting close to the island without being seen at all. A better method of sweep was instituted and Filter Room personnel were instructed in the handling of the stations.

The Filter Room was in a cellar some 500 yards from the Operations Room which was situated in the War Headquarters in Valetta. No Filter Officers were available and the duty was carried out by two A.M.E. Station Commanders, who were thus prevented from supervising their own R.D.F. stations. There was a great deal of activity. In thirty-four normal days about 20,000 plots were received in the Filter Room, the large majority of these being hostile tracks. The need for trained Filter Officers was great, as the Filter Room had insufficient experience to control the reporting of the stations.[3]

An analysis of the station records showed on the whole that the entire air defence system operated with remarkable efficiency. The Controller's task was made more difficult by the lack of height information and I.F.F. but this was

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[1] Air Ministry File S.47124, Encl. 110A.
[2] A.H.B./IIE/70, D.D.Ops. (Overseas) Folder, Encl. 72B.
[3] Report on F/O. Findlay's visit to Malta—attached to Air Ministry File S.47124.

mitigated by the smallness of the target area and the low number of friendly aircraft.[1] It was felt that it was highly desirable to have a second "floodlight" station (as opposed to the "searchlight" C.O.L. type) preferably with height-finding. This provision was most urgent consequent upon the undetected raids and the need for height reading. In view of the shortage of R.D.F. gear overseas at that time, the idea of splitting T.R.U. Nos. 241 and 242 into separate stations operating simultaneously was considered. An R.D.F. expert from Stanmore Operational Research Station attributed the non-detection of the single aircraft to their great height, as a similar phenomenon was giving rise to anxiety on the Home Chain.[2]

Various solutions were put forward to the problem of increased R.D.F. cover for Malta but it was finally decided to abandon the idea of a C.O. station at Rabat and to substitute a T.R.U., probably at the north end of the Island, to provide cover over the Island itself.[3] A fourth C.O.L. station would also be required to fill the gap caused by permanent echoes from the island of Gozo.[4]

During the early part of 1941, Headquarters, Middle East was finding it almost impossible to provide sufficient cover for their own territory against increased attacks from German aircraft, but it was arranged that M.R.U. No. 218 should be transferred to Malta from Lakoni in Mombasa.[5] It was also intended to improve the performance of the existing T.R.U.s on Malta which were using M.B.1 transmitters giving a very low power output of 30 kilowatts, by shipping out the latest type of M.B.2 transmitter which would give 200 kilowatts.[6] This new equipment unfortunately was a total loss due to enemy action on the high seas. No more equipment could be sent direct to Malta from England except for small stores, which might be sent by aircraft or submarine.

Suggestion that R.D.F. Equipment for Malta should be supplied direct from the Middle East

Once again Headquarters, Middle East were approached and requested to furnish the hard-pressed Island with two M.R.U.s, complete with height-finding gear, from their own scanty stocks. This brought forth a justifiable protest from the Middle East who considered it unreasonable that they should be expected to supply material to Malta which already possessed five stations in a small area whereas the Middle East had very few more to distribute over a far more extensive coverage.[7] Light German attacks were becoming more frequent on the Suez Canal and in order to contend with these, the non-standard R.D.F. gear which had originally been stationed at Ikingi Mariut and which had latterly been sent to Mersa Matruh, was now withdrawn and removed to Port Said. The only height-finding equipment was the new M.R.U. at Ikingi Mariut, but this had not yet been calibrated and was not therefore operational. It was considered by the Middle East staff officers that in view of the extended commitments of the Western Desert and the threat to the Canal zone, provision of cover for Egypt should have highest priority. Great disappointment was expressed at the non-materialisation of the promised additional Mobile Radio Units, on the early arrival of which all plans for R.D.F. in Egypt had been based.

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 72B.
[2] Air Ministry File S.50541/R.D.F., Encl. 130A.
[3] Inter-Service R.D.F. Committee, Minutes of 21st Meeting.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 83A.
[5] *Ibid.*, Encl. 75A, and Air Ministry File S.47124, Encl. 114A.
[6] *Ibid.*, Encl. 141A.
[7] Air Ministry File S.5734, Encl. 145A.

On receipt of this protest at Air Ministry, an attempt was made to expedite the shipment of six Mobile Radio Units awaiting despatch to Egypt and it was agreed for the time being to drop the plan for adding to the present R.D.F. equipment in Malta.[1] Replacement parts had been sent to Malta by air but the Wellington aircraft was lost en route. A duplicate set of parts was despatched and their safe arrival ensured that all three C.O.L. stations located on the island would soon be fully operational again.

The Deputy Air Officer Commanding-in-Chief, Middle East Command, Air Vice-Marshal Tedder, had personally asked Air Marshal Sir Philip Joubert, the Assistant Chief of Air Staff (Radio) at Air Ministry, that the policy for additional equipment for Malta might be reconsidered. In his reply Sir Philip Joubert assured Air Vice-Marshal Tedder that every effort was being made to expedite and despatch further R.D.F. reinforcements to the Middle East, including an early diversion of all the Freetown R.D.F. stations.[2]

By the end of February 1941 Mobile Radio Unit No. 265 and Transportable Radio Unit No. 244 had arrived in Freetown and the personnel for the C.O.L. Stations Nos. 13 and 14 had also reached their destination, though all their R.D.F. equipment had been lost at sea due to enemy action.[3] The reinforcement of the Middle East was so urgent that T.R.U. No. 244 was sent immediately to Headquarters, Middle East, and M.R.U. No. 265 and the crews of the C.O.L. stations were to follow as soon as possible. This removal of the Units from Freetown was an interim measure only. Actually the flow of R.D.F. stations from the United Kingdom was improving.[4] At the beginning of March 1941 some ten Radio Units were en route for the Middle East theatre and an early improvement in the R.D.F. cover could be anticipated.[5]

Initial Policy for G.C.I. Stations in the Middle East

As the German Forces moved into the Balkans and also advanced in the Western Desert during the early part of 1941, there was every reason to anticipate that their bombing attacks would become more intensive and sustained on important targets in the Middle East. Certain areas, vital to our war effort there, were particularly liable to attack as they were situated on the North African coast and provided excellent targets for night bombing. At home the development of Ground Control of Interception (G.C.I.) R.D.F. stations was resulting in a considerable improvement in the night defences. It was thought essential that G.C.I. units should be provided within the shortest possible time for the Middle East. The areas which were considered to have priority were selected as :—[6]

	No. of G.C.I. Sets
Malta	1
Alexandria (and Aboukir)	1
Suez Canal Area	2
Suda Bay	1
Piraeus	1
Tobruk	1
Benghazi	1

[1] Air Ministry File S.5734, Encl. 151A.
[2] *Ibid.*, Encl. 178A and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 170A.
[3] *Ibid.*, Encls. 168A and 183A.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 170A.
[5] A summary of the R.D.F. position in Middle East Command, including details of the Mobile Radio Units and C.O.L. stations en route from the United Kingdom, is given in Appendix No. 12.
[6] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 70A.

There was every indication that the warfare in the Middle East would be of a fluid nature. The ebb and flow of the war might bring other important places within range, or the war might recede from the above-mentioned areas. It was therefore recommended that the G.C.I. stations to be supplied should be mobile or transportable and that at least four sets should be held in reserve. In view of the demands of the rapidly-expanding G.C.I. "carpet" at home, it was not anticipated that G.C.I. equipment would be available for the Middle East before September 1941.

Operational Performance of R.D.F. Early Warning during the Campaigns of 1941

Greece

It will be recalled that No. 221 Mobile Radio Unit had been diverted to Greece on 17 November 1940. A siting party had selected a location at Araxos near Point Pappas in the Royal Hellenic Naval area of Patras, some 120 miles due West of Athens, on the west coast of the Peloponnese Peninsula.[1] The M.R.U. had considerable difficulty in reaching the site owing to the poor condition of the roads. It was nearly a month before the R.D.F. station became operational under the appalling conditions of rain and mud which prevailed.

Although one R.D.F. station could not possibly give adequate early warning cover for a theatre of operations of the size of Greece, the performance of No. 221 M.R.U. was very good. Its line-of-shoot was directed towards Southern Italy and it gave good warning of the approach of enemy aircraft from the Southern Italian and Sicilian airfields. Enemy aircraft were frequently observed up to a range of 170 miles. The station told its plots to the Greek Air Defence Centre at Athens by land-line, with stand-by W/T facilities to the Centre and the Headquarters of the British Air Forces in Greece. Some confusion was caused at the Air Defence Centre in Athens, raids there being duplicated on the plotting table because our R.D.F. information was usually about 20 minutes ahead of the Greek observer system of visual detection of raids. Throughout January 1941 the plotting system at the Air Defence Centre was most ineffective—often due to the absence of English-speaking plotters. During February a considerable improvement was effected, airmen from No. 221 M.R.U. taking over plotter's duties at the Air Defence Centre itself.

It had been intended to move No. 251 M.R.U. from the Sudan to Larissa, about 150 miles North of Athens, to give cover against the approach of German aircraft from Bulgaria, but events moved too rapidly.[2] The German break-through began early in April 1941 so really adequate R.D.F. cover was never supplied to our forces operating there.

On 13 April No. 221 M.R.U. at Araxos received orders to close down and move to Massawa airfield.[3] Personal instructions were sent from the Air Officer Commanding-in-Chief, Middle East, to Air Vice-Marshal J. H. D'Albiac, Air Officer Commanding British Air Forces in Greece, that he was to make quite sure that no R.D.F. equipment fell into enemy hands.[4] A warning order to No. 221 M.R.U. to prepare for a move to Crete was issued, but later cancelled

[1] No. 221 A.M.E.S., O.R.B., 26 December 1940.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 75A.
[3] No. 221 A.M.E.S., O.R.B., April 1941.
[4] British Air Forces in Greece, March–April 1941, O.R.B., D.O. letter of 18 April 1941.

to avoid any suggestion to the Greeks that the Royal Air Force was evacuating. Some two days later the R.D.F. equipment only of the unit was thoroughly destroyed by hand owing to the lack of suitable shipping for its evacuation.[1]

Without technical equipment, the morale of the R.D.F. personnel, high throughout the whole of their stay in Greece, showed to even greater advantage during the last disastrous days of the campaign. On 21 April two junior N.C.O.s manning Lewis Guns in the open shot down an enemy aircraft from some twenty which were straffing the airfield at Eleusis. Under continued bombardment from the air, the R.D.F. unit took to the hills, destroying the remainder of their equipment and all documents. A week later they were evacuated without casualties by sea to Egypt in five small groups, each in different vessels.[2]

It would be futile to claim that Royal Air Force R.D.F. made any really useful contribution to the campaign in Greece, yet the single unit which operated there did so successfully, and the personnel showed a devotion to duty at all times which augured well for future campaigns.

Crete

Reference has already been made to the intention of providing R.D.F. cover for Crete. No. 252 Mobile Radio Unit landed in Crete on 18 December 1940. A location had been selected in advance near Maleme, but this site was completely unapproachable due to the bad state of the roads, which were partially destroyed by the heavy rains. The unit was therefore installed temporarily at Aroni, on a ridge of land North of Suda Bay.[3] A three-way looking aerial array was erected in the absence of specific instructions as to line-of-shoot on this temporary site. The plots were passed to a nearby Gun Operations Room by land-line shared with a G.L. set operated by the Army.[4] All other communications were by W/T. The site could not be regarded as a good one; permanent echoes were rather bad. However, this site was considered by the Officer Commanding No. 252 M.R.U. to be far superior to that proposed at Maleme and he submitted a report elucidating the advantages and pointing out that Aroni had been the original site selected by the R.D.F. reconnaissance party.[5] Headquarters, Middle East were adamant, however, and ordered the unit to proceed to Maleme immediately the weather and adequate defences permitted. The site selected at Xamondochi, on the spur of foot-hills due South of Maleme and only 3 miles from our airfield there, gave the best possible cover on lines of approach of enemy aircraft for both the Naval anchorage at Suda Bay and our airfield. On 15 January 1941 the Mobile Radio Unit moved to its new site. Its plots were passed to the Operations Room at Canae, where an elementary form of filtering took place.[6] The ranges obtained were satisfactory, except for cover against low-flying aircraft. Fairly heavy raids were experienced and plotted successfully, but the information had little value as the Fighter defences were inadequate.

During March the R.D.F. cover on Crete was increased by the arrival of No. 220 Mobile Radio Unit and two R.D.F. pack-sets suitable for mule transport. The M.R.U. became operational at Heraklion on the northern coast of central Crete while the pack-sets were situated on hills on Cape

[1] Headquarters, Middle East File S.50503/221/R.D.F., Encl. 41D.
[2] No. 221 A.M.E.S., O.R.B., 27 April 1941.
[3] No. 252 A.M.E.S., O.R.B., Appendix " I."
[4] *Ibid.*, Appendix " K."
[5] *Ibid.*, Appendix " E."
[6] *Ibid.*, Appendix " M."

Drepanos. These pack-sets were modified aircraft A.S.V. sets used with a suitable aerial system. They were very successful in providing low cover, giving ranges of up to 35 miles.

At the termination of the hostilities in Greece at the end of April, the Germans did not give any respite to our forces, beginning an all-out attack on Crete before we had time to improve the defences there. On 14 May 1941 a message was received by the Mobile Radio Units warning them that a large-scale attack on Crete was anticipated, including landings by enemy parachute troops, the probable date being 19 May.[1] Very heavy bombing raids were being experienced in the areas of both Mobile Radio Units and the plotting results of the stations were excellent but almost useless, because the A.A. fire was gradually being reduced to only a feeble response under heavy bombing and machine-gunning attacks and our Fighter defences were practically negligible at that time.

Troop-carrying aircraft and parachutists landed on 20 May and Maleme airfield fell to the enemy the following day. No. 252 M.R.U. site became an isolated outpost—augmented by a few Royal Air Force personnel, stragglers from Maleme airfield. No instructions were received from either Air Force or Military authorities and the R.D.F. station seems to have been very much an orphan in a particularly violent storm. Fresh enemy landings were made nearby, so steps were taken to smash technical equipment and burn all documents, but the blowing up of the receiver and transmitter vans was left until a bombing attack would camouflage the explosions.[2] This occurred in a matter of hours: a heavy air attack on the Station began by more than fifty enemy aircraft, mainly *Stukas* with *Me. 109* escort and high-level bombers. The bombing was extremely accurate, gun-posts and apparatus were destroyed. The Officer Commanding, the Officer i/c Defence and one airman were wounded but the Administrative Officer managed to collect the remnants of the dispersed personnel and they took the road South towards Suya—the dust from the dive-bombing enabling them to escape under the protection of the dust-clouds. After ten days of privation they reached Sphakia. In view of their condition, instead of rejoining troops a further three hours' march away, they were taken off on board a destroyer on 29 May and transported to Alexandria. The unit had lost sixteen personnel killed and missing, including the wounded Commanding Officer, who was subsequently reported as a prisoner of war.

Meanwhile No. 220 M.R.U. at Heraklion were suffering a similar attack. The station was heavily dive-bombed and machine-gunned throughout 20 May, and in the evening enemy paratroops were dropped, entirely surrounding the compound.[3] Operations ceased, all personnel stood-to on guard, and the documents and all technical apparatus except the W/T set were destroyed to avoid possible capture by surprise night attack. The following morning a W/T message was sent to the Royal Air Force Headquarters in Heraklion that the unit, which was located outside the defended area of the town, was attempting to rejoin the main force inside the perimeter.

En route, there were several skirmishes with the enemy in which German prisoners were captured and two of the unit's personnel were killed. Eventually the defended perimeter of Heraklion, which included the aerodrome and

[1] Nos. 220 and 252 A.M.E.S., O.R.Bs , May 1941.
[2] No. 252 A.M.E.S., O.R.B., 20/21 May 1941.
[3] No. 220 A.M.E.S., O.R.B., 20 May 1941.

harbour, was reached. Here, the unit together with some Army stragglers, were heavily mortared by our own defenders—no notice being taken of the uniform as the enemy were using British uniforms as well.[1] After a brief but uncomfortable time sandwiched between the enemy and our own forces, they were allowed to enter the perimeter defences. Evacuation on H.M.T. "Orion" followed. This ship was heavily bombed and another eight of the R.D.F. personnel were killed.

By the end of the operations in Crete the R.D.F. units had not only proved themselves technically, but their high morale had also demonstrated itself in their ability as fighting men in their own defence when pressed by the enemy. Nevertheless Greece and Crete clearly demonstrated certain principles:—

(*a*) That a single R.D.F. station very rarely produced sufficient results to justify its being there. The R.D.F. stations of that time were seldom satisfactory unless part of a system or chain of stations giving a complete pattern of early warning cover for the area concerned. The exception to this was later realised to be a specialist station which did not necessarily need to provide all-round cover and which was used by a specially trained Fighter Controller. Even then a warning system was often necessary as well.

(*b*) That an observer corps was incapable of producing sufficient information for accurate interception, and that the time-lag on the information was such as to confuse other information unless it were all being filtered by skilled filterers. The outstanding value of an observer system was for identification.

(*c*) That R.D.F. information was usually valueless unless supported by the full machinery of defence, namely, fighter aircraft, guns, searchlights, operations rooms and filter rooms.

Western Desert, December 1940–May 1941

Concurrently with the operations in Greece and Crete there was considerable activity in the Western Desert. On 9 December a British offensive was launched from near Sidi Barrani in Egypt leading to a victorious advance against the Italian forces as far as Agedabia in Libya.

R.D.F. was employed to give early warning of the approach of hostile aircraft, but because of the low degree of mobility which our equipment possessed at that time it was the practice never to deploy R.D.F. units in very forward positions. Although all Mobile Radio Units were adequately briefed on the destruction of their equipment to prevent it from falling into enemy hands, unnecessary risks could not be taken.[2] Security was not the only factor to consider in this respect: the marked insufficiency of R.D.F. apparatus within the Middle East Command at that time precluded the adoption of any policy which would unnecessarily jeopardise the equipment.

The role of R.D.F. during these operations was to give cover to the lines of communication, dumping areas and coastal supply convoys. Immediately following the path of the advance in December, Nos. 216 and 235 Mobile Radio Units were moved up from the R.D.F. Reserve at Aboukir to Sollum and Sidi Omar (S.W. of Sollum) respectively.[3] As the advance of the ground forces

[1] Narrator's interview with Flight Lieutenant J. N. K. Whitford, Commanding Officer of No. 220 A.M.E.S.

[2] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[3] Nos. 216 and 235 A.M.E.S., O.R.B., January 1941.

continued, so the Mobile Radio Units leap-frogged forward. By the end of January No. 235 M.R.U. was operational at Tobruk and No. 216 M.R.U. had moved forward to Acronia, some 20 miles west of Tobruk. This latter unit changed its site to Benghazi two weeks later. By this date, 11 February 1941, our ground forces had reached the limit of their advance.

Tobruk and Benghazi were the main ports of the supply for our forces in Libya. Because of a dearth of transport suitable for desert operations, the sea route for supplies was extremely important. The enemy realised this and there was considerable aerial activity over these two ports—particularly in the case of Benghazi, which was subjected to sustained enemy bombing attacks during March. The plotting of the Mobile Radio Units was satisfactory, within the limits of their equipment. Their information was passed to No. 258 Fighter Wing for advance warning and interception purposes.

During this period of our success in Libya, enemy raids were anticipated in the Delta area and it was expected that the Suez Canal would be subjected to heavy bombing. The number of Mobile Radio Units available in the Middle East Command during the spring of 1941 was insufficient to meet all commitments. No. 204 M.R.U., which was located at El D'aba in the temporary coastal R.D.F. chain, was therefore moved back to Damietta to support the C.O. station at Ikingi Mariut and No. 219 M.R.U. at Port Said.[1] The R.D.F. policy at that time can be summarised as :—

(*a*) Early warning R.D.F. cover for the base area of the Delta and Suez against heavy bomber attacks.

(*b*) The best R.D.F. cover possible for the forward areas, against fighter-bomber and medium bomber attacks on our lines of communication and ports.

The deficiencies in R.D.F. cover were between the forward areas in Libya and the base area of the Delta—due entirely to the shortage of sufficient Mobile Radio Units to cover the extended coastline.

Before there was time to consolidate the ground gained in Libya and surmount the transport problems of our elongated lines of communication, the enemy counter-offensive commenced on 30 March 1941. The German *Afrika Corps* came into action for the first time in the desert and within four days we had to evacuate Benghazi and withdraw to Halfaya, just inside the Egyptian border, leaving forces in Tobruk. No. 216 M.R.U. appears to have been overlooked in the general retreat and withdrew when dangerously near being taken by surprise by the enemy. When the front was stabilised again at Halfaya, No. 216 M.R.U. became operational again at Mersa Matruh on 22 April, plotting to No. 204 Group Operations Control.[2]

In Tobruk, under a siege which subsequently lasted some nine months, No. 235 M.R.U. remained behind to provide R.D.F. early warning for the garrison. Its function became of much greater value than that of local cover, however, for in this location it was viewing across the enemy lines of communication and was thus able to report all enemy aircraft movements between their rear and forward areas. This information was passed in a simple code by W/T to our desert Fighter Wing Operations Control.

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[1] Headquarters, Middle East, Radio Branch, O.R.B.
[2] No. 216 A.M.E.S., O.R.B., April 1941.

Strategic Moves in the Middle East during the Summer of 1941

By the end of May our positions in the Middle East appeared somewhat precarious. The enemy had overrun the Balkans and captured Crete, and we had been pushed back in the Western Desert. During the latter part of April trouble had broken out in Iraq, fermented by German agents, and action had to be taken with very weak forces to consolidate our flank. For some time too before the fall of Crete the question of Syria had occupied the attention of the Commanders-in-Chief, Middle East. So long as the Vichy French officials were in power in Syria there was a grave danger of the Germans establishing air bases there from which they could attack Palestine, the Suez Canal, the lines of communication and oil supplies from Iraq and Iran. Cyprus, between Syria and Crete, would also be endangered if the enemy entered Syria ; nor could a German advance into Syria through Turkey be ruled out.

The operations which followed to clear the flanks, against Iraq (April/May) and Syria (June/July), and the occupation of Iran in conjunction with our Russian allies, did much to ease our position. From the point of view of R.D.F. early warning, however, some of these territories required adequate defences and thus further calls were made on the Middle East Command's slender resources of R.D.F. equipment—fortunately being steadily reinforced at this time from the United Kingdom.

R.D.F. Position in Palestine

There were three operational R.D.F. stations in Haifa by June 1941, No. 236 Transportable Radio Unit at Mount Carmel and two C.O.L. stations for low cover, No. 503 C.O.L. at Stella Maris and No. 508 at Nesher.[1] The T.R.U. at Mount Carmel was not giving complete satisfaction, due largely to lack of spares, and No. 503 C.O.L. was mainly preoccupied with the Filter Room which was located on its site. This was not a complete Filter Room, but a temporary affair acting as a buffer stage between the A.M.E. Stations and the Air Report Centre at Haifa from which severe leakage of information had from time to time occurred.[2]

There was no overlapping of stations so that all that was necessary in the way of filtering was some smoothing out of tracks, a little co-ordination of information and mainly concealment of A.M.E.S. performance and limitations from the Air Report Centre. The greatest threat to A.M.E. Stations in Haifa came from " fifth column " activities by people living in houses adjacent to the sites.[3] At that time the Filter Room was manned by a skeleton staff picked from R.D.F. officers and operators but when the second C.O.L. station became operational and the C.O. station was installed, these men were to be withdrawn to carry on with their legitimate jobs.

Haifa was eventually to become the control for the whole of Palestine, and with the completion of the chain up the Palestine coast and the formation of a defensive triangle including Cyprus, Beirut and Haifa, the Filter Room would reach full performance and had therefore to be given establishment as such. With the removal of the " back door " threat from the Syrian frontier, C.O.L. No. 508 became unnecessary and its removal to the Suez Canal area was contemplated. The buildings, however, were left intact in case a reversion to former conditions became necessary.

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[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.
[2] Air Ministry File S.50541, Encl. 4A and 18A. [3] *Ibid.*, Encl. 11A.

R.D.F. Position in Cyprus

The security of Syria, control of the Eastern Mediterranean, and the defence of the Egyptian Delta, Suez and Palestine from air attack were all intimately dependent upon the holding of Cyprus. The original provision of R.D.F. cover on the island was by No. 218 Mobile Radio Unit, which left Mombasa for Cyprus during April 1941. It was July before this station was operational, plotting to the Fighter Operations Room at Nicosia from its site at Myrton.[1] By this time planning included three M.R.U.s and three C.O.L. stations for the island as the minimum requirement for all-round cover. Aerodromes were either in existence or were under construction at Nicosia, Limassol, Larnaca and Paphos, each with satellites, and a dry-weather landing ground existed near Famagusta.[2] H.Q. No. 259 Wing was at Nicosia, and the only port was Famagusta. These then were the targets to be covered, and since the direction of attack could not be anticipated under the existing conditions—and these might possibly change at any moment—there was no alternative but to complete all-round high and low R.D.F. cover.

It was not until September 1941 that a second Mobile Unit, No. 255 M.R.U., arrived in Cyprus. After setting up on the wrong site and reporting to the Fighter Operations Room at Nicosia, it was moved to the correct site during November.[3] Unfortunately the R.D.F. receiver vehicle was completely gutted by fire just as the unit became operational again, so the station was out of action and it was four months before the unit began to take any active part in the defences of the island.

R.D.F. for Syria, following the Campaign

The only radio commitment in Syria, consequent on the Allied occupation of the country was the defence of Beirut. This was the main port and was to be defended eventually by a Fighter Sector there with full facilities. The airfields to be used were Ryak, Beirut itself, and possibly one or more satellites. A building had been selected on the edge of the town for Air Headquarters and an Operations Room. One M.R.U. and one C.O.L. station had been allocated but not yet sited. This provision was not of high priority and it was probable that the equipment would not be installed before November 1941.[4]

In the meantime, guard was kept by H.M.S. " Coventry " and two G/L sets working in their proper capacity with the guns. A suggestion had been made in June 1941 to move C.O.L. No. 508 from Aden into Syria, but having suffered losses in the past, Headquarters, Middle East were loath to place any non-mobile station outside the areas of the Delta, Suez Canal and Palestine.[5] In this respect every effort was being made to mobilise C.O.L. stations so that they could be used in other areas as well as M.R.U.s. There was still a great shortage of equipment and an even greater shortage of technical staff as the installation programme was under way. It was stressed that the use of an A.M.E. Station solely as an air raid warning was a great waste of valuable equipment. An A.M.E.S. system should, if possible, never exist without the whole machinery of fighter defence behind it. This not only included aircraft but also Sector Operations Rooms, Groups, and all the incidentals such as good R/T for Fighter Control.

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[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.
[2] Air Ministry File S.49984, Encl. 9A. [3] No. 255 A.M.E.S., O.R.B., September 1941.
[4] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 88A.
[5] Air Ministry File S.50541/R.D.F., Encl. 18A.

Possible Requirement of R.D.F. for Turkey

Between the Allied positions in Syria and the enemy in Greece, neutral Turkey acted as a buffer. There was considerable diplomatic pressure from the German side on the Turks at that time and it was considered more than a possibility that the Germans would invade Turkey later in 1941, when their supply position in the Balkans would have improved. In the event of such a German invasion, Britain was pledged to go to the assistance of Turkey. While Turkey was still neutral, however, nothing could be done openly in the way of preparations for our forces to take part in her defence. Since R.D.F. ground stations would be necessary in event of a German attack on Turkey, it was decided that the terrain should be examined covertly with a view to selecting the best possible sites for Mobile Radio Units.

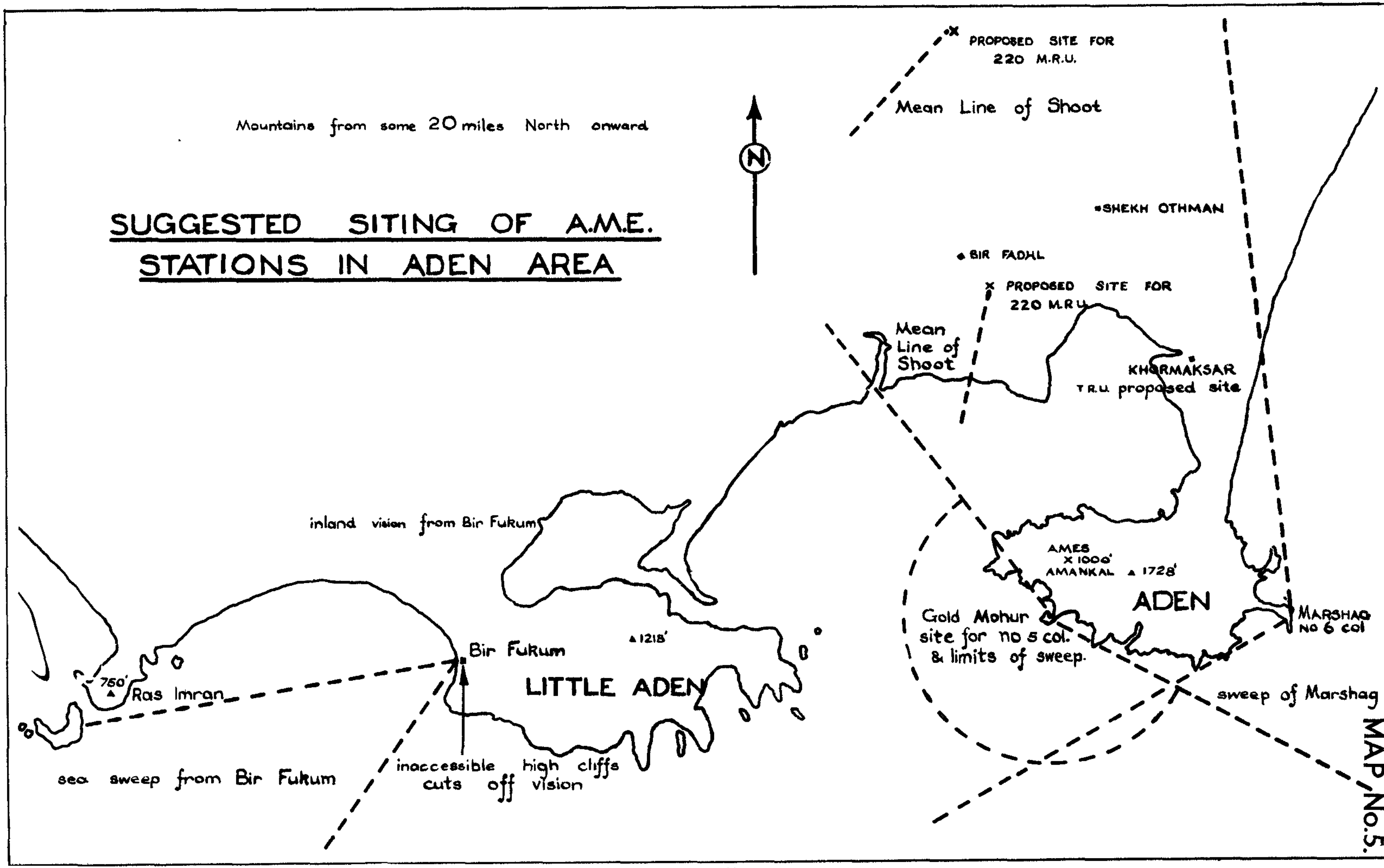
During April and May 1941 Flight Lieutenant S. N. Smith of the Directorate of Communications Development, an R.D.F. siting expert, was attached to the British Embassy at Istanboul as a civilian.[1] Working under considerable difficulties, as the Turks suspected all foreigners, Flight Lieutenant Smith managed to cover all potentially-important regions of both European and Asiatic Turkey and selected locations for Mobile Radio Units. Fortunately, the enemy did not attack Turkey, otherwise Headquarters, Middle East would have been in a bad position to supply the number of Mobile Radio Units required to give adequate R.D.F. cover to this large area.

R.D.F. Provision for Iraq

By the late summer of 1941 we had developed a large erection depot in Basrah to handle a high proportion of the American war output destined for the Middle East and Russia. Through this port also, the major part of the requirements of the land and air forces in Iraq were to pass. In addition, the oil output from the Abadan area was vital to the maintenance of our Naval, Army and Air Forces in the Middle East. The threat in this area was expected to come from a German drive through Northern Iraq and Syria or Iran. The original survey of Iraq had been carried out while the military situation was still troublesome and a complete land survey was not possible. An aerial reconnaissance was carried out and land parties visited Basrah, Shaibah, Baghdad and Habbaniya.[2] Later, in August 1941, a complete survey was made possible and it was decided that cover against high and low-flying attacks could be obtained by placing one M.R.U. at Shaibah, and one M.R.U. with two C.O.L. stations on the banks of the Shatt-el-Arab, thus affording warning for Shaibah and Basrah up to the maximum range of the M.R.U.s, with the C.O.L. stations providing fairly good range-cutting for accurate positioning in the event of interception being carried out. The Shatt-el-Arab area would be covered then from high and low-flying attacks, including the dropping of mines. To receive the R.D.F. information, an Operations Room was to be formed at Basrah or Shaibah but no H.F. D/F stations were to be available for Iraq for four to six months, so once again it looked as though R.D.F. would be used simply as an air-raid warning.

The stations on the banks of the Shatt-el-Arab were to be built on brick mounds to keep clear of the swamps. There was no telephone equipment available, and working conditions were expected to be extremely difficult—but

[1] Narrator's interview with Flight Lieutenant S. N. Smith of D.C.D., M.A.P.
[2] Air Ministry File S.49983, Encl. 11A.


SUGGESTED SITING OF A.M.E. STATIONS IN ADEN AREA
Mountains from some 20 miles North onward
N
PROPOSED SITE FOR 220 M.R.U.
Mean Line of Shoot
SHEKH OTHMAN
BIR FADHL
PROPOSED SITE FOR 220 M.R.U.
Mean Line of Shoot
KHORMAKSAR
T.R.U. proposed site
AMES
X 1000'
AMANKAL ▲ 1728'
ADEN
MARSHAG No 6 col
Gold Mohur site for no 5 col. & limits of sweep.
sweep of Marshag
inland vision from Bir Fukum
Bir Fukum
▲ 1218'
LITTLE ADEN
750'
Ras Imran
sea sweep from Bir Fukum
inaccessible high cliffs cuts off vision
MAP No. 5.

in the words of the Chief of Air Staff, " Inconvenience must be disregarded ".[1] Before the rain season came, the Air Officer Commanding-in-Chief, Iraq, pointed out that these units were liable to become isolated by the floods and requested that they should be resited. A suggestion was made that the men might live in barges and be provisioned by water. Eventually No. 256 M.R.U., which had been sited at Banadir on its arrival from India during October 1941, had to be moved and was temporarily located at Shaibah, where No. 264 M.R.U. had just arrived during October 1941.

Proposals for R.D.F. Cover in Iran

After the occupation of Iran by Allied forces, the possible directions from which light-scale attacks by long-range enemy aircraft were most likely to come were either from Crete, Rhodes or Greece, or from the north of Iran, following a German break-through on the Russian Caucasus front. Although air attack on Iran was a difficult proposition for the enemy, the potential targets were of great importance to the Allies—being principally the Anglo-Iranian Oil Company's oil-fields, refineries, and pumping stations, and the ports and shipping in the Persian Gulf.

Though Iran is much nearer to India than to Headquarters, Middle East, the latter was made responsible for the survey and provision of R.D.F. cover for the oil-fields. This responsibility was communicated to Headquarters, Middle East, in a Chiefs of Staff signal.[2] The area covered approximately 9,000 square miles. Fortunately the potential targets divided into three regions, namely, the refineries at Abadan in the south-west, the oil-fields in the north, and the Persian Gulf up to the Oman peninsula. The employment of three M.R.U.s to give early warning in these areas was envisaged, but the units could not be provided from Middle East resources during 1941 in view of the more urgent requirements in Egypt.[3]

Attempts to develop satisfactory R.D.F. Cover for Aden

It will be recalled that developments were proceeding very slowly at Aden in the provision of adequate R.D.F. cover. One Mobile Radio Unit and two C.O.L. stations planned for Aden had arrived at Headquarters, Middle East, on 21 October 1940. Air Headquarters, Aden did not agree to the sites selected for these stations and approved by Air Ministry, and much correspondence followed on this subject.[4] Meanwhile, Headquarters, Middle East, as the R.A.F. Command responsible for Aden, sent the Mobile Radio Unit to Greece instead. The dispute on the sites for the C.O.L. stations continued.

Although it would be out of context and beyond the scope of this chapter to embark at this juncture on a full description of the many delays which occurred at Aden, there are many lessons to be learned from these details.[5] Some of the factors which contributed to this failure to provide satisfactory R.D.F. early warning within a reasonable period of time were :—

(*a*) The remoteness of the superior Royal Air Force Command. Headquarters, Middle East, were approximately 1,500 miles from Aden.

(*b*) The very difficult nature of the terrain at Aden precluded perfect R.D.F. siting.

[1] Air Ministry File S.50124, Encls. 2A and 4A.

[2] Air Ministry File S.49984, Encl. 13A. [3] *Ibid.*, Encl. 20A.

[4] Air Ministry File M.S.50530/R, Encls. 16A and 23A.

[5] Narrator's comment. An appreciation of the attempts to provide R.D.F. cover for Aden is given in Appendix No. 13. Map No. 5 also refers.

(c) Climatic difficulties, chiefly excessive humidity and the consequent super-refraction, prevented C.O.L. stations and personnel from functioning near to their normal standards.

(d) By far the most important factor was the failure of higher authority to appoint a well-informed technical officer at Aden with power to act according to local conditions. The triangular correspondence between Air Ministry, Air Headquarters, Middle East, and Air Headquarters, Aden, caused much delay and lacked decisiveness.

Build-Up of R.D.F. Equipment in the Middle East, May–November 1941

Throughout 1941 the supply of R.D.F. equipment to the Middle East steadily increased. At the same time the defence commitments within the Command had also increased, so there was still a serious lag between demand and supply. This position was appreciated at Air Ministry and a decision was taken during May 1941 that the highest possible order of priority should be accorded to the shipment of R.D.F. equipment to the Middle East.[1] It is hard to appreciate that by the autumn of 1941 there were already forty-five R.D.F. units operational in the Middle East.[2] Constant references to the shortage of equipment and the huge area over which the Mobile Radio Units were deployed tend to give the false impression that the R.D.F. effort within the Command was inadequate. Actually excellent progress was being made, and the home output of R.D.F. units for the Middle East was really large at that time—some fifty more A.M.E. stations were already in transit or awaiting despatch to the Middle East.[3]

For the Delta night defences the G.C.I. equipment which had been allocated was urgently awaited. The authorities at home were fully aware of this requirement. In a draft minute to the Prime Minister, the Vice-Chief of the Air Staff intimated that three G.C.I. sets were to arrive in the Middle East by mid-September.[4] In addition, improved R.D.F. equipment for height-finding was being prepared and shipped as early as possible, as the height-finding apparatus on the existing R.D.F. stations in the Middle East was not fully satisfactory. From the point of view of successful interceptions of hostile aircraft, accurate height-finding was even more essential than really accurate positioning, so the new equipment was expected to produce a big improvement in our defences.

Improvements in R.D.F. Cover in Egypt

Re-organisation of Filter Rooms in the Middle East

Several attempts had been made to improve the value of the available R.D.F. information by establishing an adequate Filter Room organisation in Egypt. It will be recalled that the first filtering of R.D.F. information had been attempted at Headquarters, No. 256 Wing at Mex, Alexandria, but this had been little more than an information centre, formed (as a result of a general conference) as the place at which W/T plotting from the R.D.F. stations was to be received.[5] At first the filter organisation worked in temporary quarters in the Air Defence Centre. The Filter Room there had too large a roof span

[1] Inter-Service Committee on R.D.F., Minutes of 21st Meeting, item 7, para. (a).

[2] Appendix No. 14 gives the locations of all R.D.F. stations in the Middle East, November 1941.

[3] The A.M.E. stations in transit or awaiting despatch from the United Kingdom in November 1941 are listed in Appendix No. 14.

[4] Chief of Air Staff Folder 719.

[5] No. 256 Wing, O.R.B., 22 May 1940.

to enable it to be covered with any form of protection—leading to some trouble with the Egyptian operators who objected to the lack of safe accommodation in this temporary building. However, by the end of January 1941 a special annexe to the buildings had been constructed and fitted as a complete Filter Room.

During January, too, a filter organisation was developed at No. 250 Wing at Ismailia for the defence of the Suez Canal.[1] The two Filter Rooms at Nos. 250 and 256 Wings functioned separately though only 130 miles apart because of the bad communications, No. 250 Wing being concerned with the Fighter defence of the Suez and No. 256 Wing the defence of the Delta (later handed over to No. 252 Wing). The efficiency of the Filter Room crews was low during the early part of 1941—due largely to the lack of training. However, the arrival of Senior Filter Officers improved the organisation considerably; a Filter School was started, regular practice exercises were introduced, and morale and discipline gradually became better.

Operations Room Fighter Control Officers

R.D.F. information is of most value if the Sector Controllers are really experienced in its use. The only experienced Operations Room Officers at that time were in the United Kingdom, so a demand was made in May 1941 to Fighter Command for twenty Sector Controllers to be sent to the Middle East before the end of the month.[2] This came as a great shock to Fighter Command, already some forty-seven Controllers short on their own establishment, with the prospect that when the home G.C.I. " carpet " developed fully they would be approximately one-hundred Controllers short. Fighter Command were anxious to do all they could, however, for the overseas commitments and arrangements were made to supply nine Sector Control Officers for the Delta area and four Wing Controllers needed for the Western Desert.

Extended Egyptian Chain of R.D.F. Stations

By November some twenty-five R.D.F. stations were in operation in Egypt giving R.D.F. cover against high-flying hostile aircraft.[3] The coastal chain was fairly satisfactory, but the Suez Canal defences were still in an extremely embryo state—the low cover for the canal area being negligible.[4] The chief difficulty here was that of suitable locations for C.O.L. stations. The terrain was really difficult for R.D.F. early warning of an adequate nature and this gave considerable worry. No real solution was forthcoming, though the Command Chief Radio Officer gave much attention to this matter.[5] Even a most lavish scale of deployment of R.D.F. equipment in the Suez Canal area failed to overcome the difficulties of the terrain. Why the Germans never put in a serious attack with a large heavy bomber force remains a mystery: only eight attacks were experienced, though at times there was a mass of valuable shipping as a target—as instanced when the " Queen Mary," " Queen Elizabeth," the " Georgic " and many others were all in the Suez roads together, yet only the " Georgic " was damaged in a light attack.

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[1] Headquarters, Middle East, O.R.B., 5 January 1941.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 79B.
[3] The locations of these stations are given in Appendix No. 14.
[4] Air Ministry File S.4422, Encl. 64A.
[5] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

As a means of improving the R.D.F. information available from individual R.D.F. stations, in England it had been found necessary to introduce Officer Supervisors on every watch at C.H. stations. Their supervision and the increase in efficiency of the radio operators under them due to their constant operational training had been most effective.[1] It was becoming apparent that similar provision must be made for the Middle East. A number of Radio Operators were therefore trained as Supervisors at home, posted to the Middle East and used as Supervisor-Instructors on R.D.F. stations in Egypt as required by the Chief Radio Officer, during the latter part of 1941.

By November 1941 the R.D.F. system had been improved considerably throughout each link in the system. The number of stations had been increased, the efficiency of the individual stations improved, the filter organisation developed, and Controllers experienced in the use of R.D.F. information were in charge of base area Sectors and desert Wings.

The " Crusader " Operations in the Western Desert[2]

Preparations.—The development of the defensive R.D.F. cover for the Delta and Suez regions was not allowed to take priority over R.D.F. requirements for the ultimate military major project of operations in the Western Desert. By November 1941, three R.D.F. pack-sets, suitable for mule or camel transport in the absence of motor transport, had been made up from aircraft A.S.V. sets, and a further five were nearing completion. These sets had been so successful in the operations in Crete that considerable attention was devoted to their production for desert operations. This had repercussions on the progress made in increasing the mobility of other types of R.D.F. equipment.[3] Only one C.O.L. station was produced in mobile form during the period June-November 1941 : this was No. 510 C.O.L. Unit.

The R.D.F. pack-sets operated by Nos. 610 and 602 A.M.E.S. were sent forward to give R.D.F. cover to advanced landing grounds.[4] As this was an innovation untried in previous desert operations, a wireless observer screen, also reporting back to Wing Operations, was thrown round the Advanced Landing Ground Area. The Air Officer Commanding, Air Headquarters, Western Desert, was notified that the portable R.D.F. sets provided might be of little use and that it was clearly better to make all plans assuming no R.D.F. cover in the forward desert area.[5]

It will be recalled that there were three Mobile Radio Units located on the coast, situated at :—[6]

(*a*) *Mersa Matruh* (No. 216 A.M.E.S.).—This R.D.F. station covered the fighter base area, the important dumping area at Charing Cross and Matruh itself.

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[1] Air Ministry File S.44501, Encl. 202A.

[2] " Crusader " was the code name given to operations in the Western Desert from 18 November 1941–20 January 1942. Its aim was to destroy the enemy's armoured forces in Cyrenaica and thus pave the way for an invasion of Tripolitania.

[3] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[4] A.H.B./IIJ6/7/3, " Notes on Fighter Wing Organisation and Control—Crusader Operations," 17 January 1942, p. 6.

[5] Headquarters, Middle East Radio Branch O.R.B., 5 November 1941.

[6] A.H.B./IIJ1/12, R.A.F. Middle East Ops. Records, " R.A.F. Operations in the Western Desert and Eastern Mediterranean, November 1941–May 1942," and Headquarters, Middle East, Radio Branch, O.R.B., 14 September 1941.

(b) *Sidi Barrani* (No. 263 A.M.E.S.).—No. 263 A.M.E.S., located here, had evacuated the site on 14 September 1941 under enemy pressure but became operational again some ten days later on the same site. It gave good R.D.F. cover to the forward area where our troops were disposed, and behind which forward dumps were being built.

(c) *Tobruk* (No. 235 A.M.E.S.).—This R.D.F. station was in a unique position across the enemy's lines of communication and was able to report by W/T the movements of enemy aircraft far behind the German lines.

These stations were reporting to No. 258 and No. 262 Fighter Wings, and to nearby Army Gun Operations Rooms. Immediately prior to "Crusader" campaign these R.D.F. units had effectively pin-pointed all enemy advanced landing grounds by observations on enemy aircraft movement and their disappearances on landing.[1]

Before the "Crusader" operations commenced it was thought that the R.D.F. contribution could only be effective in providing protection to our lines of communication and dumping areas—chiefly from the enemy aircraft operating from airfields in Crete.[2]

R.D.F. during the "Crusader" Operation

The ground offensive began at dawn on 18 November 1941 and was very successful at first. Some anxious days were spent prior to the raising of the siege of Tobruk on 9 December, during the enemy's armoured counter-attack which caused temporary disorganisation behind our fluid front. Eventually the enemy armour retreated and Benghazi was recaptured on 24 December. The "Crusader" offensive ended some 150 miles beyond Benghazi, at El Agheila, on 20 January 1942.

As our troops cleared the coastal ports of Cyrenaica, Mobile Radio Units were moved forward to give R.D.F. cover. No. 263 M.R.U. was moved from Sidi Barrani to Derna on Christmas Day, 1941.[3] Some idea of the lack of real mobility in the Mobile Radio Units for the war of rapid movement in the desert may be gained from the fact that this unit was not operational at Derna until 13 January 1942—eighteen days to dismantle the station, move 250 miles and set up again, though the move was carried out quite efficiently.

No. 220 M.R.U. moved up about the same time from their location at Abu Haggag, east of Mersa Matruh, to Benghazi.[4] Thus in January 1942 there was R.D.F. cover at Mersah Matruh, Sollum, Tobruk, Derna and Benghazi, so that the Cyrenaican and Libyan Desert coast-lines were provided with early warning and our lines of communication were reasonably covered. Of these locations, Benghazi and Tobruk were the most important as supply ports. In addition, for the first time in Western Desert operations, low R.D.F. cover became available. Nos. 516 and 520 C.O.L. Units had recently arrived from England and were set up at Mersa Matruh and Tobruk respectively.[5]

The plotting of the Mobile Radio Units was of a good standard but the use to which the available information was put was at times most discouraging. According to a report by the Chief Radio Officer, this was having an adverse

[1] No. 263 A.M.E.S., O.R.B., 14 October 1941.
[2] A.H.B./IIJ6/7/3—Crusader Ops.
[3] No. 263 A.M.E.S., O.R.B., December 1941.
[4] No. 220 A.M.E.S., O.R.B., January 1942.
[5] Headquarters, Middle East, Radio Branch Appendices.

effect on the morale of the R.D.F. operating personnel who realised that few interceptions were attempted as a result of their efforts.[1] The Fighter Wing Operations Controllers at this time were mostly untrained in the use of R.D.F. information. Every effort was made to simplify the R.D.F. information before presenting it to the Controller and to standardise rather than minimise the timelag which occurred during the plotting of tracks. For this reason, where two R.D.F. stations existed in one area, an effort was made to weld them together as an information unit; thus information from a C.O.L. station was passed to the nearby M.R.U. where an elementary filtering process was carried out to present the finished article in the way of a track to the Controller.

Meanwhile, in the Western Desert itself in the region of our advanced landing grounds, the two portable A.S.V. sets being operated by Nos. 601 and 602 A.M.E.S. were not a success.[2] The ranges obtained were inadequate for satisfactory early warning and the sets were returned as being useless during December 1941. On investigation however it was found they had been operating on flat sites in the desert and obviously no adequate ranges could be expected under these conditions. It was decided to check the performance of the sets themselves, so they were resited with the M.R.U. at Mersa Matruh —where they produced ranges of 30 and 40 miles on aircraft of unknown height and an aircraft flying at only 500 feet was observed up to 20 miles range. These results proved there was nothing wrong with the equipment if properly sited.

To replace A.S.V. sets, No. 510 C.O.L. station was moved forward during December 1941. It will be remembered that this C.O.L. unit had been made fully mobile during the previous preparatory period for operations in the Western Desert. It was used well forward to try it out in co-operation with our fighter aircraft. Advanced area commanders were impressed with its performance. It had very quickly two " flamers " to its credit in addition to the provision of satisfactory early warning.[3] The results obtained initially with No. 510 C.O.L. station were so good that in January the Command Radio Officer, Wing Commander J. A. Tester, took command of the station personally with the intention of controlling fighter aircraft directly from the site of the C.O.L. station.[4] No. 522 C.O.L. Unit took over from No. 510 C.O.L. Unit at Benghazi and the latter station was pushed forward to a site just behind the limit of the advance of our ground forces at El Agheila. Before R.D.F.-controlled fighter operations were possible, evacuation orders were received. A German attack was anticipated. Premature evacuation orders were received by No. 510 C.O.L. station (being given and rescinded several times) but on the 21 January 1942 the anticipated German attack commenced.

The Royal Air Force had supremacy in the air over the front at this time, and morale was very high. The weight of the German armoured attack was however so great that our ground forces could not hold the enemy—there was no alternative but to withdraw.

The Retreat to Gazala—R.D.F. Unit Movements (21 January–14 February 1942)

The rapidity with which the enemy had re-organised and launched their counter-offensive was surprising. As a result, the withdrawal of the R.D.F units was somewhat chaotic. No. 510 C.O.L. Unit was ordered back to Msus

[1] Headquarters, Middle East, Radio Branch Appendices, Appendix " A," 1 February 1942.
[2] Headquarters, Middle East, File S.50503/220/R.D.F., Encl. 89A.
[3] Headquarters, Middle East, Radio Branch O.R.B., December 1941.
[4] No. 510 A.M.E.S., O.R.B., December 1941–January 1942.

on 21 January, but in view of petrol shortage and unserviceable transport the unit took the shorter route to Benghazi. On arrival at No. 522 C.O.L. site, the two Commanding Officers of these R.D.F. units attended a conference at the local Army Headquarters, where they were warned that the Army could offer them no special support in the event of an evacuation.[1]

No. 522 C.O.L. Unit received orders to move eastwards immediately towards Tobruk on 24 January and joined No. 263 M.R.U. at Derna the following day, having to burn their receiver mast which was beyond repair as a result of the rough journey. Meanwhile No. 510 C.O.L. Unit also received orders to evacuate from Benghazi but was stopped on the road and told to return—only to find its former site ablaze. Several hours later a further order came to retreat to Gazala and the convoy set off, towing the receiver vehicle. After many miles were covered, one more attempt was made to return to Benghazi. By this time the German break-through was well advanced and the unit was turned back, eventually reaching Gazala on 29 January, and becoming operational the following day.

When the two C.O.L. stations left Benghazi, No. 220 M.R.U. was still there, unserviceable as it had previously lost its transmitter and receiver aerial towers in a violent storm. Receiving evacuation orders late on 24 January, the unit was on the road in one and half hours—only to meet No. 510 C.O.L. on its way back to Benghazi.[2] No. 220 M.R.U. was also ordered back to their site at Benghazi, but after half an hour there, the unit was instructed to move again.

At Derna, No. 263 M.R.U. had a similar but more prolonged experience. From 24–29 January, the personnel spent most of their time dismantling and re-erecting their station. Contradictory signals were received, some favouring a move forward ; others a retreat to Tobruk. To quote the Officer Commanding this unit " At this time orders to advance and retreat were coming so fast the A.M.E. stations were passing each other in opposite directions on the road."[3] It was a very surprised No. 510 C.O.L. Unit advancing on Benghazi that met No. 263 M.R.U. retreating to El Adem. Fortunately, the Chief Radio Officer of H.Q., R.A.F., M.E., was right forward at that time and hurried back to Benghazi and then to Derna, evacuating the units which were still there and turning back other units moving the wrong way.

Eventually all the units reached their retired positions safely despite the confusion. No. 522 C.O.L. departed from Derna and, after a refit at the Radio Installation and Maintenance Unit, were sent to El Dhaba to give low R.D.F. cover over the Delta area as a warning against sea landings which might be carried out by the Axis forces. The locations of the R.D.F. units employed in desert operations, after the retreat of the ground forces to Gazala, were :—

No. 220 M.R.U.	Abu Haggag.
No. 235 M.R.U.	Tobruk.
No. 257 M.R.U.	El Dhaba.
No. 263 M.R.U.	El Adem.
No. 510 C.O.L.	Gazala.
No. 516 C.O.L.	Mersa Matruh.
No. 520 C.O.L.	Tobruk.
No. 522 C.O.L.	El Dhaba.

[1] Nos. 510 and 522 A.M.E.S., O.R.B.s, January 1942.
[2] No. 220 A.M.E.S., O.R.B., January 1942.
[3] No. 263 A.M.E.S., O.R.B., January 1942.

First Successful Mobile R.D.F. Day-Fighter Control Post

On 2 February No. 510 A.M.E.S., the mobile C.O.L. station, was moved back from Gazala to Gambut, a position between Tobruk and Bardia, giving cover to our airfields in the El Adem area. Some four days later, before the line had stabilised fully in front of Gazala, the unit was moved forward again to near Gazala, in advance of our most forward airfields. Four armoured cars and a detachment of Bofors guns were provided for the station's defence in this exposed position.[1] The location proved extremely favourable ; looking across the Gulf of Bomba at the main enemy airfields around Derna. The C.O.L. station was able to call our fighter aircraft directly through nearby forward Operations R/T vehicles. On 14 February a directly controlled operation was arranged against enemy aircraft attacking our front line positions and twenty enemy aircraft were shot down. During the first week of operations under this R.D.F. Forward Control sixty-four enemy aircraft were claimed as destroyed for the loss of only four of ours.

One factor which contributed to the success of these operations was that a reasonably accurate method of estimating heights had been devised from theoretical considerations by one of the unit's own operators. This was very successful and led to satisfactory flying heights being given to our pilots before the interceptions were attempted—a very big advantage in air fighting.[2] The Germans were completely surprised and did not realise we were using R.D.F. for direct ground control. Knowing from their losses that we had some new and effective form of control, they attempted unavailingly to weaken it by jamming ground-to-air R/T communications.

This was the first successful use of forward R.D.F. control of day fighter aircraft in support of ground forces, a method which subsequently played a big part in the operation of fighter aircraft during the remainder of the War, and the forerunner of the more efficient Forward Fighter Director Posts used later in Italy and the North-West European operations.

First Use of G.C.I. Equipment in the Western Desert

Towards the end of 1941 the G.C.I. equipment planned for the Middle East Command began to arrive as complete units from the United Kingdom. Although the first of these units were naturally allocated to the more important task of the night defence of the Delta and Suez Zones, one G.C.I. unit, No. 833 A.M.E.S., was moved into the Western Desert on 21 February 1942.[3] It was the intention not only to provide the ground control of interception at night but also to exploit to the full the possibilities of day interception of the enemy under this R.D.F. control. At that time such a control appeared likely to be of great use both by day and night in intercepting the many Axis raids on Tobruk and Gambut.[4]

The unit was sited some fifty miles behind the front line at a location East of Tobruk in the El Adem area, where our important fighter airfields were situated. There was considerable delay before the G.C.I. station was functioning, due largely to the tardiness with which aircraft were provided for calibration flights. It was six weeks after arrival on site before the unit was fully operational.[5]

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[1] No. 510 A.M.E.S., O.R.B., February 1942.

[2] Narrator's interview with Group Captain J. A. Tester, Chief Radio Officer, Headquarters, Middle East.

[3] No. 833 A.M.E.S., O.R.B., 19 February 1942.

[4] *Ibid.*, 5 April 1942.

[5] *Ibid.*, 13 April 1942.

The results obtained were disappointing during the two months in which this ground control was used. Many interceptions were attempted but the number of " kills " was negligible. The technical equipment worked well so it is difficult to account for the lack of success. Although the lack of experience of both pilots and controllers probably had some effect, a major cause of inefficiency, which could have been avoided, was the radio operators themselves.[1] The majority of the operators sent out with this unit had no experience on G.C.I. When the unit had arrived in the Middle East from the United Kingdom it had been absorbed in the R.D.F. reserve pool. On re-posting from the pool to the Western Desert, an entirely new set of Radio Operators and Mechanics, very few of whom had ever seen G.C.I. apparatus, were placed on the strength of this unit.

A second G.C.I. unit, No. 845 A.M.E.S., was brought up as far as Abu Haggag, but the absence of night fighter aircraft in this area for most of the period of operations rendered its presence almost useless. Hostile aircraft appeared with great regularity, almost nightly whether or not there was a moon, and many opportunities of night interception were lost.[2] This first deployment of G.C.I. units in the Western Desert was far from impressive. In view of the efficiency of the technical equipment, this must be interpreted as being due to faulty organisation.

Reorganisation of Responsibility for R.D.F. Matters in the Middle East Command

Since October 1940 R.D.F. had been constituted as a separate Branch from Signals in the Middle East. This was contrary to Air Ministry policy in 1941, so Air Marshal Tedder, Air Officer Commanding, Headquarters, Middle East, gave instructions in December 1941 that R.D.F. should be brought under the control of the Command Chief Signals Officer.[3] This merging of the two Branches took place gradually during the spring of 1942, hence there was no lack of continuity in the development of R.D.F. facilities within the Command.

Under this re-establishment there was an interchange of information between Signals and Radio Officers in the Cairo area by means of lectures and friendly discussions. Radio Staffs were established at the Headquarters of subordinate Commands, and every effort was made to encourage Signals Officers to become conversant with R.D.F. work and Radio Officers to acquire a knowledge of Royal Air Force Signals procedure and practice.[4] By this merging of R.D.F. into the Signals Branch it was felt that a more competent entity was being produced than the former method with each Branch working separately.

Malta and the Battle for Supplies

With the stabilisation of our lines at Gazala, there was a lull in active ground operations though there was considerable aerial activity. Both sides were engrossed in the building up of supplies in the Western Desert in order to resume the offensive. From the German point of view, supremacy in the Central Mediterranean was essential for the safety of their supply convoys. Malta was our base for offensive action against enemy shipping in this region and had also been used successfully as a base for our bombers operating against the Axis

[1] No. 833 A.M.E.S., O.R.B., 14 April 1942. [2] No. 845 A.M.E.S., O.R.B., May 1942.
[3] Air Ministry File M.S.50124, Encl. 9B.
[4] Headquarters, Middle East, O.R.B., Signals Appendices.

principal supply ports of Naples and Tripoli. It was therefore to be expected that the enemy would again attempt to neutralise this serious threat to the striking power of their forces in Libya.

During December 1941 the Germans transferred a large force of some 400 aircraft to Sicily, under the command of Field Marshal Kesselring, consisting largely of units formerly engaged on the Russian front. Towards the end of December enemy raids of increasing intensity commenced on the Island, evidently intended to neutralise it as an air and naval base by destroying all essential installations.[1] These attacks reached their peak in April 1942, attaining a weight far greater than anything the Island had ever previously experienced. In addition, the enemy sea and air blockade of the approaches to Malta was so effective that it was impossible for our supply convoys to reach the Island. It was virtually cut off, except for meagre air and submarine supplies, throughout this period.

R.D.F. during the Siege of Malta (January–May 1942)

It had been the aim of Air Ministry to build up Malta's R.D.F. stations to give complete cover round the coastline and also over the Island itself by means of a G.C.I. station. At this time R.D.F. cover was provided by :—[2]

Type of Station	*Location*	*Remarks*
C.O. station ..	.. Fort Dingli ..	Formed from No. 242 M.R.U. with new M.B.2 Transmitter and R.F.7 Receiver. Old mobile equipment used as standby. Now constituted an Advance C.O. station.
No. 501 C.O.L.	.. Fort Ta Silch ..	These three C.O.L. stations were giving all-round low cover.
No. 502 C.O.L.	.. Fort Magdalena..	
No. 504 C.O.L.	.. Fort Dingli ..	
No. 314 T.R.U.	.. Kaura Point ..	Used in conjunction with the C.O. station.
No. 841 G.C.I.	.. Gudia	—

Notes.—(*a*) A fourth C.O.L. station, No. 521 C.O.L., was located on the island of Gozo, north-west of Malta. Installation work progressed during this period but the unit was recalled to Malta on 29 April 1942 on the eve of becoming operational, it having been decided that Gozo could not be adequately defended.

(*b*) No. 241 M.R.U., which had been operational with No. 242 M.R.U. at Fort Dingli, had its personnel merged with the latter unit operating the C.O. station for a time.[3] Eventually a site was selected for No. 241 M.R.U. at Ghar Lapsi giving cover to the south and west approaches to Malta against possible raids from Tripolitania. The work of installation was hampered by enemy raids so that the station did not become operational until May 1942.

[1] Headquarters, Mediterranean O.R.B., Appendix " A," Extract from Air Ministry Weekly Intelligence Summary No. 158, para. 126.
[2] These locations were obtained from the O.R.B.s of relevant R.D.F. Units.
[3] Nos. 241 and 242 A.M.E.S., O.R.B.

Theoretically one C.O. station and three C.O.L. stations were sufficient to give adequate high and low R.D.F. cover, all reporting to the Filter Room at Valetta. In practice, due largely to the lack of ideal sites, the R.D.F. cover was not perfect. The addition of No. 314 T.R.U. had provided a useful asset in arranging day-fighter interceptions, as the C.O. station could keep track on our fighter aircraft while the T.R.U. concentrated on the hostile tracks.

When the enemy aircraft took off from Sicilian airfields and climbed to their operational height before setting course for Malta, the R.D.F. early warning given by the stations was excellent.[1] There was ample time to "scramble" our fighter aircraft for interceptions to be made. The enemy soon developed the tactics they had used from France against England, of taking off and climbing to their operational height en route. Since the distance of Malta from their Sicilian bases was only a little over sixty miles, by the time the enemy aircraft were observed by R.D.F. the warning was too short to enable our defending fighters to reach their operational height for successful interceptions.

By February 1942 under the increasing scale of enemy attacks against our airfields, our shortage of fighter aircraft, spare parts, and civilian labour for emergency repairs, proper use of the available R.D.F. information for interception purposes could not be carried out. In effect, the R.D.F. system was little more than a long-range air raid warning system.

The Germans adopted a system of standing fighter patrols over the Island. These were assisted by the installation of highly efficient enemy R.D.F. in Sicily. The latter passed movements of our fighter aircraft to their patrols, which were then able to swoop down on our outnumbered defending aircraft, who were at a great disadvantage against these surprise tactics.[2]

After the experience in Crete, a sea and airborne invasion of Malta could not be ruled out during the period of the siege. During 1941 the C.O.L. stations had kept a watch on all shipping and in July of that year No. 504 had given warning of an attack by twenty Italian E-boats on the Grand Harbour. As a result of the station's plots the element of surprise was lost to the enemy and the coastal defences destroyed practically the entire attacking force.[3] This shipping watch was maintained throughout the months of siege.

Despite the concentrated air bombardment, which during the heaviest periods in March and April 1942 averaged 200 enemy sorties per 24 hours, there were few R.D.F. casualties.[4] The maintenance of damaged reporting land-lines was heavy but the stations themselves received no major hits, despite the many bombs in their vicinity. One R.D.F. officer, three N.C.O.s and two airmen were killed by the explosion of the bombs on a crashed enemy *Ju. 87* aircraft they were attempting to salvage.[5]

In common with all forces on the Island, the R.D.F. personnel were very short of food. During these months, January to April 1942, the operators were kept watching at high pressure night and day. Mental strain and general fatigue began to tell on the R.D.F. personnel by April and, saving their physical strength for their duty hours, all personnel stopped taking any form of exercise ;

[1] Headquarters, Middle East, O.R.B.
[2] Headquarters, Mediterranean O.R.B., February 1942, para. 3.
[3] No. 504 A.M.E.S., O.R.B., July 1941.
[4] Air Ministry Weekly Intelligence Summary No. 158, May 1942.
[5] No. 501 A.M.E.S., O.R.B., 1 April 1942.

many of the men never went outside their camps for months.[1] Even so, morale remained good and the devotion to duty of R.D.F. personnel was very high during these hardest days.

Large deliveries of Spitfire aircraft to the Island on 7 May 1942 brought about a temporary increase in the enemy attacks, but these were however of shorter duration. The Island was now in a better position to fight back. One particularly interesting application of R.D.F. in Malta at this time was the use of the G.C.I. station, No. 841, near Gudia, for day interception of very high-flying enemy aircraft.[2] Successful " kills " were achieved on these raiders using a night-interception technique during the day.

Towards the end of May 1942 the enemy's attacks on Malta had died down. Malta had withstood the weight of German bombardment successfully. The R.D.F. stations had contributed considerably to the defence of the Island by their efficient early warning. The smallness of our fighter force on Malta had made it impossible to use the available R.D.F. information to the full but the successful interceptions achieved had taken toll of the enemy air forces—this major effort had been accompanied by heavy losses in their aircraft.

Although the tide of the air battle was turned by the defenders in May, June and July, the siege was still tightening. Two gallant attempts had been made to relieve the Island by convoys during June 1942, but both had proved unsuccessful. In August 1942 a large convoy had planned to sail from England through the Straits of Gibraltar. It was a desperate bid and only four ships out of 13 got through to the Grand Harbour. Finally, a convoy, which sailed from Egypt on 15 November 1942 raised the siege of the Island when its reserve stocks were practically finished.

From July 1942 the enemy began an intensive radio jamming campaign directed against the Malta R.D.F. stations with the intention of disrupting the night fighter defences.[3] This interference increased in intensity until the end of August. It was then noticed that the jamming was not synchronised with the enemy's raids. This was later ascribed to disagreement between the German scientists and Air Staff ; a state of affairs probably arising from Malta's policy of scrambling fighter aircraft during raids despite the fact that the jamming prevented correct height reading and thus the chance of effective interceptions. Anti-jamming devices were developed and constructed by the personnel of the C.O. station at Fort Dingli to combat this interference.[4] They were highly successful and were later issued to all stations on the Island. With the day fighter strength greatly increased, and the enemy superiority in numbers dwindling, the policy of forward interception was inaugurated, and although unable entirely to ward off a heavy offensive, proved itself as it had done in the Battle of Britain.

The Retreat in the Western Desert to El Alamein (25 May–8 July 1942)

Meanwhile the battle for supplies for the ground forces in the Western Desert, involved as it had been with the siege of Malta, had ended by May 1942. On 26 May 1942 the Germans launched their opening attack in the campaign popularly termed " The Battle of Egypt " with an assault on our line at Gazala.

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[1] No. 242 A.M.E.S., O.R.B., April 1942. [2] Headquarters, Malta O.R.B., May 1942.
[3] Narrator's interview with Wing Commander N. Goodman, Chief Signals Officer, Air Headquarters, Malta. [4] No. 242 A.M.E.S., O.R.B.

When the Axis ground offensive commenced, although the ground forces could not hold the weight of the enemy attack, the Royal Air Force held supremacy in the air. Their rôle was therefore to inflict as many losses as possible on the enemy and fight a delaying action in support of our retreat. In common with this aggressive air policy, the R.D.F. stations along the East Cyrenaican and Egyptian coasts were left operational until the last possible moment before the capture of their locations by the enemy, so that the fighter aircraft and fighter bombers had the maximum of information on which to make successful interceptions.

It is beyond the scope of this work to deal with the many adventures of the individual R.D.F. units in these circumstances. They all continued to pass plots until the last possible moment and then moved back in leap-frog manner.[1] One station passed 744 plots in seven hours by W/T and did not leave until its position was immediately threatened by the enemy—a typical indication of the morale of the R.D.F. personnel at that time. Not all stations were able to remove their equipment in time. The M.R.U. and C.O.L. at Tobruk had to destroy all their equipment before the enemy captured the port on 21 June. Twenty of the R.D.F. personnel escaped by sea, eventually reaching the M.R.U. at Mersa Matruh, where they were re-equipped.[2] At this latter station some four days later, emergency evacuation had to be carried out, blowing up the aerial masts and firing the buildings before leaving on the long road back to Cairo for overhaul at the Radio Installation and Maintenance Unit.

The mobile C.O.L. stations were very successful in bringing about effective fighter interceptions as our forces fell back to their El Alamein positions. No. 510 C.O.L. Unit, after being cut off by enemy tanks and infantry, was given an escort of fifteen Valentine tanks and was able to continue plotting.[3] Precautionary destruction of all secret documents and correspondence was carried out because of the unit's very forward position. Although the station was subjected to strafing, bombing and shelling it was able to render useful assistance to our aircraft in the mauling of the Axis air forces. When the unit eventually retired on 26 June 1942 the number of enemy aircraft claimed as shot down as a result of interceptions brought about by this unit's operation was ninety-six.

Altogether the performance of the R.D.F. units in retreat was quite in keeping with the aggressive Royal Air Force ascendency over the enemy air forces at this time in the Western Desert. There could be little doubt that when the moment arrived for our ground forces to launch their counter-offensive, the experience and technical efficiency of the mobile R.D.F. units would be adequate to meet all calls upon them.

While the front line was static at El Alamein the enemy were only about 80 miles from Alexandria. A full dispersal of those R.D.F. units not immediately required for operations in the Western Desert was undertaken to extend the Mediterranean Coastal screen to give early warning of enemy aircraft threatening Suez. Enemy bombers had adopted an approach from the East, flying down through Palestine and across Sinai.

[1] Air Headquarters, Middle East O.R.B., Signals Branch Appendices, and Nos. 216, 220, 235, 257, 263, 510, 516, 522, and 526 A.M.E.S., O.R.B.s, 25 May–8 July 1942.
[2] No. 216 A.M.E.S., O.R.B., 23 June 1942.
[3] No. 510 A.M.E.S., O.R.B., 29 May 1942.

R.D.F. Defence of the Delta and Suez (July–October 1942)

Because of the proximity of the enemy to Cairo, heavy bomber raids over the Delta area and the Suez Canal zone were anticipated. Fortunately, in addition to the eleven R.D.F. stations giving early warning there were also nine G.C.I. stations now operational,[1] the first having commenced operations during February 1942. The combination of the R.D.F. early warning, and the G.C.I. stations' control of our A.I. equipped night-fighter aircraft gave good reason for optimism that any attempt by the enemy on mass raids over Egypt would result in heavy losses to their bomber forces, with perhaps the possible exception of an attack on Suez from the East. By this time the G.C.I. stations had nearly six months' experience. According to the Chief Signals Officer, Headquarters, Middle East, they had really "found their feet."[2] Their performances compared very favourably with those which obtained at home, and the only cause for concern was the inadequacy of the supply of replacement spare parts—for which urgent requests had been made to the United Kingdom. For some inexplicable reason, however, despite the advantageous position of the Axis forces at the time, there were no really heavy raids on the Delta and Suez. The R.D.F. stations were kept busy by the raids which occurred, but were never called upon to play a major role in defence.

Emphasis was placed on the provision of good cover for the Naval Base of the Mediterranean Fleet at Alexandria, special precautions being taken against low-flying aircraft and shipping.[3] Two C.O.L. units using CD/CHL aerial arrays (as used at home on our coastal defence CH/CHL Triple Service Stations) and three of the portable modified A.S.V. sets, which also provided excellent all-round low cover, were all sited in the vicinity of Alexandria. One Naval Type 271 R.D.F. set was also operated to sweep the approaches to the harbour. The Fleet anchorages had thus excellent R.D.F. cover not only against high and low-flying aircraft but all against enemy E-Boats and one-man submarines.

R.D.F. Preparations for an Offensive in the Western Desert (July–October 1942)

Following the retreat of our ground forces to El Alamein there was a period of great activity at the Radio Installation and Maintenance Unit near Cairo.[4] Those R.D.F. units which had been evacuated from the Western Desert required overhauls and in some cases, re-kitting. New A.M.E. Stations were also arriving from the United Kingdom, including a really mobile R.D.F. station termed the Light Warning set (L.W.S.). This latter equipment was capable of erection in under one hour, housed in a tent on a collapsible metal framework. It was readily transportable in one three-ton lorry and was considered ideal for giving R.D.F. early warning to Advanced Landing Grounds.

Previous campaigns in the Western Desert had given ample experience in the use of R.D.F. in highly mobile operations. All R.D.F. motor transport was overhauled and existing technical gear was "cleaned up" with a view to increasing its mobility. There were occasions when early warning by R.D.F. equipment might be required before it was possible to reach an Advanced Landing Ground by motor transport. In keeping with the policy of manning such Advanced Landing Grounds by personnel and equipment flown in by air,

[1] *See* Appendix No. 15 for the location of the early warning R.D.F. stations and the G.C.I. stations at this time.
[2] Headquarters, Middle East File S.54205/Signals, and Headquarters, Middle East O.R.B.
[3] Report on Alexandria Area low-flying cover by Flight Lieutenant S. N. Smith of D.C.D., M.A.P. (Narrator's interview).
[4] R.I. and M.U., Egypt O.R.B., August/September 1942.

two L.W.S. and crew were prepared, suitable for air-lift in either Bombay or Hudson aircraft.[1] The crews were specially trained in the use of their equipment and were capable of becoming operational in under 45 minutes.

The Mobile Radio Units in the forward areas along the coast usually had to plot by W/T to their appropriate Filter Centre. The W/T plotting code was revised and simplified, track numbering and identification procedure by the Filter Room was altered, and the standard Middle East grid map was adopted. Every effort was made to improve the efficiency of the R.D.F. raid reporting system.

Early in October 1942 there were ample R.D.F. units to support the coming land offensive. Light Warning sets were already deployed covering our Advanced Landing Grounds and mobile C.O.L. stations were in the forward areas being used for day fighter control purposes. A programme had been drawn up for the role of R.D.F. stations in the forthcoming advance ; this was explained to the commanding officers of the various mobile R.D.F. units concerned at a conference held on 18 October 1942 at Advanced Air Headquarters, Western Desert.[2]

The R.D.F. plan for the campaign was based on the technique which had been developed in the Middle East in the previous advance and retreat in the Western Desert. Briefly this was to be :—

(*a*) Forward area early warning from Light Warning Sets, and the control of fighter aircraft by mobile C.O.L. stations in the tactical area.

(*b*) As the ground forces advanced, there was to be an extension of the R.D.F. cover along the African coast by the siting of mobile R.D.F. units at intervals. G.C.I. units and additional C.O.L. stations were also to move forward from those held in reserve, to give good defensive cover and night fighter control over important ports which were to be captured.

This scheme involved more than the mobile R.D.F. units already under the Western Desert Command ;[3] a further five Mobile Radio Units, three C.O.L. units and two G.C.I. units were to be moved up as reinforcements from the reserve R.D.F. pool. This made a total of fifteen R.D.F. stations envisaged as required for employment in our impending advance. This was, of course, a ridiculously small number viewed by home standards but to the Western Desert Air Force it was luxury.

The Advance from El Alamein to Algeria (October 1942–February 1943)

The British offensive opened on the evening of 23 October at El Alamein. After hard fighting there were signs of an enemy withdrawal by 3 November. As the momentum of our advance developed the enemy was unable to mass for more than momentary stands and our pursuit continued, its speed being limited mainly by the rate with which our supplies could be brought up.

In the air the Royal Air Force held an almost complete mastery of the Axis air forces. The employment of R.D.F. units both in early warning and fighter interceptions was by now quite stereotyped and there are several references in relevant documents to the appreciations by our Fighter Control Officers of the

[1] Air Headquarters, Middle East O.R.B., Signals Appendices.
[2] No. 220 A.M.E.S., O.R.B., 20 October 1942.
[3] These Units were No. 220 M.R.U. and Nos. 510, 515, 522 and 526 C.O.L. stations.

accuracy of the R.D.F. information supplied by the mobile C.O.L. stations.[1] These stations, employed in forward areas, were frequently given direct control of tactical aircraft far beyond the enemy's lines. Nos. 510 and 522 C.O.L. Units, the two most experienced mobile stations in this type of work, continued to enhance the high reputation they had established in the Western Desert earlier in the year.

With so many R.D.F. units involved in this campaign, to deal with their movements individually in this vast theatre of operations would obscure their real contribution to the campaign. Even in terms of the appropriate dates it is hard to appreciate the speed of our advance. Nevertheless, some impression can be gained from the movement of No. 515 C.O.L. Unit, which travelled 740 miles under rough desert conditions in only seven and a half days during November. As had been foreseen during the preparations for this offensive, it was not always possible for the R.D.F. stations using motor transport to keep up with the speed of the advance. The airborne L.W.S. early warning station was therefore used on 18 December, when it was transported to the Marble Arch landing ground by air.[2] The standard attained by its specially trained R.D.F. crew was excellent—they were able to set up the station and give R.D.F. cover to the landing ground within three-quarters of an hour.

By 23 January 1943 the British ground forces entered Tripoli—nearly 1,500 miles of North African coastline had fallen into our hands since the Battle of El Alamein had started. During February this was increased, but the enemy made a stand at the " Mareth Line " in Algeria. Along this coastline both M.R.U.s and C.O.L. stations were installed rapidly to give cover against both high- and low-level enemy attacks on our elongated lines of communication.[3]

The only major R.D.F. problem at that time was the maintenance of the many stations operating in this Chain. The available stock of spare parts in the Middle East was too low to permit each unit to hold adequate spare parts to cover all possible technical breakdowns. Replacement spare parts were, therefore, held at the Radio Installation and Maintenance Unit at Tura.[4] The front was 1,500 miles away at that time, and the air transport position was extremely bad—the Air Freight Centre at Heliopolis claimed that each day they were receiving twice as much equipment as they could carry. The roads along the coast were in very poor condition and the distance so great that supplying the Chain by road was a very slow procedure. The most forward R.D.F. units supplied by the R.I. and M.U. were actually nearer to London than the Delta, so it was necessary to split the R.I. and M.U. and send a forward R.I. and M.U. detachment with adequate stores and technicians to function in Tunisia. This provided an effective solution to the acute stores and servicing problems.

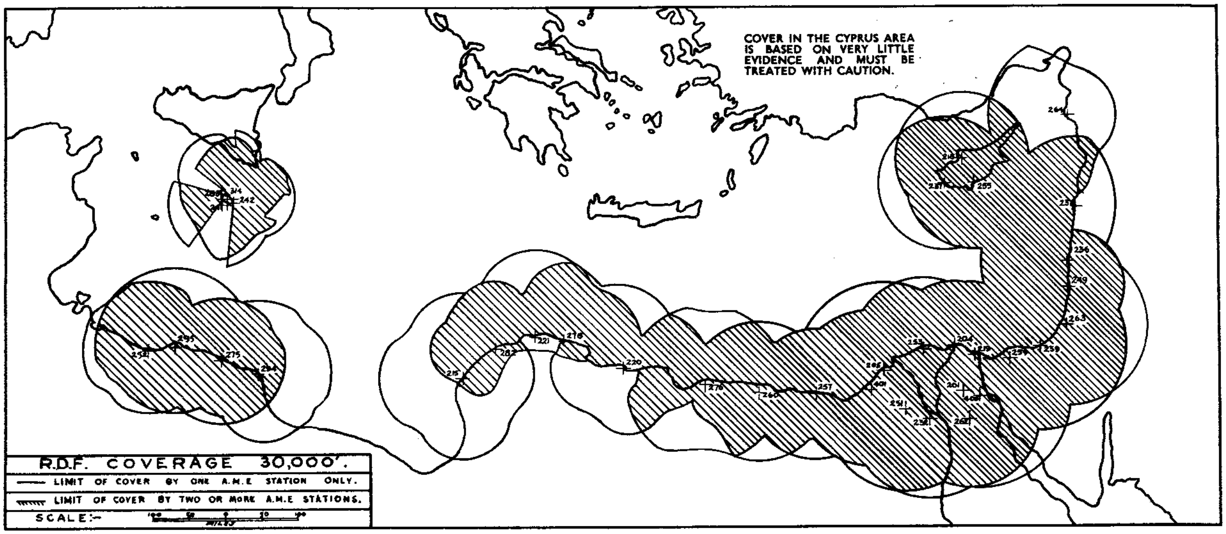
This chapter ends on the flood-tide of our successes in Egypt, Cyrenaica, Libya and Tripolitania. In its adaptability to the very mobile warfare of this theatre of operations, the R.D.F. early warning system had functioned very successfully. It is appreciated that details have been omitted from this narrative of the development of static R.D.F. cover in such localities as East

[1] Nos. 510 and 522 A.M.E S., O.R.B., December 1942–February 1943.
[2] Air Headquarters, Middle East O.R.B., Signals Appendices, 18 December 1942.
[3] Diagrams of the high and low R.D.F. cover available and the number of R.D.F. units involved at this time are given in Map No. 6.
[4] R.I. and M.U., O.R.B., 28 February 1943.

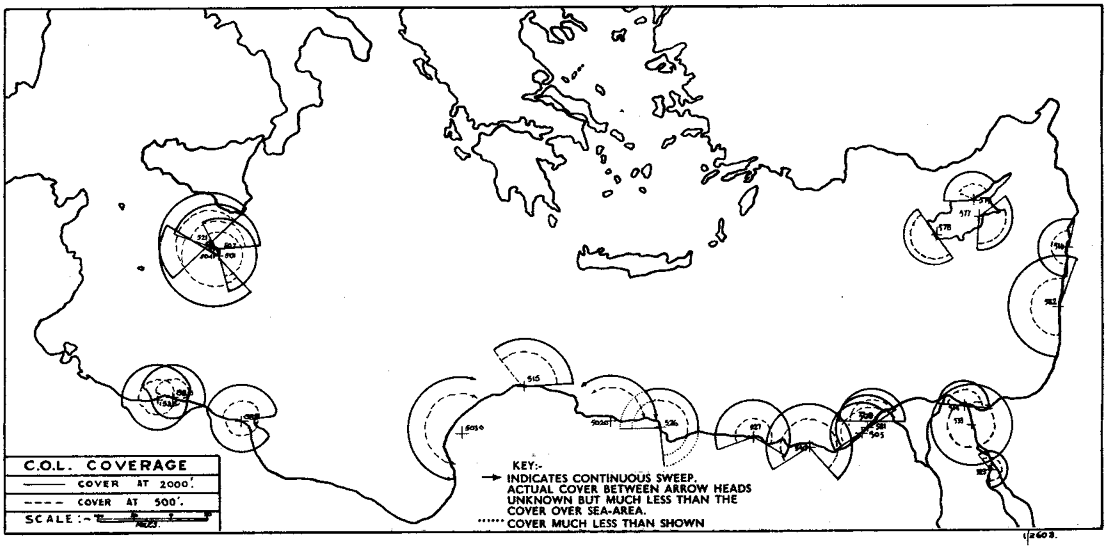
MAP No. 6.

MARCH, 1943
R.D.F. COVER IN CENTRAL AND EASTERN MEDITERRANEAN UNDER H.Q. MIDDLE EAST, AFTER THE FINAL ADVANCE FROM EL ALAMEIN.

(.1.) HIGH COVER BY C.O. STATIONS, T.R.U., AND M.R.U..



(.2.) LOW COVER BY C.O.L. STATIONS.



and West Africa, under the aegis of the Middle East Command but remote from the major operations against the enemy. Rather has attention been focussed throughout this chapter chiefly on the support offered by ground R.D.F. stations to the various military campaign requirements in the Middle East.

With the Axis forces driven back into Tunisia, the operational importance of the Middle East Command declined. The American and British landings in North-West Africa on 8 November 1942, following the victory of El Alamein, swung the centre of operations towards the Western and Central Mediterranean. By the end of January 1943 the newly-forming Mediterranean Air Command was taking over the major direction of operations, embracing the subordinate Commands of the Allied Air Forces in North-West Africa, the R.A.F. in the Middle East and the Royal Air Force in Malta.

The part played by R.D.F. ground stations in the subsequent final defeat of the enemy in North Africa is dealt with later in this volume.[1]

[1] The relevant chapters are :—

Chapter 17—" R.D.F. Raid Reporting in the Invasion of North-West Africa (Operation Torch)."

Chapter 18—" Ground R.D.F. in the Final Phases of the Tunisian Campaign (January–May 1943)."

R.D.F. RAID REPORTING IN THE FAR EAST, JULY 1940–MAY 1942

This chapter includes the period before our declaration of war on the Japanese on 8 December 1941, following their attack on Pearl Harbour, and ends with the peak of the Japanese military successes in the British theatre of operations —the fall of Mandalay, 1 May 1942. The narrative therefore covers our attempts to build up an early warning raid reporting system at strategic points in the Far East, followed by details of the R.D.F. units during the short campaign culminating in the collapse of our forces.

The most vital factor controlling the slow development of R.D.F. cover in the Far East was the general shortage of R.D.F. equipment during the period under consideration, and the even more important demands of the Home Chain and Middle East requirements. These production difficulties at home were emphasised still more by the fact that R.D.F. apparatus for the Far East had to be fully tropicalised—the components in the normal Home Chain equipment would not stand up to the rigours of the climate in the Far East, and research into adequate tropicalisation was making slow progress in the United Kingdom.

The location of R.D.F. stations in the Far East was coloured largely by factors of general policy of the War Cabinet. Of these, the basic principle which exercised most influence was that R.D.F. had a useful contribution to make only when used in conjunction with the active defences of fighter aircraft and A.A. guns. In order to appreciate the lack of progress in R.D.F. provision in the Far East during the first year of the War it is necessary to recapitulate briefly[1] the early history of the organisation there.

Early History of R.D.F. Organisation in the Far East

Before 1941 no more than a superficial consideration had been given to the possibility of erecting R.D.F. stations in the Far East. The only work that had been done was a brief survey made in 1938 when all-round looking C.O. Type stations were recommended for Hong Kong, Singapore, Penang, Rangoon, Trincomalee and Colombo, but no sites were chosen except in the case of Singapore.[2] It will be remembered that in April 1939 the Air Officer Commanding, Far East, Air Vice-Marshal A. W. Tedder, had asked for the erection of at least one single R.D.F. station near Singapore as soon as possible, but due to the lack of R.D.F. supplies, no equipment was available when war broke out in Europe.[3]

A provisional programme of one MB2 transmitter and ~~MB1a~~ RF3 receiver to arrive in Singapore by April 1940 and a C.H.L. set in May 1940 was agreed upon by the Port Defence Committee in January 1940. In June 1940 no siting reconnaissance had yet been carried out and it was proposed to send F/Lt. Atherton, who had done such work in the Middle East, to make a survey of both Singapore and Burma as soon as possible.[4] A month later Air Marshal

[1] Full details of the early plans for R.D.F. cover in the Far East are given in Chapters 5 and 8 of this volume.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.
[3] Air Ministry File S.44211, Encls. 26A and B.
[4] A.H.B./IIE/68, Minutes of the Inter-Service Committee on R.D.F., 11th Meeting.

Sir Philip Joubert, Assistant Chief of Air Staff (Radio), in a letter to the Director of Communications Development, pointed out that the problem of defended ports abroad was of low priority, and east of Suez could be regarded mainly as a C.H.L. commitment. There were, however, two exceptions to this :—

(*a*) the probability that both Rangoon and Singapore, owing to the danger of Japanese air attack from land bases, might require full C.O. equipment.

(*b*) the mobile defence of the North-West Frontier.

By August 1940 the Governor of Burma was still in ignorance on the subject of R.D.F. The siting expert, F/Lt. Atherton, had travelled no farther than India. There was still great insistence on the urgency for R.D.F. installation in Singapore, but the minimum needs of the ports in the war zones had to be satisfied first.[1]

In October 1940 the 14th Inter-Service R.D.F. Committee meeting decided that the Directorate of Communications Development must make available the necessary personnel to make a survey of Singapore and Burma.[2] In November 1940 the question of R.D.F. for overseas was on the agenda of the 15th Meeting of the Inter-Service R.D.F. Committee but was postponed for discussion until the 17th Meeting in March 1941. It noted however that some equipment was intended for despatch in the near future to Singapore. Thus it was not until toward the end of the year, following the appointment of Air Chief Marshal Sir Robert Brooke-Popham as Commander-in-Chief, Far East, that the Air Ministry finally arranged for the despatch of R.D.F. equipment to that theatre. In addition a Chief Radio Officer and Radio staff officers were to be added to the establishment of Air Headquarters, Far East, including Directorate of Communications Development scientific representatives.[3] A Radio Installation and Maintenance Unit was to be formed in Singapore and initially one M.R.U., one T.R.U., and two C.O.L. stations were to be sent.

Re-allocation of Priorities for Installing C.O. Stations

On the agenda for the 17th Meeting of the Inter-Service R.D.F. Committee held on 18 March 1941, a proposal was made to amend the order of priority for C.O. stations which had been agreed at the 14th Meeting.[4] This new policy affected stations in the Far East mainly, and involved the following changes :—

Old Order.	*Revised Order.*
Hong Kong.	Penang.
Trincomalee.	Rangoon.
Rangoon.	Hong Kong.
Colombo.	Trincomalee.
Penang.	Colombo.

This was the decision agreed upon at War Cabinet level but local conditions produced differing opinions. Following discussions between the Commander-in-Chief, Far East, and the newly-formed Radio Branch there, a

[1] A.H.B./IIE/68, giving the 9th Meeting of the Ports Defence Committee, 23 August 1940.
[2] *Ibid.*, Inter-Service Committee on R.D.F., Minutes of 14th and 15th Meetings.
[3] Air Ministry Files S.4422, Encl. 1A, and S.52465, Encl. 55A.
[4] This order of priority was indicated in Chapter 12. The new policy is shown in A.H.B./IIE/68, 17th Meeting, Item 5 (*b*). Map No. 4 refers.

policy was formulated giving first priority to the provision of R.D.F. cover for Singapore, particularly against attack over the sea from the north-east and providing for the expansion of R.D.F. cover along the eastern coast of Malaya, to be followed by a station at Penang and subsequent cover down the western coast of Malaya.[1] R.D.F. cover for Hong Kong was not considered justifiable, nor was the provision of R.D.F. for Ceylon necessary at this time. Rangoon and the oil-fields of Burma were deemed to be low priority and the possibility of providing cover for Manila and the Netherlands East Indies was thought to be neither desirable nor politically possible at this stage. Fighter aircraft were not available in the Far East and both wireless and telephone communications were rudimentary in the extreme. Thus the all-important accessories to perfect R.D.F. functioning were non-existent and the recurring trouble of the Middle East of single R.D.F. stations acting purely as air raid warnings was even more difficult to overcome in this partially uncivilised and impenetrable territory.

Erection of R.D.F. Stations in the Far East

The first site chosen was for a Mobile Radio Unit, to be situated on the south-east side of Singapore Island at Tanah Merah Besar, close to Changi. M.R.U. No. 250 was erected there shortly after its arrival in Singapore during March 1941.[2] It was a sea-shore site and the station had a one-way looking aerial array with a line-of-shoot of 067° covering an approach from the sea, giving good height measurements over an arc 020° to 160°.

T.R.U. No. 243, which had arrived with M.R.U. No. 250, was next erected with considerable delay on the part of the Directorate of Works at Mersing, a sea-shore site on the east coast of Malaya about 100 miles from Singapore.[3] The station, with a line-of-shoot of 045°, gave comparatively good heights but its performance in the ranges of 40 to 50 miles was poor owing to the presence of large permanent echoes from the 2,000-foot island of Pulau Tioman, which lay practically on the line-of-shoot of the station.

The next two A.M.E. stations to arrive in the Far East were C.O.L.s Nos. 511 and 512 in April 1941, and although they were sited immediately, Works Services were not completed until December 1941.[4] It was a marked characteristic of the Far East theatre, that the whole of the R.D.F. programme was consistently held up by the extreme slowness of the Directorate of Works.[5] Provision of hutted buildings for C.O.L. stations took at least six times the time required for similar work in the United Kingdom, apart from which the huts were badly built and seldom completed. Part of the reason for this slowness was undoubtedly the extreme peace-time financial control which the Ministry Auditors appeared to exert over the Chief Engineer.

C.O.L. stations Nos. 511 and 512 were sited in Johore, No. 511 at Bukit Chunang, on the extreme south-east tip of Johore overlooking the sea, with a clear sweep from 010° to 260° over the sea and further round to 290° to cover Singapore Island and south-west Johore. No. 512 was sited on the corresponding south-west tip of Johore at Tanjong Kupang.

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[1] A.H.B /IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.
[2] No. 250 A.M.E.S., O.R.B.
[3] No. 243 A.M.E.S., O.R.B.
[4] Nos. 511 and 512 A.M.E.S., O.R.B., April 1941.
[5] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

Additional Cover for Singapore

In early May 1941, Air Vice-Marshal Pulford became Air Officer Commanding Headquarters, Far East. He immediately appreciated the fact that Singapore was virtually undefended from attack overland and insisted that at least one R.D.F. station should be sited to give some attempt at providing cover against overland attack. During the month two further C.O.L. sets had arrived in the Far East and one of these, No. 518 A.M.E.S., was therefore placed at Kota Tinggi, halfway between Singapore and Mersing.[1] This site, 550 feet above sea level, had a reasonably good sweep over broken country, but was almost blind in the sector 270° to 000° due to a range of mountains some 2,000 feet high. After a survey of Burma had been carried out, No. 517 A.M.E.S., the second C.O.L. set, was sent to a site alongside the airfield at Moulmein in South Burma.

Cancellation of the C.O. Station Programme

In May 1941, with the Home Chain passing through the transition stage from " Intermediate " to " Final " form and the Middle East needing replacements of equipment lost in Crete and Greece together with reinforcements to consolidate our position on all flanks, it was finally decided that the C.O. Type stations must be abandoned at Aden, Gibraltar, Freetown, Takoradi, Kilindini, Penang, Rangoon, Hong Kong, Singapore, Trincomalee and Trinidad.[2] The construction of a C.O. station was necessarily a long-term programme, and in view of the fact that a Transportable Radio Unit, using MB2 equipment and 105 feet transportable aerial masts might be regarded as giving an adequate performance, they were to be substituted for the proposed C.O. stations on the sites mentioned above, with variations in the type of towers as might be dictated by local conditions and the substitution, subject to availability of equipment, of the RF7 receiver for the RM3B. An added advantage of a Transportable Radio Unit was the fact that it could be erected in temporary buildings in from three to four weeks, and a further consideration influencing this drastic step in R.D.F. policy was the lack of trained personnel to undertake the necessarily elaborate installation work in the construction of a full C.O. station.

Production of R.D.F. Equipment in Australia

With the threat of a hostile Japan always in mind, satisfactory R.D.F. cover for Australia became essential. It was hoped that the Australian authorities might be able to meet their own R.D.F. requirements. Up to date, May 1941, they had approximately fifty C.D. sets in production which they hoped would be completed by the end of 1941.[3] Twenty of these would then become available for use outside Australia. In general, Australian production was limited to low-power sets using a very small type of valve and they were engaged in making A.S.V. as well as C.D. equipment, but neither was to British pattern.[4] Crews and wood for masts were also required from Australian sources, in fact the Inter-Services R.D.F. Committee would only sanction a Transportable Radio Unit for Rangoon on the understanding that the crew personnel could be obtained from Australia and the masts made locally in the Far East.[5]

[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A, and Air Ministry File S.4422, Encl. 67A

[2] Air Ministry File S.44211, Encl. 111A.

[3] Inter-Service Committee on R.D.F., Minutes of 20th Meeting, para. 11.

[4] *Ibid.*, 21st Meeting, Item 7, para. (*f*).

[5] Air Ministry File S.44211, Encl. 110A.

Increased Demands for R.D.F. Equipment for the Far East

Although a much more remote problem at the time, the Far East presented a more formidable task for R.D.F. provision than the Middle East, in that far greater stretches of coast-line had to be adequately covered, often encroaching on uncivilised and hostile territory, spreading over a far wider area than had ever before been envisaged in R.D.F. organisation. In July 1941 Air Headquarters, Far East, submitted an estimate of the ground R.D.F. station requirements that they considered essential for safeguarding the area with which the Command was concerned, namely, Malaya and Burma.[1] This estimate was based on two surveys that had been carried out by R.D.F. experts and far exceeded any original plans made in the past.[2] This change in policy was the direct outcome of a scheme for strengthening the entire air defence of Malaya and Burma and included the construction and equipping of both fighter and bomber airfields. The scale of equipment considered necessary was as follows :—

T.R.U.s	*M.R.U.s*	*C.O.L.s*
23	7	32

The R.D.F. Policy Sub-Committee agreed that this demand should be met and anticipated that all such equipments would have been shipped by April 1942.

R.D.F. Provision for the Netherlands Indies

In September 1941 a letter was received from the Royal Netherlands Navy Department concerning the establishment of an R.D.F. organisation in the Netherlands Indies as soon as possible. The strategical position of the Netherlands Indies made this question not only one of mutual interest, but also, in view of the political situation in the Pacific, one of great urgency.[3] Sourabaya Bay was the first strategic point to come under consideration, the Dutch Naval Base, major Air Base and centre of industry forming a vulnerable target for high and low-flying attack from the Java Sea, the region north of Java and Madoera, or from an easterly direction north of Bali and Java and south of Madoera. Cover from surface shipping attacks from these areas would also be required. The War Cabinet concurred with the idea that R.D.F. should be provided to the Netherlands but stated that the equipment must come from the Far East Pool, to be released to the Dutch after the Commander-in-Chief was satisfied that his more urgent commitments had been fulfilled, as it was impossible to create extra supplies for this purpose.[4]

R.D.F. Policy for India—Emergency Action

Having regard to the urgent requirements at home and the even more pressing commitments for the Middle East Command during May 1941 the provision of R.D.F. equipment for India was postponed first until the beginning of 1942 and later to an indefinite date. Owing to the highly secret nature of R.D.F., it was considered inadvisable to train Indian personnel in operational details.[5] By August 1941, however, the increasing Japanese threat to India

[1] War Cabinet R.D.F. Policy Sub-Committee, 7th Meeting, R.D.F. (41), Annex 11.

[2] The survey of Burma and the Radio Branch report on R.D.F. cover in Malaya are given in Appendices Nos. 16 and 17.

[3] War Cabinet R.D.F. Policy Sub-Committee, 7th Meeting, Appendix to papers.

[4] *Ibid.*, R.D.F. (41) 7th Meeting, para. 6, sub-paras. (i) and (ii).

[5] Inter-Service Committee on R.D.F., Agenda for 21st Meeting, Item 7, para. (*b*), and Air Ministry File S.49984.

could no longer be ignored; it was felt that India should have priority of equipment over Aden and that provision should be made for R.D.F. sets for Calcutta and Madras from those becoming immediately available.

Scarcity of trained crews presented a particularly acute problem and to relieve the even greater pressure that Indian demands would create on the shortage of manpower from the home country, it was agreed at the second meeting of the War Cabinet R.D.F. Policy Sub-Committee that Indian personnel generally should be accepted and trained to operate the earlier types of R.D.F. equipment.[1]

Disclosure of R.D.F. Information to Russia

Prompted no doubt by the signing of the Anglo-Soviet Pact in July 1941, the same R.D.F. Policy Sub-Committee also decided that the Russian authorities should be given technical details to the extent of those given to India. It was believed that the Russians already possessed a fairly comprehensive knowledge of R.D.F. and if this equipment fell into the hands of the Germans through a Russian collapse it was not now of such a secret nature that it would harm the Allied cause. No information however was to be given on up-to-date equipment such as I.F.F. other than Mark II, G.C.I., G.L., Mark II, S.L.C., A.I., A.S.V. or anti-jamming equipment for C.H. stations.

To meet unforeseen requirements a reserve pool of ten M.R.U.s had been held in the United Kingdom, but to substantiate the technical knowledge imparted to the Russians and to assist in their training facilities, three of these sets were released to Russia, despite overwhelming demands from the Middle East and requests for M.R.U.s from the Royal Navy to afford R.D.F. control at certain Naval Air Stations for the training of fighter aircraft in air interception.[2] By this time all existing demands for M.R.U.s had been met. This left a deficiency of eleven sets and no reserve—the latter being considered vitally important to meet the almost unpredictable requests of future operations, or additional demands from Russia or other Allies. It was therefore arranged to place an immediate order for eighteen more M.R.U.s for overseas use.

Difficulties Encountered in Effecting an Efficient R.D.F. Organisation in the Far East

By mid-summer 1941 three things became apparent in the light of experience. The first was that telecommunications in Malaya were the major limiting factor in any expansion of R.D.F. cover; the second was that Seletar airfield, which was already overcrowded, had insufficient accommodation to absorb the expanding Radio Installation and Maintenance Unit, and the third was that the parent unit system of administration of A.M.E. Stations (No. 151 M.U. had been the parent unit for all A.M.E. Stations in the Far East) was a failure.[3]

The problem of communications was tackled from two sides. On the long-term basis arrangements were initiated for the provision of trunk tie-lines from each area in which A.M.E. Stations were to be erected, to their respective Filter Rooms; and inter-linking by lines between the two Filter Rooms. Provision was also to be made in each area for the A.M.E. Stations to plot direct to the Fighter Operations Room at the local aerodrome. In view of

[1] War Cabinet R.D.F. Policy Sub-Committee (41), 2nd Meeting, para. (4).
[2] *Ibid.*, 7th Meeting, para. 8 and Annex III.
[3] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

the delay, however, which was anticipated in the provision of these circuits (at least eighteen months for the equipment to be obtained from the United States) and the fact that the slow rate of working of the Directorate of Works had necessarily entailed considerable misemployment of radio mechanics, it was decided to tackle the communications problem from a second side. This was the provision of V.H.F. R/T links for ground-to-ground working. Air Ministry had informed Headquarters, Far East, that no V.H.F. R/T would be available for shipment to their Command before June 1942; and as H.F. R/T and W/T were almost useless for the ranges required in the Far East (where electric storms are the normal state of the atmosphere) it was decided to concentrate on locally-made V.H.F. R/T links. The task was given to the Officer Commanding No. 518 C.O.L. Station and he and his crew were installed in the top flat of the Cathay skyscraper in Singapore. There they produced a highly successful V.H.F. R/T transmitter and receiver from locally obtained components. The essence of the design was simplicity itself and links were finally installed between the Cathay and all existing A.M.E. Stations. Wherever these links were installed, communications never failed right up to the time of the withdrawal or the demolition of the stations concerned.

The second main problem of keeping pace with the expansion of the Radio Installation and Maintenance Unit was settled by moving the unit to a new site at Ponggol, three miles East of Seletar. Making it responsible for the administration of the A.M.E. Stations disposed of the third problem. It became, in effect, a South Malaya Radio Wing.

Expansion of the Air Reporting System in Malaya, August 1941–December 1941

By August 1941 the R.D.F. plan for Malaya was fairly well crystallised. Siting had been carried out throughout Malaya, Burma and Trincomalee and two stations, M.R.U. No. 250 at Tanah Merah Besar and T.R.U. No. 243 at Mersing, were operational, plotting to a Filter Room situated temporarily at Katong.[1] Towards the end of August 1941 the expansion of the R.D.F. programme in Malaya began and stations which had been requested from Air Ministry started to arrive. No. 575 (C.D./C.H.L.), No. 306 and No. 370 (A.C.O.s) and two C.D./C.H.L. stations provided by the War Office were in the Far East before September 1941.

To implement the R.D.F. cover and fill in the numerous gaps in the information which were unavoidable in a country so unsuited to the use of R.D.F. equipment, it was found necessary to bring the Observer Corps up to date. In August 1941 the responsibility for the organisation and training of the air watching scheme was transferred from the General Officer Commanding, Malaya, to the Air Officer Commanding, Far East.[2] This organisation consisted of 171 Observer Posts and six Observer Centres to be supplemented by fifty further posts and an additional centre. The method of manning these posts by Service personnel and local police was considered unsuitable for conditions of active warfare and Air Vice-Marshal Pulford set about reorganising the Corps to run on similar lines to those on which the Royal Observer Corps was run at home.

The period from September to December 1941 was marked chiefly by continual difficulties over the Works Services for A.M.E. stations. Sometimes the hold-up lay in the fact that it was necessary to erect a station in an Unfederated Malay

[1] A.H.B./IIE/202, Far East Operational Reports.
[2] Air Headquarters, Far East O.R.B., August 1941.

State and this required prior sanction from the ruler of the state, which usually took some time to obtain—especially in the case of Johore. More often it was just the administrative machinery that was not used to or designed for working with any great speed. This difficulty became so onerous that eventually Air Vice-Marshal Pulford found it necessary to attach three officers, who had had Works experience in civil life, to the Radio Branch as Works Liaison Officers for the sole purpose of hastening the Works Services of A.M.E. stations. The fruits of their labours very shortly became visible, and it was largely due to their efforts that Nos. 511, 512 and 518 A.M.E.S. became operational at the beginning of December 1941.

R.D.F. Provision for Hong Kong

Although Hong Kong had been one of the earliest ports selected for R.D.F. provision, namely, one C.O. type station, this was contrary to War Cabinet policy as it was realised that the island could not be defended for any length of time. At the C.H.L. Planning Sub-Committee meeting held in April 1941 no provision was made for a C.O.L. station as no fighter aircraft were being despatched to Hong Kong and it was considered inadvisable to instal any important equipment which might have to be destroyed to avoid capture.[1] In August 1941, the War Cabinet R.D.F. Policy Sub-Committee went so far as to note that no operational requirements now existed for R.D.F. at Hong Kong and that the only likely account on which equipment might be desirable would be for the purpose of stiffening morale.[2] Despite the somewhat gloomy view taken by higher authority, however, a siting party visited Hong Kong in November 1941, also making a preliminary survey of Manila and the more important parts of the Philippine Islands.

Before any R.D.F. equipment arrived in Hong Kong, Japan opened hostilities without any formal declaration of war and Hong Kong received surprise aerial attacks on 7 December 1941, the same date as Pearl Harbour. Only eighteen days after the outbreak of war with Japan, Hong Kong was captured by the Japanese, our position there being virtually untenable. The original War Cabinet decision not to risk R.D.F. equipment without adequate defence thereby proved to be correct.

The Position of R.D.F. in the Far East at the Outbreak of War with Japan

The outbreak of the war with Japan on 7 December 1941 found the following A.M.E. stations[3] operational in the Far East :—

(*a*) No. 243 T.R.U. operational at Mersing.

(*b*) No. 250 M.R.U. operational at Tanah Merah Besar.

(*c*) No. 511 C.O.L. operational at Bukit Chunang.

(*d*) No. 512 C.O.L. operational at Tanjong Kupang.

No. 518 C.O.L. at Kota Tinggi was approaching completion and works services were well advanced for No. 575 C.D./C.H.L. to be erected at Bukit Dinding in the middle of Malaya, west of Mersing: for No. 307 T.R.U. at Kahang,

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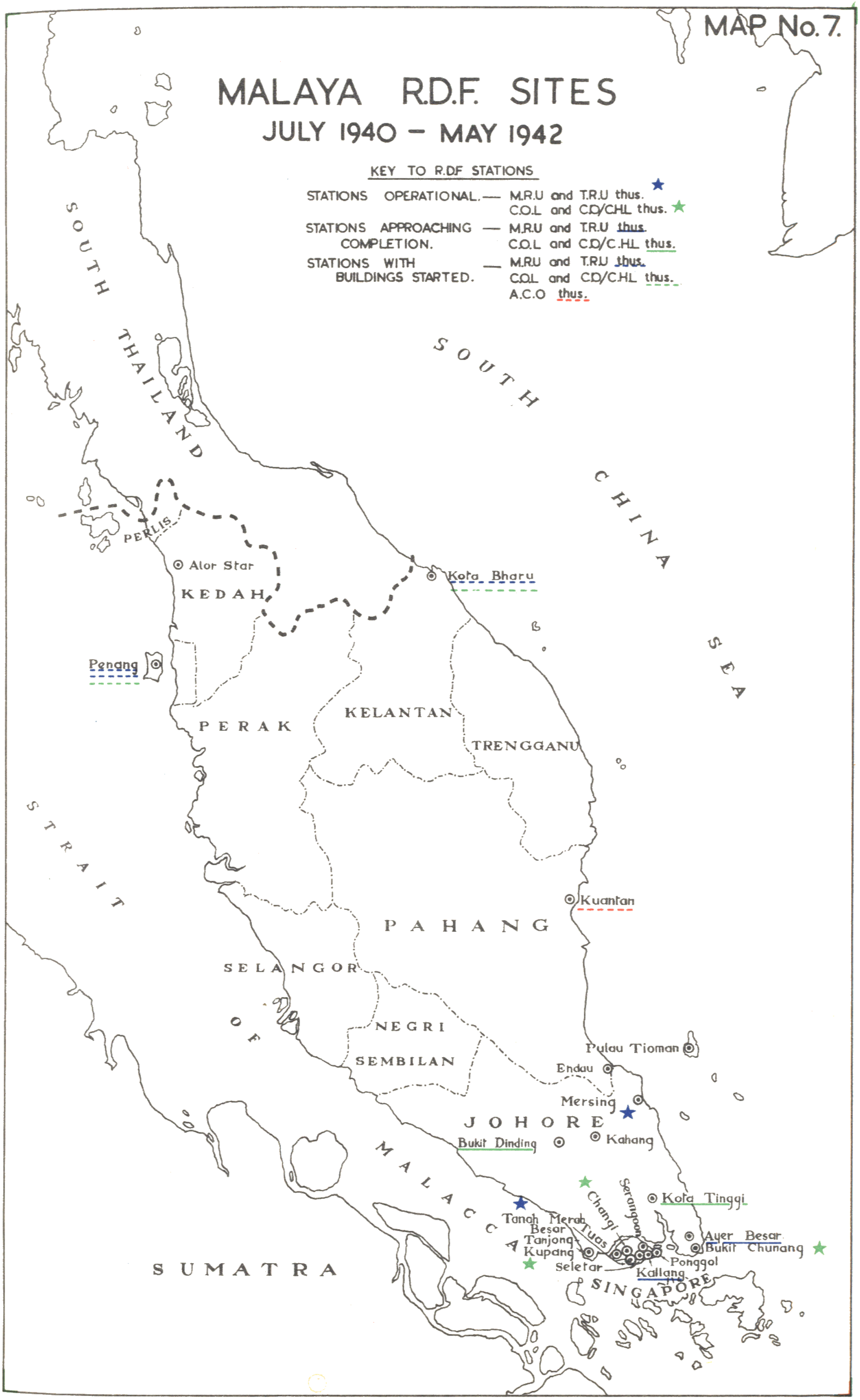
[1] War Cabinet Paper W.P. (40) 302, " Report by Chiefs of Staff on the Situation in the Far East in event of Japanese aggression," 5 August 1940 ; and A.H.B./IIE/67, C.H.L. Planning Sub-Committee of the Inter-Services R.D.F. Committee, Interim Report, 24 April 1941, para. 22.

[2] War Cabinet R.D.F. Policy Sub-Committee (41), 3rd Meeting, para. 6, and A.H.B./IIE/70, Encl. 80A.

[3] The locations of both proposed and actual R.D.F. sites at the outbreak of war with Japan are shown on Map. No. 7.


MAP No. 7.
MALAYA R.D.F. SITES
JULY 1940 — MAY 1942
KEY TO R.D.F. STATIONS
STATIONS OPERATIONAL. — M.R.U and T.R.U thus.
C.O.L and C.D/C.H.L thus.
STATIONS APPROACHING COMPLETION. — M.R.U and T.R.U thus.
C.O.L and C.D/C.H.L thus.
STATIONS WITH BUILDINGS STARTED. — M.R.U and T.R.U thus.
C.O.L and C.D/C.H.L thus.
A.C.O thus.
SOUTH THAILAND
SOUTH CHINA SEA
PERLIS
Alor Star
KEDAH
Kota Bharu
Penang
PERAK
KELANTAN
TRENGGANU
STRAIT OF MALACCA
Kuantan
PAHANG
SELANGOR
NEGRI SEMBILAN
Pulau Tioman
Endau
Mersing
JOHORE
Bukit Dinding
Kahang
Kota Tinggi
Serangoon
Changi
Tuas
Tanah Merah Besar
Tanjong Kupang
Seletar
Ayer Besar
Bukit Chunang
Ponggol
Kallang
SINGAPORE
SUMATRA
A.H.B./I. 972

two miles from No. 575 and for No. 306 T.R.U. at Ayer Besar, about a mile from No. 511.[1] Building had also been started on two M.R.U.s and one C.O.L. station at Penang; on one T.R.U. and one C.O.L. station at Kota Bharu and on one A.C.O. station at Kuantan. Three of the four operational stations were plotting by V.H.F. R/T links from the Cathay to the Filter Room at Katong, and the fourth, No. 243 T.R.U., was plotting by telephone when it was serviceable (which was not very often) and by W/T when it was not. Six M.R.U.s, fourteen C.O.L. stations, eight C.D./C.H.L. stations and six more T.R.U.s were also allocated to the Far East pool, but were diverted after the collapse of the entire Malayan front.[2]

Operations During the Malayan Campaign

The first raid on Singapore occurred in the early hours of the morning of 8 December. It was first picked up by No. 243 A.M.E.S. at approximately 0320 hours at a range of 75 miles on the line-of-shoot, flying south. About ten minutes later No. 250 A.M.E.S. started plotting this raid, and it was given a filtered height of 18,000 feet.[3] Almost immediately afterwards, No. 511 A.M.E.S. started plotting it, followed by No. 512, No. 243 in the meantime losing it. By this time some 35 minutes had passed and the raid was 30 miles off the south-east tip of Johore and due east of it. The raid next turned west. An auditory plot was passed on it about ten minutes later by No. 511 who reported that it consisted of a large formation flying high. It continued flying due west, plotted by Nos. 250 and 512 A.M.E.S. until directly over Singapore when bombs were dropped, the first to fall being a stick across Seletar aerodrome, 55 minutes after the first plot had been passed by No. 243 A.M.E.S. The air raid sirens had not been sounded nor had any aircraft taken off. The station personnel were for the most part still in bed. The raid was again picked up by the R.D.F. stations on its way out and was plotted due north from Singapore, passing inland at Mersing to a range of 110 miles in the direction of Saigon.

No. 518 A.M.E.S. went on the air at Kota Tinggi during the third week of December 1941.[4] During the first two weeks after the outbreak of war the Japanese raided Singapore by night, and they usually flew high. They were flying from Saigon, and this gave the R.D.F. stations then operational excellent opportunities for good tracking which they used to full advantage.

Emphasis was, however, being laid by Air Vice-Marshal Pulford on the necessity for providing more and better R.D.F. cover for the overland approaches to Singapore ; he considered that the provision of this cover was essential in view of the fact that the Japanese then had possession of the airfields at Alor Star and Kota Bharu. The buildings for No. 575 CD/CHL at Bukit Dinging and No. 307 T.R.U. at Kahang were practically completed. Both these sites were approximately 70 miles north of Singapore and, although technically both very poor, were the best obtainable in this very difficult country.[5] A new site was also chosen at Serangoon on the north side of

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[1] Air Ministry File S.4422, Encl. 49A, and A.H.B./IIE/70, D.D. Ops (Overseas) Folder, Encl. 80A.
[2] A.H.B./IIE/70, Encl. 93A.
[3] A.H.B./IIJ/50/4, Operations Room Narrative, Air Headquarters, Far East, 8 December 1941, 0408 hours.
[4] No. 518 A.M.E.S. (C.O.L.), O.R.B., December 1941.
[5] A.H.B./IIJ/50/4, Ops. Room Narrative, A.H.Q., F.E.

Singapore Island for an A.C.O. station to be equipped with 125-foot towers. These towers, however, were never completed beyond the 50-foot level and No. 307 T.R.U. was rushed on the air at this site late in January 1942, using a very simple type of improvised aerial.

On 15 January 1942 the Officer Commanding, No. 243 T.R.U. at Mersing, reported that the position was becoming undefendable following the Japanese landing at Endau, 20 miles to the north of the station. The enemy were infiltrating south and the Australian forces, who had been holding Mersing, withdrew.[1] No. 243 T.R.U. was finally given orders to withdraw, which they did under extreme difficulties. Out of the fifty-eight airmen on the station only nineteen were not suffering from malaria. Throughout the withdrawal the unit was consistently bombed and machine-gunned from a low level and transport, as usual, was inadequate. Despite these obstacles the Officer Commanding removed his transmitter, receiver, both masts and aerial arrays and reached Singapore with them undamaged. He unfortunately was unable to remove the electrical power generators and one mast base and although a volunteer party essayed to salvage these the following night, the attempt was unsuccessful except for the salvaging of a large number of generator accessories.

No. 243 A.M.E.S. was then converted from a T.R.U. into an M.R.U. by the Radio and Installation Maintenance Unit and went on the air at its new site at Tuas on the west coast of Singapore Island on the 29 January 1942, fourteen days after its withdrawal from Mersing. No. 243 M.R.U., at this new site, now gave high-flying cover over the approach to Singapore down the Malacca Straits and the mainland of Malaya. The Japanese by this time were in possession of all the airfields in the north of Malaya and were using them to base their aircraft for attacks on Singapore.

Between 20 and 29 January 1942 it became necessary to withdraw Nos. 511, 512 and 518 C.O.L.s from Bukit Chunang, Tanjong Kupang and Kota Tinggi respectively. This equipment, with that of No. 575 CD/CHL and one of the Army CD/CHL.s, was taken to the R.I.M.U., overhauled, carefully packed and put on the S.S. *Loch Ranza* for Sumatra and Java. During this period, however, all evacuee shipping was being subjected to heavy bombardment and although various distress signals were received throughout the long days, lack of sufficient fighter aircraft made any air cover impossible. On 6 February a message was received reporting the loss of the S.S. *Loch Ranza* and instructions were immediately given for the ship to be salvaged or else blown up as it carried 1,000 tons of R.D.F. equipment aboard.[2] In the general chaos neither plan was implemented. The crews of these stations, however, fared better and with 70 per cent. of the personnel of the R.I.M.U. and the remainder of the Radio Branch of the Headquarters, they left Singapore for Java on the evening of the 6 February 1942, reaching Batavia without casualties.

The position in Singapore was then as follows :—

(*a*) No. 250 M.R.U. was still operational at Tanah Merah Besar, giving a reasonably good performance both in heights and ranges. The military tieline to the Filter Room was not particularly satisfactory but the V.H.F. reporting system never gave any trouble.

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[2] A.H.B./IIJ/50/4, Ops. Room Narrative, A.H.Q., F.E., 20 January 1942, and A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

[3] *Ibid.*, 6 February 1942.

(*b*) A CD/CHL station was operational about half a mile from No. 250 M.R.U., having been erected on the top of the water-tower of Changi Gaol—and appropriately named "A.M.E.S. Calaboose." This station was manned by the Army and told plots by means of a tie-line and field telephone to No. 250 M.R.U. Its performance was not up to standard, as it had only recently been erected under extreme technical difficulties and the receiver required an almost complete rebuild in its power supply circuits.

(*c*) No. 243 M.R.U. was operational at Tuas on the west coast of Singapore Island, having been removed from Mersing. Its performance was highly commendable considering its lightning transformation from a T.R.U. to an M.R.U. and its first plot was at a range of 110 miles. Ranges of 120 miles were frequently passed on high-flying enemy aircraft presumably based on Butterworth or Alor Star airfields. Unfortunately it was not calibrated for height or D/F as the enemy were only four miles away (on the one time site of No. 512 A.M.E.S.) when the station was erected.

(*d*) No. 307 A.C.O. station was operational at Serangoon half a mile to the north of the R.I.M.U. at Ponggol. The aerial arrays were a simple type, formerly used on a G.M. set,[1] and mounted on the 50-foot high stubs of the half-erected 125-foot towers previously intended for the station. Erection of these towers had been going on for some time with relays of Malabri riggers working throughout the hours of daylight, but as supplies had to be obtained locally the wood was green, which necessitated burning out practically all the prebored holes before the bolts would fit, making it an extremely slow process.

The "Radio R/T Unit," as it was termed, was doing excellent work in its elevated position in the top flat of the Cathay Skyscraper. A series of R/T sets working on 100 megacycles per second frequency were manned, receiving the reports from the various A.M.E. Stations; the receivers were monitored by R/T operators who had fortunately been sent out under the incorrect title of Radio Operators, and the output of the receivers was fed through a telephone switchboard to the tie-lines linking the building with the Filter Room. Duplex operation was provided, and operators and plotters invariably preferred to plot by means of this system, since it was louder and clearer than the telephonic communications available in Malaya. Results were excellent and more than justified the expenditure of men and materials that had been put into building the system up, not the least of the difficulties being the hard and tedious task of requisitioning the flat in question.

The remaining personnel of the R.I.M.U. stayed at Ponggol, their chief concern being the completion of the modification of C.O.L. receivers to make them work under tropical conditions and, having accomplished this, to send them complete with non-technical gear to the main party of the R.I.M.U. for erection in Java and Sumatra.[2] Part of the unit's small stock of spares which had been retained in Singapore were held at the Cathay Skyscraper to provide an "immediate maintenance party" run by a few selected Radio Mechanics

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[1] *See* Appendix No. 10 for details of this type of R.D.F. equipment.
[2] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

equipped with a Ford van and two Ford Mercury cars. The other equally vital job of the skeleton R.I.M.U. was attempting to obtain information of impending changes in the Army dispositions. These were liable to take place without any warning whatsoever leaving the A.M.E. stations in the unenviable position of being in front of the front line. On 9 February No. 243 M.R.U. found itself in such a position and finally, receiving orders for an immediate withdrawal, got out just in time to evade the enemy, but having to leave masts and aerial arrays behind.

By that time, the Japanese had advanced on the north side of the Island past the Naval Base, towards Seletar and the R.I.M.U. site at Ponggol was threatened. All stocks were therefore moved to a building on the south-east side of the Island by the following day, and No. 243 A.M.E.S., this now highly-seasoned traveller, once more began to bed down under the protection of the R.I.M.U. site. Work went on throughout the night on the re-erection of spare masts and technical equipment.

R.D.F. Units during the Fall of Singapore

On 11 February 1942 instructions were received for personnel of all A.M.E. stations and R.I.M.U. to be detailed into two parties, armed and unarmed, issued with four days' rations and, in the event of a withdrawal becoming necessary, the unarmed party was to move first, followed by the armed party, each man taking the bare minimum of personal kit.[1] The destination in the event of a move was Alexandra Evacuation Camp. Kallang airfield was under shell-fire and was being denied to the enemy. The Fighter Operations Room was being destroyed and the personnel withdrawn, thus leaving the Gun Operations Room the only recipient of the Filter Room information.

By that time there were only two surviving Observer Posts. These were wired to tell directly into Filter Room, and the R.I.M.U. were instructed to form further posts. At midday on 11 February 1942, No. 307 A.M.E.S. reported that the local Army authorities gave them one hour to get out. This was confirmed five minutes later by the Gun Operations Room and instructions were accordingly given for the station to be destroyed in the order (*a*) technical spares, (*b*) non-technical equipment, (*c*) technical equipment, (*d*) telephone equipment, but the V.H.F. R/T equipment was to be removed intact. The next move was a suggestion for a fourth possible alternative site for No. 243 A.M.E.S. on Bukit Brown, but a siting officer driving up to A.H.Q., Sime Road, to make a reconnaissance of the proposed spot was met by a warm but distinctly hostile reception from a machine gun. Communications were cut intermittently with Air Headquarters and news came through that the evacuation centre at Alexandra Camp was in enemy hands. A Group Captain from Air Headquarters visited Filter Room to enquire the whereabouts of the personnel from Air Headquarters, as he had been detailed to embark with the remaining troops but the ship had been rushed by armed deserters.

On 12 February the situation in the Changi area had become highly dangerous and No. 250 M.R.U. was instructed to remove its transmitter reflectors in order to give an improved performance to the South from which direction the heaviest raids were emanating. In the event of a withdrawal the Officer Commanding was warned to save his receiver aerial arrays at all cost, as they could be erected rapidly on telegraph poles, and the deserted Fighter Operations

[1] A.H.B./IIE/70, Encl. 80A.

building was selected as the best spot for the station's next move as the line to Filter Room was still intact. The CD/CHL " Calaboose " was to remain operational until it had to be destroyed.

During the afternoon many reports were received of heavy enemy troop movements in the West but no confirmation could be obtained from the Gun Operations Room and the local Brigadier could not be contacted. By the evening of 12 February 1942 instructions finally came through from the Army for the withdrawal or destruction of all secret equipment in the Changi area as the Japanese had landed in force at Loyang. By this time the crews of No. 250 M.R.U. and CD/CHL " Calaboose " had arrived at the R.I.M.U., both sets of equipment having been destroyed for fear of them falling into enemy hands on the road. These men were then told to report to the Filter Room in company with the personnel from a nearby Observer Post and the crews of No. 307 and No. 243 M.R.U., the latter complaining bitterly that they had just become operational on their new site. At 2130 hours the Air Officer Commanding instructed the Senior Radio Officer to meet him at Fort Canning and in conference with the local Army Commander it was decided that No. 243 M.R.U., which had maintained all its technical equipment, should be re-erected on Fort Canning as soon as possible.

The following morning at daybreak No. 243 M.R.U. moved to Fort Canning and once more made preparations to go on the air. The Air Officer Commanding again contacted the Senior Radio Officer and informed him that shipping accommodation had been found for 152 radio personnel in S.S. *Tien Kwong* and S.S. *Kuala*. The crews of No. 250, 307 A.M.E.S. and the remainder of the R.I.M.U. were detailed to embark from Laburnum Pier in Telok Ayer Basin between 1500 and 1700 hours. Great care was to be taken to avoid observation, no kit or bedding was to be carried, only arms and rations sufficient for four days, and the last mile of the journey was to be made on foot in groups of not more than ten men. The crew of the Filter Room were to be handed over to the Gun Operations Room and the Radio R/T Unit was to join the Army signals. No. 243 M.R.U. was to continue with its preparations for becoming operational.

At 1400 hours word was received from the Army that they were withdrawing and that the enemy were a mile away. Steps were taken to destroy the Filter Room and later instructions were received to destroy the V.H/F R/T equipment and have the personnel embarked. The Senior Radio Officer contacted the Air Officer Commanding who considered that it was hardly worthwhile waiting for No. 243 M.R.U. to become operational but that he would not give the word for its destruction unless the Army authorities agreed, promising to ring the Senior Radio Officer back. Telephone lines were cut, however, and an hour and a half later, on contacting the Senior Army Officer, the Senior Radio Officer was told that Singapore would fall before the R.D.F. station could become operational and he was therefore advised to destroy the equipment and get the crew embarked. Singapore was taken by the Japanese two days later on 15 February 1942.

At 2000 hours the Senior Radio Officer, Officers and Airmen of No. 243 M.R.U. arrived at the docks only to find they were not allowed entry unless they had passes. After some difficulty the Senior Radio Officer argued his way in and located the Air Officer Commanding in a motor launch in company with an Admiral who issued a pass for the crew of No. 243 M.R.U. to enter the basin and embark on the S.S. *Chukwong* and S.S. *Tenggarch*. Some time later the demolition party of No. 243 A.M.E.S. arrived and embarked on the S.S. *Tanjong Pinang*. Shelling of the Telok Ayer Basin from a battery in the direction of Changi took place. Explosions were very heavy and shelling continued throughout the night. All the dock area was burning furiously, particularly the coal dumps and the oil tanks on the Dutch Islands. S.S. *Tanjong Pinang* moved outside the basin and went aground.

S.S. *Chukwongi*, in which the Senior Radio Officer had embarked, was subjected to heavy bombing during the morning of 14 February 1942. Despite the zigzag course she adopted she was finally hit in the engine-room and the forward hold killing thirty men, and while she lay with her engines unserviceable and a heavy list to starboard, three enemy aircraft returned and scored another direct hit on the forward hold and one on the port side amidships, causing twelve more fatal casualties. S.S. *Tenggaroh* and the S.S. *Tanjong Pinang* hove to to pick up survivors and the Senior Radio Officer once again joined the demolition party of No. 243 M.R.U. They continued their journey up the Inderagiri River on the East side of central Sumatra, reaching Padang on 20 February, only to find that Royal Air Force personnel from the local airfields were awaiting evacuation. At Ayer Moeloek they were joined by nine airmen of the Filter Room and Radio R/T Unit personnel who reported that they thought they were the only Royal Air Force survivors from the S.S. *Chang Tei*, in which those two units had embarked. They had reached the coast in a boat, taking it in turns to be towed behind her as she was overloaded, some personnel having been in the water for 25 hours.

On 1 March 1942 the Senior Radio Officer and a party of radio personnel now numbering twenty-eight embarked in two naval craft which had put into Padang for oil, en route to Ceylon. Four airmen, ex-Nos. 250 and 307 A.M.E.S., had arrived at Padang stating that the S.S. *Tien Kwong* had been sunk. The Senior Radio Officer was most anxious that he should return to Sawahloento to check that no more radio personnel had arrived in Sumatra but he was refused permission. On 9 March the party finally found a home on the racecourse in Colombo, and three more airmen, ex-No. 307 A.M.E.S., joined them with the information that a number of officers and airmen previously believed killed or drowned were in fact alive at Ayer Moeloek in Sumatra.

Meanwhile the main party of the R.I.M.U. and Radio Branch of Air Headquarters had not fared so well. On arriving in Java on 7 February 1942 they found there was no organised R.D.F. defence of the Island.[1] The sole aircraft attack warning system was a Dutch air observer post organisation which reported in R/T clear communication to a combined Gun and Fighter Operations Room about 12-foot square, situated 3 miles out of Batavia.

Although most of the R.D.F. equipment evacuated from Singapore had been lost in the S.S. *Loch Ranza*, it was found that three Army G.L. sets and six excellently packed and complete M.R.U.s from the Royal Air Force Station, Kidbrooke, England, were stored in the Batavian transit camp. It was immediately decided to provide R.D.F. cover against Japanese air attack for Batavia initially with two M.R.U.s and later to cover Sourabaya from the mainland and from the island of Madoera. The exact locations for these

[1] A.H.B./IIJ/53/10, Malayan Report Section File M.R.S. 2019 in Directorate of Staff Training Folder titled " Signals Matters—Malaya."

stations would be decided by the findings of a siting party. A decision was also made to set up a new Filter Room in Batavia on the lines of Headquarters Fighter Command and to place the two M.R.U.s within the Batavia defence zone. Suitable sites were found and installation began at once. The Dutch supplied and erected 95-foot aerial towers with ladders and platforms made of bamboo, temporary buildings and telephone lines.

On 20 February 1942 orders were received to install the three Army G.L. sets on the West coast of Java to provide a better and earlier warning system than the existing observer corps. As this area was outside the Batavia defence zone the Dutch authorities were approached to determine how much warning of attack from the sea these sites might expect. Dutch Army Headquarters guaranteed 48 hours warning.

To the East, four G.L. sets with extended range had been left behind by the Americans and these were manned by Royal Air Force personnel to give cover over Sourabaya. The Army G.L. sets became operational on 25 February 1942. Two days later notification was received of an expected Japanese invasion and the G.L. stations were told to pull out. Two hours later the order was rescinded as the warning had proved to be a false alarm and the stations resumed operations. The following day the T.R.U. at Tengarang began plotting on a tie line to the new Filter Room and although uncalibrated it seemed to give good D/F and range. The time taken to bring the T.R.U. and Filter Room into working order from scratch was ten days.

That night information of a pending invasion was again received and this time it was no false alarm. The promised 48 hours warning had not been given and the shore stations were immediately called in to Headquarters. A Royal Air Force pilot officer was intercepted and killed while trying to evacuate his G.L. set. A driver of a lorry and transmitter trailer was stopped by the Japanese firing a shell at close range. The projectile cleared the cab of the lorry and exploded in the trailer. The driver was surrounded and ordered at pistol point to back the trailer down a 30-foot bank into a wet Padi field. When this had been completed a Japanese officer got in alongside the driver and again with revolver drawn, told him to proceed across a narrow bridge which lay ahead guarded by the Dutch. The driver accelerated, but half way over the bridge he locked the lorry sharply into the parapet where it blocked the whole road and then dived into the river. He swam to the opposite bank, warned the Dutch and the bridge was blown up.

The Japanese advance was so rapid that on the morning of 1 March 1942 Batavia was expected to fall within 48 hours. Orders were given for all secret equipment to be destroyed and for a general withdrawal of the R.D.F. personnel to Tjilitjab to be available for evacuation by sea. The several convoys met at the appointed rendezvous but found that evacuation was impossible and on 4 March 1942 all parties were ordered to return to Poerwokerto to surrender arms and ammunition in capitulation. Personnel travelled back by train and were ambushed by a force of Japanese who had wheeled westwards to cut the railway line. Casualties were not high but the wounded who were unable to walk were bayoneted by the Japanese.

Full casualty lists of R.D.F. unit personnel were ultimately compiled from statements of survivors. Two officers and twenty-nine airmen reached Ceylon out of the forty officers and five hundred airmen who manned the R.D.F. organisation in the Far East.

R.D.F. in the Burma Campaign

The Japanese were not only pressing south into the islands of the East Indies at this time. When the R.D.F. units were driven from Malaya, Burma was also being subjected to air attacks to soften up the ground defences preparatory to an attack by the Japanese Army. No. 517 A.M.E.S. C.O.L. station at Moulmein was putting up an excellent performance against heavy enemy air raids.[1] The station was installed on the top floor of the chemical laboratory of the Rangoon University. This site had been chosen after an exhaustive search of the neighbourhood. Three partly-built R.D.F. sites existed, two at Syriam, 10 miles south of Rangoon and one 18 miles to the north, but labour and supplies problems were becoming acute and the University site was practically ideal from the technical point of view as it was 700 feet above sea-level and the R.D.F. aerials were therefore clear of nearby trees and obstacles. Speed in erection and calibration had been essential as Japanese air raids were frequent, and the station personnel were congratulated by the Air Officer Commanding on the rapid manner in which they had become operational. The unit was in operation continuously, using the municipal electrical mains supply for power, and plots were passed to a temporary underground Sector Operations Room at Mingaladon airfield, pending the opening of the new Group Operations Room near No. 221 Group Headquarters.

Enemy activity was fairly heavy and several interceptions were confirmed, the Controller indicating that the R.D.F. plots were far more accurate than the Observer Post information. During the beginning of February several experiments were carried out under increasingly difficult circumstances with modified aerial systems, and ranges were improved. The situation in Burma however deteriorated, and No. 517 C.O.L. was warned to formulate some sort of evacuation scheme. Two were prepared, one covering the destruction of the equipment and evacuation of personnel at the last moment and the second one provided for the withdrawal of equipment. One of the difficulties of the latter was the risk of the equipment being intercepted on the road, as the enemy was advancing slowly down the main Mandalay–Rangoon road and it was possible they would reach the Prome Junction 20 miles north of Rangoon before the heavily-laden convoy.

On 21 February 1942 the Observer Corps ceased functioning at 1800 hours. The Chief Operations Officer was doubtful as to whether a C.O.L. station could carry on alone as it was expecting too much to ask that type of station to observe over 360° with no long-distance warning, especially as raids were coming in simultaneously from different directions. The following day the enemy carried out heavy daylight raids but failed to break through. By this time No. 517 A.M.E.S. had all its available gear packed on lorries and Group had given instructions that the station was to remain operational as long as there were any of our fighter aircraft operating from Mingaladon ; when the last aircraft had left, No. 517 A.M.E.S. was to blow up the equipment and leave by the " most suitable means." The equipment was working extremely well and there was plenty of work to be done but the administrative difficulties were almost insuperable. The ration organisation had broken down and only odd items of food were issued, medical arrangements had failed completely and the entire night was spent searching for a doctor for a sick airman. Most of the Army key-men had left the city, the City Fire Brigade, Civil Defence and Police

[1] No. 517 A.M.E.S., O.R.B., January/March 1942.

had gone, the telephones were cut and 1,500 convicts and 200 native mental cases had been let loose in the city. Looting was general and many fires were raging, including 4,000 " Lease and Lend " lorries on fire at the docks. The Adjutant of No. 517 A.M.E.S. investigated the possibilities of escape up river by boat should the road become completely blocked.

Air raids continued all through the night, and on 23 February the unit was told to stand by at half an hour's notice under the first evacuation scheme. Operations continued, and on 24 February 1942 the air attacks increased. The Japanese were now definitely trying stronger tactics to smash Mingaladon by drawing off our fighter aircraft to the West after approaching South of the city, while the really heavy raids approached from due East. This state of affairs continued for three days, reports of an outbreak of cholera adding to the general disorder. Thirty enemy aircraft were destroyed over Rangoon and Moulmein but attacks became even heavier. On the evening of 26 February 1942 the Officer Commanding No. 517 C.O.L. was called to a conference with the Air Officer Commanding at No. 221 Group and given instructions to evacuate under the second scheme, although the time limit for reaching the Prome–Mandalay Road Junction was 22 hours instead of the original 48 hours. Work was immediately started on dismantling the R.D.F. station and, working through the night, the convoy was ready to leave Rangoon at 0705 hours the next morning. It consisted of sixteen vehicles, one of which contained Burmese and Indian Army guards.

The party arrived at Magwe on 28 February 1942 and were instructed to hand over to the Army Guard for evacuation to India by air, after destroying their equipment. On the following day, however, the policy was again changed and it was decided to keep the unit at Magwe pending the arrival of our fighter aircraft. It was imperative that the unit should become operational as soon as possible, so instead of applying to the Works Directorate for technical buildings, it was considered that far less time would be taken in building coachwork bodies on to the vehicles, thus providing ultimate mobility for the whole unit.[1] On 3 March 1942 the technical lorries were run in to the Burma Oil Company workshop and four days later the now-mobile C.O.L. unit moved to its site at Yenangyaung, three miles north of the Khodoung Chaung, 11 miles north of Magwe, where it was possible to get off the road into the desert scrub for camouflage—a remarkable feat of technical skill, improvisation, and co-operation between a small unit of men.

During the next two weeks the unit changed its site five times. No trouble was spared to give the best performance possible under the most exacting conditions. On 22 March 1942 the unit packed up and left for Yenangyaung on its way to Lashio, but was stopped and told to return as aircraft reinforcements were expected at Magwe. Ten days were spent waiting for Royal Air Force personnel to return to the airfield, the time being put to good use in overhauling the equipment and, as the local Army Signals Section could not be located, the unit set to work to lay their own telephone lines. These were placed as far away from the town as possible, for the enemy had a habit of burning built-up areas to destroy communications.

In the absence of instructions from any higher authority a drain under the main road was selected as an Operations Room, being the only protected, ready-built shelter within suitable distance of our aircraft dispersal points. Again taking matters into their own hands, the unit moved to Magwe and set

[1] No. 517 A.M.E.S., O.R.B., March 1942.

up within two miles north of the airfield. Two days later they were once again on the road to Lashio. The receiver vehicle sustained damage and repairs were delayed due to heavy air raids. Eventually the unit, still intact, arrived at Maymyo only to find there was no accommodation available. The surrounding terrain was almost impossible country for R.D.F. operations, consisting as it did of mountain ranges running from north to south and separated by river valleys roughly two miles wide. Several days were spent in an exhaustive search for a suitable site, not only from a technical point of view but from the point of view of accommodation for the crews, as the rains of the monsoon had started. To build housing was out of the question as the Works Services labour had deserted, and the type of rough shelter used by the occupying Chinese Sixth Army was primitive to a degree. The equipment was eventually set up near a private bungalow loaned by the Burma Oil Corporation and became operational on 17 April 1942. The site was poor and there was no means of obtaining test flights as there were no aircraft at Lashio airfield. The food situation became increasingly serious. No Service rations were available and supplies of certain articles from local sources were non-existent.

The Japanese army in the meantime were making two new drives northwards, one from the Southern Shan States towards Haipaw, and the other up the Salween.[1] This situation required careful watching in view of the unit's valuable equipment, as the convoy on evacuation would have to return to Lashio by a difficult road before it could reach the main North road, and might easily be cut off by advancing enemy troops. On 24 April 1942 W/T signals were intercepted from the N.C.O. in charge of a portable R.D.F. set sited in the Lashio basin that they were surrounded by enemy forces and no Allied troops were in the vicinity. The following day the Officer Commanding, No. 517 C.O.L., drove into Lashio to review the position and wirelessed the unit to pack up and withdraw immediately.

Great hardships and privation were endured on the journey towards the Chinese border. Personnel slept in the vehicles and food supplies were reduced to a ration of oatmeal per man. On arrival at Wanting on the border, the town was so badly jammed with refugees and Chinese military traffic that the unit took the law into its own hands and crossed over into Chinese territory—a fortuitous decision, as Royal Air Force units who did not take such a serious view of the situation remained and had to leave Burma the next day in a hurry without their equipment.

In these circumstances, accompanied by four vehicles of the portable unit (W6B2), No. 517 A.M.E.S. set out on its hazardous 600 miles journey to Chengtu. Many adventures befell them on the way, food was terribly scarce and roads in parts were non-existent. At one stage the party were halted by overhanging rock on a narrow path which ran high above the river. The tops of the built-up lorries had to be lopped off and jettisoned into the river and the rock blasted and hammered away before the convoy could force its way through. For three weeks during the worst of the monsoon season they travelled non-stop and reached Chungking, having been diverted from Chengtu, on 23 May 1942. Here they found that the surrounding terrain was even more disappointing from an R.D.F. point of view than the Lashio area had been. The whole point of diverting No. 517 A.M.E.S. from Chengtu lay in the fact that the Chinese Air Force were not worried about long-range warning as this

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[1] A.H.B./IIE/70, D.D. Ops. (Overseas) Folder, Encl. 80A.

was provided by the Chinese Observer system but required merely close-range ground control for Fighter interception. This changed the whole situation as it was considered impossible to obtain all-round coverage without C.O.L. No. 517 being sited on a peak in the mountain range. After some discussion it was decided that W6B2, the portable unit brought out of Burma, should be brought to Chungking and installed on a mountain peak (which would be a relatively easy task for the lighter equipment) and No. 517 C.O.L. unit should make for Chengtu.[1]

Arriving at Chengtu, the unit found the usual difficulty of lack of accommodation, shortage of food and difficulty in obtaining supplies for reconditioning of equipment. It is significant that the unit reached Chengtu on 29 May 1942, but by the beginning of July 1942 the station was still not sited. The ground was not so difficult as previous locations from the technical point of view but food, accommodation, rate of exchange, clothing, etc., formed a major problem—as did the suspicious attitude of the Chinese Air Force towards something they did not quite understand. By 11 July 1942 it was pretty obvious to the unit that the Chinese Air Force were not going out of their way to be helpful. The only method left to stimulate them into full co-operation was to provoke the local Chinese Air Force authorities into witnessing a practical demonstration of the R.D.F. equipment and then see if "results" would produce a more favourable attitude.

By this time the spares position was acute. The unit had not received any further supplies since the initial meagre issue in July 1941. The receiver cathode ray tube eventually gave out and it was proposed to convert the monitoring cathode ray tube from the transmitter into use for the receiver, as it seemed hardly likely that spares would be forthcoming. On top of these major difficulties, the Headquarters Unit, Royal Air Force in China, attempted to incorporate the unit as part of Headquarters—which was vastly irritating, considering the hardships with which the unit already had to contend. The long journey was beginning to tell on the technical condition of the equipment and breakdown followed breakdown. Practically all the diesel oil that had been brought from Burma was used up and still none was forthcoming as promised by the Chinese. Periodical rains saturated everything and no cover could be found for the equipment. Most trying of all to bear was the thought that but for the unsatisfactory technical position the unit might have proceeded to the fighting front to assist the United States Army Air Corps.

There was no co-operation from the Chinese Air Force, and in the city itself there were several hostile incidents against the lorries belonging to the unit. Repeatedly the Officer Commanding asked for prior notice of aircraft flights in order to bring the unit on the air and check its performance, but no advance information was ever given. Finally on 13 August 1942, after a great deal of persuasion and diplomacy, a test flight took place and two officials of the Chinese Air Force were invited to witness the results. The flight actually failed in its specific purpose, *i.e.*, to obtain suitable data for the station, as its course was decidedly erratic, varying from 20 to 60 degrees off the agreed bearing. Nevertheless it at least impressed the two Chinese officials to such a degree that they were finally convinced of the strange powers of this equipment and of the mutual benefit that might be derived from closer co-operation between A.M.E.S. No. 517 and the Chinese Air Force.

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[1] No. 517 A.M.E.S., O.R.B.

Unfortunately the Chinese Air Force was controlled by three co-equal generals and the only suitable site for the unit happened to come under the jurisdiction of the least friendly of the three. After many delays and setbacks, inevitable in a country prone to dealing with all matters in a leisurely manner, it was finally arranged to train Chinese personnel in both Operators' and Mechanics' duties. Lectures and practical instruction were started on 11 January 1943, and on 28 April 1943 the equipment of C.O.L. No. 517 was handed over in its entirety to the Chinese Air Force.

R.D.F. Position in the Far East at the Beginning of 1942

The seriousness of the situation in the Far East was fully appreciated in the United Kingdom. Despite the welter of R.D.F. requirements for Home, Allied, Dominion and Middle East theatres, plans were made to send additional R.D.F. units to the Far East as soon as possible in support of fighter aircraft then being diverted there.[1] The full benefits of R.D.F. planning occasioned by the entry of the Japanese into the war had not been reaped so far in the Far East. The disastrous Malayan campaign had ended before many of the R.D.F. units intended for its support had arrived in the theatre of operations. Eight R.D.F. units were already en route by sea and fifteen more were expected to follow by the end of January 1942. The first step was therefore to re-allocate these in attempts to contain the Japanese within the already-existing land and sea fronts.

Emergency Defensive R.D.F. Measures against further Japanese Aggression

With the collapse of Hong Kong, Singapore, the Andaman Islands and Mandalay, all between 25 December 1941 and 1 May 1942, Air Headquarters, Far East, ceased to exist and Air Headquarters, India, took over command. The few R.D.F. personnel who had managed to escape the Malayan debacle were withdrawn to India and units and equipment in transit were diverted where they could be saved, and sent to India and Ceylon.

Allocations were hastily made for supplying R.D.F. as quickly as possible to the remaining bulwarks against further Japanese expansion. By the late spring of 1942 the situation could be summarised as follows :—[2]

India.—On the 1 March 1942, one M.R.U. was at last in transit for Calcutta. Three A.C.O.s, four M.R.U./T.R.U.s, eight C.O.L.s and two G.C.I.s had been allocated and were awaiting despatch for dispersal in India.

Ceylon.—Two CD/CHL.s were on site in Trincomalee at Chapel Hill and Kodipotumalai Hill and five M.R.U./T.R.U.s, six C.O.L.s and one G.C.I. were in transit with a further G.C.I. having been allocated. Three of these sets had been diverted from the Middle East.

Australia.—Two CD/CHL.s for Port Darwin and Sydney were in transit accompanied by five C.O.L.s to form the nucleus of an Australian pool. Two A.C.O.s, six C.O.L.s and a G.C.I. were allocated and were awaiting despatch.

New Zealand.—Two A.C.O.s were on their way to New Zealand and five C.O.L.s were allocated and awaiting despatch.

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[1] A.H.B./IIJ/50/24/5, "R.D.F.—Far East (including Anzac)" D. of Ops. (Overseas) F.O.S. Folder G.D.S., Encl. 48A.
[2] A.H.B./IIE/70, D.D. Ops (Overseas) Folder, Encl. 99A.

There were many lessons to be learned from the failure to resist the Japanese attack on Burma and Malaya—and particularly the loss of the key-port of the Far East, Singapore, on the defence of which considerable expenditure had occurred. As far as the R.D.F. raid reporting organisation was concerned, perhaps the chief lesson to be pressed home was that although the individual R.D.F. units and the Maintenance Unit locally had functioned extremely well under the most adverse conditions, Singapore was so far away from the supply bases in the United Kingdom that it had largely to depend in wartime on its own local resources.[1] These should have been backed up by technical information and drawings sent from the United Kingdom and by extensive provision of workshop facilities, skilled tradesmen, mechanical transport and wide local purchase powers. Much could have been accomplished locally if these facilities had been available. In their absence, and more particularly while rigid contract procedure was demanded in dealing with local sources of supply, the stranglehold was such that little or no effective progress could be made. It is interesting to conjecture whether the situation would have been any easier if Malaya had been administered from Australia during the initial phase of the war.

The serious setback of the Japanese successes in the Far East, coming as they did when the Germans were at the peak of their territorial gains in Europe and the Middle East, clearly indicated that the road back for the Allied forces in the Far East was to be a hard one. From the R.D.F. point of view a build-up of mobile units and equipment, all to be shipped over more than ten thousand miles from the United Kingdom, was the first essential. These units were necessary not only to strengthen the existing defensive raid reporting systems but also to prepare for the day when our forces would assail the areas then occupied by the enemy. The story of this build-up under what became South East Asia Command (S.E.A.C.) is written in a later chapter of this volume.

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[1] R.I. and M.U., Seletar O.R.B., December 1941.

CHAPTER 14

ENEMY COUNTER-MEASURES AGAINST THE HOME CHAIN R.D.F. RAID REPORTING SYSTEM

During the first year of the War the enemy had been slow to realise the value to home defences of the R.D.F. Chain, although during August 1940 an attempt had been made by direct bombing attacks to strike a blow at the South coast R.D.F. stations.[1] Subsequent interrogation of high-ranking officers of the *Luftwaffe* showed that the enemy held the opinion that R.D.F. stations were considered difficult targets to damage effectively by direct attack, especially in face of the opposition of Fighter Command.[2]

Nevertheless, direct attacks continued on a much-reduced scale. More than forty-seven such incidents were reported during the years 1942–1943, directed either in whole or in part against the R.D.F. stations ; three of these attacks were made on Swingate (Dover) by shell-fire across the English Channel, and this station received more attention from the enemy than any other in the R.D.F. Chain.[3] The aerial attacks were mainly concentrated on the East and South-East coasts, with a few on the South coast. One fatality was sustained at Bawdsey C.H. Station, but on the whole very little damage was done to technical installations and no station was put out of action as a result. More than eight enemy aircraft taking part in these raids were destroyed. Operations were carried out as usual through even the heaviest attacks.

The alternative method which the enemy might employ of indirectly attacking the Home Chain had not been overlooked, namely, by attempting to render R.D.F. raid reporting impossible by the use of jamming transmissions on the frequency bands within which the R.D.F. stations functioned. Such a method, if successful, would have masked the observation of enemy aircraft on the cathode ray tube itself by blanketing the " echoes " of the aircraft in some curve or pulses sweeping across the face of the tube. Fortunately the possibility of enemy jamming had been foreseen as far back as 1935 and considerable research and development had been done, with the result that the R.D.F. stations were not unprepared. An account of the preparatory work appears at Appendix 18.

Spasmodic attempts had been made by the enemy to jam R.D.F. transmissions during the Battle of Britain and had been continued along experimental lines throughout the 1941 period. Jamming before February 1942 was probably largely experimental on the enemy's part, as the periods of interference were very intermittent and the jamming rarely intense. Nevertheless, it is necessary to consider the earlier forms of jamming employed by the enemy in order to appreciate the degree of success achieved by his radio counter-measures.

Frequency Modulated Continuous Wave Jamming

The jamming first employed in 1940–1941 against the C.H. stations was Frequency Modulated Continuous Wave (F.M.C.W.)—a continuous wave the frequency of which was not fixed but varied rapidly between definite limits.

[1] An account of these attacks is given in Chapter 10.
[2] These interrogations are described from the R.D.F. viewpoint in Chapter 10.
[3] Headquarters, No. 60 Group, O.R.B.

For instance to jam an R.D.F. station working on a frequency of 26·6 megacycles per second the enemy transmission varied between about 26·2 to 27 megacycles per second about 200 times per second. On the cathode ray tube of the C.H. station, part of the trace was displaced into an inverted bell-shaped curve which moved along the trace from end to end, the " bell " on occasions reaching saturation.[1] When the selectivity of the C.H. station receiver was increased, the bandwidth of the receiver, *i.e.*, the range of frequencies to which it was sensitive, was correspondingly reduced, and for that purpose a switch was provided on the set which would automatically tune the receiver to either wide, medium or narrow bandwidth. When the receiver bandwidth was reduced, the width of the " bell " was correspondingly reduced, generally covering a distance of approximately 20 miles on the tube time-base when narrow bandwidth was employed. Scientific observers were sent to the R.D.F. stations at Great Bromley, Canewdon and Dover to make observations on this jamming. By the end of 1940 all C.H. stations from Worth Matravers to West Beckham were experiencing regular F.M.C.W. from enemy jamming stations located in the Boulogne and Calais areas, and from Holland.[2]

C.H. stations were equipped with several devices designed to modify the effects of accidental interference and jamming, and these devices were as a rule effective either by cutting out the offending signal or minimising its effects so that operations were possible in at least a modified form. The chief palliative was the Intermediate Frequency Rejector Unit (I.F.R.U.) which was fitted in pairs to all C.H. receivers and which, used separately or together, was capable of cutting out a small frequency band. This was very effective if the interfering signal came within its range. The Intermediate Frequency Rejector Unit could not, however, completely reduce the effects of F.M.C.W. as it was only capable of dealing with one small frequency band at a time, whereas the jamming was sweeping continuously through a whole range of C.H. station frequencies. C.H.L. receivers were not at that time fitted with I.F.R.U.s though later in April 1942 a version for C.H.L. stations was proposed and a prototype model was available on 24 June 1942.[3]

In addition to the I.F.R.U.s and the Anti-Clutter Gain Control (referred to in App. 59), C.H. stations were provided with special anti-jamming cathode ray tubes which had a long afterglow screen. This remained luminous for some time after the electron beam had moved off, thus enabling responses to be plotted through a heavy interfering signal. C.H. stations were also provided with a set of coloured filters to be placed in front of the tube and these were a considerable help in minimising interference, by separating the afterglow from the instantaneous trace on the tube. For instance, a yellow filter placed over the blue instantaneous trace on the tube would allow the afterglow to appear, but very little of the instantaneous trace. Aircraft echoes remained luminous on the screen for some seconds and so could be seen, but the jamming signal appearing on the instantaneous trace would be cut out or at any rate considerably reduced. Operators on the R.D.F. stations soon became used to F.M.C.W. jamming and skilled, experienced operators were generally able to plot very satisfactorily through it. At first, then, the enemy's attempts at jamming had a " nuisance " value only.

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[1] Headquarters, No. 60 Group File 60G/S.742/Sigs., November 1940.
[2] Air Ministry File S.44413, Encl. 42B.
[3] Headquarters, No. 60 Group File 60G/50/11/1/Ops., Encl. 70A.

" Railings " Jamming

A new and far more troublesome form of jamming had been first seen at the C.H. station, Great Bromley, in the autumn of 1940, though at the time it was not considered as such but was thought to be some form of accidental interference.[1] After an interval, however, it appeared at several South coast R.D.F. stations in May and June 1941. This was called " railings " from its appearance on the tube, which consisted of a series of close pulses of equal amplitude sweeping across the whole time base. The pulses were about 5 megacycles per second wide with a recurrence frequency of 50 kilocycles per second and were not locked to the time-base or mains. The amplitude, though constant across the trace at any one moment, varied suddenly from time to time, from saturation to something very small.[2] It was possible to plot through this jamming with the aid of an afterglow tube but its great drawback was that it tended to mask I.F.F. responses. On the C.H. stations the I.F.R.U. was ineffective for this form of jamming, though its effects were largely alleviated by the use of a wide bandwidth to give the narrowest possible interfering pulse, and a wide transmitter pulse to give larger responses. The C.H.L. stations had no remedy against " railings " and in consequence their operations suffered more than those of the C.H. stations from this type of jamming.

Initial Organisation for the Investigation of Enemy Jamming

On 3 October 1940 Air Ministry Research Establishment suggested the formation of a specialised body of experts to deal with the whole question of jamming, and this work was therefore undertaken by scientists of the Telecommunications Research Establishment.[3] A mobile jamming van, in charge of a scientific officer, was prepared so that it could be rushed immediately to areas where jamming was being experienced. By the middle of November 1940, however, most of the jamming ceased temporarily. When it began again in March 1941 the mobile van was already installed at Stoke Holy Cross R.D.F. Station in Norfolk, where it investigated jamming signals coming from the Dutch coast. The van was moved to the C.H. station at Dunkirk on 11 January 1942 and did valuable work in investigating jamming whilst it was still in progress, as a result of information passed to it by stations affected.

Before the investigation into this jamming was complete the enemy resorted to its employment on a scale never before experienced. This was in his attempt to cover that most important operational incident of February 1942—the escape of the enemy warships *Scharnhorst*, *Gneisenau* and *Prinz Eugen* through the English Channel from the French port of Brest. During the war, secrecy restrictions precluded a full public disclosure of the details of this event, leading to a popular rumour that the R.D.F. system had failed. It is therefore expedient to consider this incident in relation to effect of jamming on the efficiency of the Home Chain at that time.

The Home Chain and the Escape of the Enemy Warships " Scharnhorst," " Gneisenau " and " Prinz Eugen "

It will be recalled that the *Scharnhorst* and *Gneisenau* had been cooped up at Brest from March 1941, being joined in May of the same year by the *Prinz Eugen* after the sinking of her consort, the *Bismarck*. During this time the

[1] Air Ministry File S.44413, Encl. 77B.
[2] Headquarters, No. 60 Group, File 60G/S.742/Sigs.
[3] Air Ministry File S.44413, Encls. 59A, 84A and 114B.

battle cruisers had been bombed repeatedly and heavily by the Royal Air Force, and though damage was inflicted, none of the ships was destroyed. Early in 1942 a reconnaissance aircraft revealed that the three ships were apparently again seaworthy and reports indicated that they were preparing to leave the port for Germany, where they would be in a safer and more distant harbourage.[1]

This in fact they did on the night of 11 February 1942, slipping out of harbour about 2200 hours and escaping detection at the time through the unfortunate breakdown of the A.S.V. equipment on the aircraft patrolling the area. This aircraft had been forced to return to base pending the despatch of a relief, and it was during this short interval that the ships actually left Brest. By bold tactics the ships succeeded in passing up the English Channel and getting through the narrow waters of the Strait of Dover, despite R.D.F. observation, before being engaged in action by British forces, and finally they reached port in Germany.

It was not until 1230 hours on 12 February that contact was made with the enemy. The story of the pursuit and the battle which ensued, in which both the Royal Navy and the Royal Air Force played a gallant part, is not one for this chapter, but is dealt with fully elsewhere in the Naval accounts of the engagement and in Royal Air Force operational narratives.

Enemy Attempts to Blind our R.D.F. Stations by Jamming

The outstanding features of the day, as far as the R.D.F. stations were concerned, was the use by the enemy of measures designed to jam the stations.[2] Deliberate jamming by the enemy was no new thing, and had been used in a crude form on occasions to mask offensive aerial action by the enemy, but this was the first occasion on which all stations in a certain area were deliberately jammed for any length of time. Enemy jamming on 12 February lasted from approximately 0930 to 1930 hours and affected to a lesser or greater degree all types of R.D.F. stations except those working on the higher frequencies of 600 and 3,000 megacycles per second. Frequency-Modulated Continuous Wave Jamming was employed by the enemy, and was of a more severe type than had previously been experienced, being particularly severe against C.H.L. stations.

Jamming of Home Chain Stations

With the exception of Newchurch C.H. Station, the operating efficiency of the C.H. stations generally was not greatly impaired. Stations between North Foreland and Beachy Head were jammed on two bands about 1 megacycle per second wide on approximately 22·6 and 26·8 megacycles per second. Newchurch was singled out for particular attention by the enemy and had a special jammer working on 27·7 megacycles per second. The interference here was sufficiently severe to cause the station to become non-effective between 1200 hours and 1930 hours, although it did operate eventually to some extent at a much reduced efficiency by detuning the C.H. station receiver.[3] At a meeting held in Air Ministry on 23 February, when the whole question of the jamming of R.D.F. stations on 12 February was considered, it was decided that the existing anti-jamming facilities on a C.H. station were sufficient to

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[1] A.H.B./IIK/18/7, Battle Summary No. 11, " The Passage of the *Scharnhorst, Gneisenau* and *Prinz Eugen* through the English Channel, 12 February 1942," C B. 3081 (7).

[2] A.H.B./IIK/7, " Evidence and Report of the Board of Enquiry."

[3] No. 75 Wing, O.R.B., 12 February 1942.

deal with the crude type of jamming and the low power employed on this occasion by the enemy, although it was stressed that if the enemy improved the type and extent of jamming in future the relief afforded by existing measures would be less.[1]

Jamming of C.H.L. Stations

The C.H.L. stations were affected in a varying degree from Bawdsey to Beachy Head by jamming on a frequency band of 190–210 megacycles per second using 1 microsecond pulses at a repetition rate of 150 kilocycles per second, fully amplitude-modulated at 100 megacycles per second. Swingate C.H.L. Station was completely blotted out, as were the C.D./C.H.L. stations between Foreness and Beachy Head, whilst the C.H.L. stations between these two points could not plot along the French coast within fifteen miles of Cap Gris Nez. The pulses were lengthened to 3 microseconds by the narrow band radio-frequency amplifier of the C.H.L. receiver equipment and this affected both the Range and the Plan Position Indicator cathode ray tubes. Naval Type 271 stations, working on the 3,000 megacycles per second frequency, were unaffected. In most cases the jamming began intermittently around 0930 hours, varying in intensity from a very slight disturbance to saturation point, but it was not until about 1000 hours that it became really serious and continuous.

R.D.F. Information on the Enemy Ships and Escorting Aircraft

Despite the care with which the Germans had prepared their jamming programme, the enemy force did not go unobserved by our R.D.F. stations. The first recorded plots on enemy activity came from the C.H.L. station at Beachy Head at 0824 hours, when it began plotting on hostile aircraft off the French coast. A report to this effect, with a statement that the aircraft did not seem to be moving very much but were circling all the time, was made to Filter Room at Headquarters, Fighter Command immediately, via the C.H. station at Pevensey, as the C.H.L. station itself did not then possess a direct telephone tie-line to the Filter Room. These plots were at a bearing which, when worked out later, showed them to have been the umbrella of enemy aircraft over the battleships.

Interference at this station began at 0920 though it was able to pass a few further plots on the same aircraft. Later it appeared to the Radio Operator observing at the cathode ray tube that there was a shipping response associated with the aircraft, and at 1014 and 1016 hours respectively two plots were passed from two different responses, reported as being three ships each, at ranges of 44 and 46 miles. Instructions were given for these shipping plots to be passed to the Naval Plotting Room at Dover at 1014 hours, but unfortunately due to trouble on the telephone line this could not be done. The information was, however, passed by another telephone line to the corresponding Plotting Room at Portsmouth at 1019 hours with a request that it be passed on by them to Dover. At the same time it was reported via Pevensey C.H. Station to the Filter Room that six vessels were at that spot. Dover Naval authorities were eventually contacted by Beachy Head C.H.L. Station at 1040 hours and a repetition of the same shipping plots was passed.

Up to the time—1014 hours—when the shipping responses were seen, the interference had been slight, but from then on it became much more severe and

[1] Air Ministry File S.6412, Encl. 99A.

continuous until the cathode ray tube was completely blotted out, further plotting being impossible. The shipping responses were on the tube for approximately five minutes. Pevensey were informed at 1016 hours that the interference was Frequency-Modulated Continuous Wave and was now permanent and were requested to pass this information to Filter Room.

The R.D.F. station at Bembridge later plotted several hostile aircraft at a range from them of 120 miles, the tracks being plotted for 190 miles, and Fairlight R.D.F. Station also plotted hostile formations of aircraft in the Channel 15 miles west of Le Touquet, just before these stations experienced interference.[1] From 1015 hours Fairlight Station reported great activity in the Channel and hostile aircraft were plotted continuously till after 1140 hours. Thirty-two tracks were plotted by the station in this period, despite heavy interference.

Capel, Type 271, Station picked up a track at 1054 hours at a range of 35 nautical miles (40 land miles) which was plotted for two hours and fifty minutes to a range of 52 land miles, this being claimed as a record range on surface craft for a station of this type. The track was estimated as consisting of 20 plus surface craft.

At 1045 hours Fairlight, Type 271, Station observed a plot 27 miles S.W. of Cap Gris Nez. No details as to size and number of vessels could at first be made out, but as it was a very long-range plot and the first indication from any source of shipping in that area which he had then received, the Air Staff Officer attached to Vice-Admiral, Dover, "wisely warned" both No. 16 Group of Coastal Command and No. 11 Fighter Group, in addition to impressing on the latter the necessity for another "Jim Crow" report.[2] "Jim Crows" were reconnaissance aircraft from Fighter Command sent out to investigate specific areas or targets about which further or confirmatory information was required. These reconnaissances had a rigidly observed rule which ensured that absolute wireless silence was kept in the air, so that any reports had to be made verbally immediately the aircraft landed on return to base. At 1105 hours the "Jim Crow" report was received by Vice-Admiral Ramsay at Dover, which stated that the long-range shipping plot consisted of from twenty-five to thirty vessels, small destroyers or sloops, with E- or R-boats, in two groups, one of the latter appearing to be making smoke. No mention was made of the three battle cruisers by name.

In the meantime, Group Captain Beamish and Wing Commander Boyd, the Officer Commanding and second-in-command respectively of Kenley (Fighter) Royal Air Force Station had, in the course of an offensive fighter sweep south of Boulogne unconnected with shipping reconnaissance, attacked two *Messerschmitt* aircraft, and in the pursuit which followed they found themselves flying immediately over the German ships, which they recognised. In accordance with the rule for observing wireless silence, Group Captain Beamish returned at once to his base, landing at 1109 hours. His report was immediately transmitted through No. 11 Group to Fighter Command and to all other authorities concerned. This message was the first really definite indication that the three battleships were actually in the Channel, and consequent on this information all possible steps were taken by all three Services to make contact with the enemy forces.

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[1] No. 75 Wing, O.R.B., 12 February 1942.
[2] A.H.B./IIK/18/7, Battle Summary No. 11, pp. 8 and 9.

Investigation by the Board of Enquiry

A full enquiry into the whole circumstances of the escape of the three battleships was undertaken by a Board of Enquiry under the chairmanship of the Hon. Mr. Justice Bucknill.[1] In its report it was confirmed that the R.D.F. plots had clearly indicated aircraft circling in a small area and later, indications of shipping had appeared. The R.D.F. stations had functioned satisfactorily despite the enemy jamming. The significance of the plots was not recognised immediately as such plots were common in the area concerned—the Germans had intentionally carried out exercises over Brittany for several days. No particular significance would normally have been attached to these plots as they were outside the area of day-to-day fighter interceptions. Had these plots been investigated, however, as soon as their character came under suspicion, it was possible that the enemy warships would have been sighted an appreciable time earlier than they were.

Besides the R.D.F. plots, another indication that something unusual was afoot was the intense jamming by the enemy of the R.D.F. Chain. The significance of this jamming was missed initially because the Germans employed it intermittently at first and the R.D.F. stations reported it as " interference." It was only after the first hour that action was taken by the Filter Room staff, the " interference " reported then being recognised as deliberate jamming.

German Impressions of the Success of Jamming

A few days prior to the passage of the warships through the Channel, Dr. Scholz, a civilian employee of the *Reichpost Zentrole* in charge of radio counter-measures, was specially brought from Berlin to supervise this first big operation of their whole jamming chain against British R.D.F. ground stations. The R.D.F. cover of the C.H. and C.H.L. stations had been carefully plotted by the enemy and it was ascertained that the ships would come within their range as they passed off Fécamp, where they were scheduled to be at 10 a.m. At that hour every available jammer was switched on. The fact that the battleships passed through unscathed was, in the opinion of Dr. Scholz when interrogated, the best proof of the effectiveness of German counter-measures. He was not aware that we had either decimetre or centimetre R.D.F. in operation at this time.

Summary of the Part played by R.D.F. Stations during the Escape

For full details of the Royal Air Force activities in the belated attempts to stop the German force escaping, the reader will have recourse to the findings of the Board of Enquiry which investigated the whole episode. From the Signals viewpoint, it is apparent that the R.D.F. stations themselves could not have done more in the circumstances to enable earlier detection to have been made. The jamming experienced undoubtedly hampered operations considerably, but valuable information was given by the Chain stations in spite of this disability. It is doubtful whether much earlier warning could have been given of the ships themselves, as they were at very long range from the stations and their protective aircraft " umbrella " circled over them as low as possible in order to escape detection by R.D.F. Every station in the area appeared to have passed promptly all the information it possibly could. No blame could be attached to the R.D.F. stations—they had functioned well, despite the most effective jamming

[1] A.H.B./IIK/7, " Evidence and Report of the Board of Enquiry," Finding and Summary from p. 5.

the Germans had yet produced. The main trouble appears to have been a lack of liaison and the failure of the Inter-Service organisation, in that insufficient use of the information available was made at the time, and insufficient attention was paid to the fact that steadily-increasing interference was being reported by so many stations. It did not appear to be realised immediately that the trouble had a much deeper significance than mere spasmodic interference and that it was, in fact, deliberate jamming by the enemy designed to mask important operations.

The whole episode must be regarded as a triumph for the German organisation, and to some degree it ventilated what had always been a defect in our use of the Home Chain system—namely, that maximum advantage was not always taken of the R.D.F. information available. There is no doubt that the incident provided adequate stimulus for the eradication of minor defects in the organisation and improvement in inter-Service liaison.

Emergency Alternative Higher Frequency Equipment for use to Counter Jamming

Subsequent scientific investigation of the jamming experienced during the escape of the enemy battleships through the English Channel showed that the principal jammer stations used on this occasions by the enemy were in a chain along the whole French Channel coast.[1] There was every reason to anticipate an increase in jamming activity to mask enemy operations. Accordingly at a meeting held at Air Ministry on 23 February 1942 to discuss proposals for counteracting jamming of R.D.F. stations it was decided to install emergency R.D.F. equipment working on higher frequencies at the more important C.H.L. stations, only to be brought into use when jamming rendered the 200 megacycles per second frequency band stations unserviceable.[2] The higher frequency band selected was 500–600 megacycles per second. This was the German R.D.F. frequency band, so there was less likelihood that the enemy would resort to jamming on this band.

On 29 April 1942, three mobile Type 11 sets on the new waveband, and using vertically polarised waves, were installed at Beachy Head, Swingate and North Foreland.[3] By the end of 1942 three more were established at Foreness, Ventnor and Truleigh Hill. The Type 11 sets, however, provided for plan position location only and a comparable equipment was therefore needed (with the same anti-jamming properties as the Type 11) which could be used for height determination. Consequently a decision was made to produce a 500–600 megacycles per second frequency-band equipment (Decimetre Height or D.M.H.) for use with the Type 11, Mark II, set, which would be designed to work over the same variable frequency band as the Type 11 equipment, namely 500–600 megacycles per second. The purpose of having variable frequency equipment was to enable station technical officers to change the frequency of operation of the station (according to pre-arranged spot-frequencies) in order to attempt to avoid the jamming.[4]

Reorganisation of Jamming Investigations

Until July 1942 the work of investigating jamming and of testing counter-measures had been one part only of the many duties undertaken by the research staff at Telecommunications Research Establishment, but the volume of work increased so much that it was decided a larger staff for this special purpose was

[1] A.H.B./IIE/209, Air Ministry Signals Branch Folder R.C.M./141, Encls. 2A and 7A.
[2] Air Ministry File S.6412, Encl. 99A. [3] Air Ministry File C.S. 16601, Encl. 19A.
[4] Headquarters, A.D.G.B. S.30806, 18 September 1942.

essential if adequate control was to be maintained over the investigation of jamming and the testing of anti-jamming measures. Accordingly a special unit known as "Central J. Watch" was established on 4 July 1942, with a specially trained staff under the command of a Squadron Leader. It was stationed at Telecommunications Research Establishment but came under the operational control of Headquarters No. 60 Group. Later, special sub-sections were stationed at the C.H. stations of Ringstead, Dunkirk (later moved to Dover Hill) and Stoke Holy Cross, each being responsible for special investigations into jamming at the R.D.F. Stations in their area. These sub-sections covered all the areas where enemy jamming had been experienced ; stations in other districts would if necessary report direct to Central J. Watch.[1] R.D.F. stations had very strict instructions to report all cases of jamming or suspected jamming immediately to the nearest J. Watch giving all details possible. Telephoned reports in accordance with a pre-arranged code were made, using a "Priority One" call if an open telephone line had to be used.[2] These telephoned reports were followed up the same or next day by written detailed reports to Central J. Watch, giving additional details and accompanied where possible by sketches or photographs. In this way J. Watch knew the moment the enemy started jamming and were generally able to observe its effects for themselves by tuning their specially devised sets to the frequencies of the stations affected, and so were able to co-ordinate results reported by the various stations. Stations also reported immediately to Filter Room whenever interference was experienced, whether this was accidental, suspected, or of proved enemy origin.

In addition to collecting all possible information on jamming, collating measures designed to combat it, and doing research into further methods of anti-jamming, J. Watch were responsible for training operators at R.D.F. stations to recognise and overcome enemy jamming. This was done by means of lectures and demonstrations, and the training proved very valuable.

In December 1942 it was decided that an anti-jamming unit would be formed in No. 80 (Signals) Wing, the Royal Air Force formation in charge of radio counter-measures against the enemy, and accordingly the functions of J. Watch were transferred from Telecommunications Research Establishment and No. 60 Group to No. 80 Wing on 5 February 1943.[3] In order to provide mobile jamming units for ultimate employment in the Allied Expeditionary Air Forces, four J. Watch Units at No. 80 Wing were disbanded on 15 May 1944, all surplus personnel being transferred to No. 60 Group. This Headquarters thus resumed its old responsibility for the investigation of enemy jamming of the Home Chain. The J. Watch static stations in No. 60 Group were finally closed on 1 January 1945, with just a nucleus maintained at No. 60 Group, equipped with a mobile van available for analysis should the need arise.

Jamming during 1942 and 1943

The increased enemy aerial activity in the spring of 1942 brought a return of jamming, more particularly affecting the C.H.L. stations. This was generally F.M.C.W. on the C.H. stations and a mixture of F.M.C.W., "railings," and other pulsed transmissions on the C.H.L. stations. On 18 and 19 March all

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[1] Headquarters, No. 60 Group, O.R.B.

[2] The highest G.P.O. priority for Service purposes at this time—tantamount to having a telephone line cleared and made available for the call immediately.

[3] Air Ministry File C.S. 6412, Encl. 193A, and No. 60 Group O.R.B.

C.H.L. stations between Walton and Beachy Head were fairly heavily jammed though operations were still possible.[1] This continued intermittently until June 1942, when, from the 21st of the month, jamming again became very heavy, from Hopton in Norfolk round to Ringstead in Hampshire, being particularly heavy in the area round the Strait of Dover. Here it was sufficiently serious to render a number of stations non-operational for some two hours. The C.H. stations were affected to a lesser degree than the C.H.L. stations ; in some cases G.C.I. (Ground Controlled Interception) stations were also affected. This jamming corresponded with enemy attacks made during moonlight nights on Southampton (21/22 June), Birmingham (24/25), Norwich (26/27) and Weston-super-Mare (27/28/29). The jamming continued from July to about November, again the C.H.L. stations suffering most.[2]

The jamming interference generally came on at night and nearly always coincided with a period of heavy enemy bomber activity, although sometimes it appeared that the enemy was using it to mask our own offensive bombing operations. Whitstable C.H.L. station experienced very heavy enemy jamming between 1648 hours on 31 October and 0245 hours on 1 November during which period there was considerable enemy activity around Canterbury and district. A fighter-bomber raid in the late afternoon was followed by two bomber raids at night, about twenty-six enemy aircraft being involved in the latter raids.

The onset of winter brought a welcome relief from the enemy's jamming activities, but it again came into operation on 17 January 1943, with the obvious intention of covering an attack on London.[3] This was the enemy's first night of intensive raiding for nearly six months, with the exception of the Canterbury raids of 31 October/1 November 1942, and was a reprisal for a heavy British raid the previous night on Berlin.[4] About seventy-five long-range bombers, flying in two waves, set out to attack London, whilst another fifteen or so laid mines in the Thames Estuary ; about thirty aircraft succeeded in getting through to the capital and eight enemy aircraft were destroyed. On this occasion the C.H. stations were not badly affected, except for Swingate. This was operational on its "Buried Reserve" equipment, which lacked anti-jamming devices, and raid reporting operations were in consequence much hindered. The C.H.L. stations, however, from Walton to Bembridge were much more seriously jammed, the effects increasing around the Strait of Dover area. Generally, stations working on 200 megacycles per second frequency band were completely blotted out when looking in the Calais-Boulogne area. G.C.I. stations nearest the Continent were not seriously jammed, but their operations were restricted. Swingate C.H. Station was also seriously jammed again on the next day, and during this period, between 1955 and 2030 hours, the station itself was attacked by six enemy aircraft dropping incendiaries and H.E. bombs. Two Army personnel were injured by an explosive incendiary bomb.

Types of Jamming Employed

All types of station were jammed with the sole exception of those working on decimetre or centimetre waves. C.H. stations were mostly jammed by F.M.C.W., although "railings" was used in the early part of 1942. Later other forms of pulsed transmission were tried by the enemy. One of these

[1] No. 60 Group and No. 75 Wing, O.R.B.s.
[2] Headquarters, Fighter Command, O.R.B.
[3] Air Ministry File S.6412, Encl. 190A.
[4] Headquarters, Fighter Command, O.R.B., Intelligence Summary No. 376.

was called " Road Drill " (from its sound when monitored in the loud-speaker) and it came into use in April 1942. gradually replacing " railings."[1] Its appearance on the cathode ray tube was of evenly-spaced pulses spread right across the time base. The signals persisted for 4 milliseconds in every 20 milliseconds and then slowly drifted off the time-base. Another form was known as " Spaced Pulses." Of these, " railings " was by far the most troublesome. After November 1942 most pulse transmissions ceased against the C.H. stations and only F.M.C.W. was used.

On the 157–236 megacycles per second frequency band (covering Mark III I.F.F., A.I., A.S.V., C.H.L., G.C.I., Light Warning and Oboe installations) other types of modulation were used, in addition to the jamming experienced by the C.H. stations. The signals usually contained low frequency and high frequency amplitude modulations—frequency modulation often being present also. During a typical jamming period on this frequency band some twelve to fifteen enemy transmitters were active, the calculated number available in the Calais-Boulogne area being about twenty-four. The transmissions were either horizontally or vertically polarised.

Some C.H.L. stations had special modifications to the receivers installed which permitted improvement to the I.F.R.U., although it was noted in some instances that the relief afforded by the wider bandwidth of the new Intermediate Frequency Unit was partially annulled by a reduction in signal/noise ratio. This was overcome at Beachy Head C.H.L. Station by fitting both units to the receiver with a change-over switch, so that wide bandwidth could be brought into use. C.H.L. stations were being issued as rapidly as possible with anti-jamming cathode ray tubes and filters, and variable bandwidth devices were gradually being installed in the equipment. The new C.H.L. station I.F.R.U.s were being gradually fitted from the spring of 1943.

Much time and thought was devoted in 1943 to anti-jamming measures for the C.H.L./G.C.I. stations, but the full results of this policy were not seen till the following year. The main measures tested were Pulse Width Discriminators and a Rejector Unit, Type 7. Experimental equipment was installed at Sandwich, Swingate and North Foreland Stations, giving satisfactory results. From the summer of 1943 the C.H.L. stations, which had previously worked on a uniform frequency of 200 megacycles per second, were staggered on the two frequencies 200 and 193 megacycles per second for the whole of the Southern area of England between Bempton and Kete.[2] It was thought that by this means the enemy would have to double his transmitters if he wished effectively to jam all C.H.L. stations at the same time.

" Window " Jamming

A form of jamming had been developed by the British as a counter-measure against German radar stations and was known by the code name " Window."[3] It consisted of thin strips of metallised paper, cut to the wavelengths of the radar stations, and dropped from aircraft. These paper strips gave a response on a cathode ray tube much like that of aircraft and proved very confusing, giving an appearance of several hundred aircraft. Amidst this confusion the tracks of the real aircraft were often able to escape detection. This form of counter-measure was first used by us with great success on 23 July 1943.

[1] No. 75 Wing, O.R.B., and Air Ministry File C.S. 15041, Encl. 73A.
[2] Air Ministry File S.3522, Encl. 24A.
[3] Volume VII gives a full account of " Window."

Not unnaturally, the enemy soon reciprocated with this method of producing spurious " echoes," and his first attack with " Window " jamming was made on 7 October 1943.[1] It caused slight confusion at first, but was quickly recognised and operators were able to plot through it successfully. Fortunately, operators had been warned to look out for this type of jamming, so that they were prepared when it finally came. There was no known form of anti-jamming device to combat it, but skilful and experienced operators were soon able to plot successfully through it. The chief disadvantage was that it made the counting of aircraft difficult and estimations of raid strengths were often unreliable in consequence. It is certainly true to say that at this time our efforts at jamming by " Window " caused far more trouble to the enemy than his caused to us. Nevertheless, it must be appreciated that the success of the Home Chain in continuing operations in face of " Window " was partly due to the fact that the enemy did not lay " Window " with any degree of skill during these attacks. Had he made a real effort, operations of both control and raid reporting stations would have been greatly reduced. Within No. 60 Group it was felt that " Window " remained a most serious menace to the ground search R.D.F. system—an opinion which was to prove extremely accurate in the light of subsequent operations.[2]

Final Enemy Policy against Early Warning R.D.F. Stations

During the last year of the War the Germans maintained their policy of countermeasures against early warning metric R.D.F. by using ground jammers against our C.H. and C.H.L. stations during their bomber operations. They experimented with jammers in special aircraft, but decided that these were not so effective as the ground jammers, because the frequencies on which R.D.F. Chain stations worked had to be constantly monitored and adjustments made to their transmitters to " follow " our stations : the airborne jammers were therefore abandoned.[3]

The newer higher frequency Chain stations (decimetre and centimetre stations) working on the " beam " principle, had very narrow beams, so it was impossible to jam them effectively. Even up to the end of the war the enemy were experimenting vigorously in an attempt to improve their jamming technique.

Although the enemy jamming proved effective on occasions against C.H.L. stations and partially effective against the C.H. stations, it was never capable of crippling the Home Chain completely. The original Air Ministry decision, taken in February 1942, to increase the number of frequencies in use and expand the decimetre and centimetre chain proved the most useful counter to enemy jamming efforts. Alternative frequency working of stations, together with the invulnerability of the centimetre " beam " stations against jamming meant that the early warning system could survive the enemy's attacks. Technically the Germans were never permitted to establish an appreciable lead over us in this jamming, though their efforts involved us in much inconvenience, research, and expense.

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[1] The Germans used the code name " Duppel " for " Window," a word with a similar pronunciation to the German word " dipol " (dipole), indicating the function of the metal strips.

[2] This was borne out during the operations in Italy during the early part of 1944. Details of this are given in Chapter 21, " Ground Search Radar in the Mediterranean Campaign, September 1943–May 1945," in this volume.

[3] A.D.I.(K) Report No. 380, 1945, para. 49.

CHAPTER 15

THE DEVELOPMENT OF LOW-LEVEL R.D.F. COVER AFTER 1941—C.H.L. STATIONS AND CENTIMETRIC WAVELENGTH OPERATIONS

By the beginning of 1942 there were many indications that despite the undoubted strength of the Axis forces, the opposition was stiffening considerably. During January 1942 the United Nations' Anti-Axis Pact had been signed in Washington by twenty-six nations. Only one year previously, Britain and her Empire had stood alone and our Island had borne the entire weight of aerial attack from the undivided forces of the *Luftwaffe*. Now, in 1942, the German Air Force was heavily involved on the Russian front and in the Middle East. As a direct consequence of this geographical dissipation of effort, the scale of the German aerial offensive against this country fell. The weight of bombs dropped on Britain during the entire year of 1942 was roughly only equivalent to one month's bombing during the intensive 1940–1941 winter *blitz*.

Based on a superficial examination of the weight of bombs dropped and the numbers of enemy aircraft involved, it would appear that the R.D.F. Home Chain had fulfilled its major task before 1942. Nothing could be further from the truth. The enemy made every effort to obtain a higher return from this reduced bomb tonnage—the raids were much more accurate and effective. In an attempt to achieve this, German pilots adopted tactics calculated to evade observation by R.D.F. The method which had given them most success in 1941 had been to approach our coast, flying very low. The Home Chain during 1941 had been unable to give adequate cover against such wave-hopping raiders, though it will be recalled that developments were in progress to counter this weakness in the raid-reporting system.[1]

The principal methods adopted may be summarised as :—

(*a*) An improvement in the C.H.L. Chain of stations, involving technical improvements, standardisation, and the completion of the Triple Service C.D./C.H.L. Chain.

(*b*) The adaptation of C.H.L. stations on high towers in an attempt to increase the range of detection on very low-flying aircraft.

(*c*) By far the most important method—the development of a chain of centimetric R.D.F. stations.

Although this narrative is concerned largely with the aircraft raid-reporting system, these low-cover R.D.F. stations also had the important role of surface-watching, giving information on the movements of enemy shipping in the English Channel and, very often, useful navigational information on the movement of our own shipping. Both the aircraft raid-reporting and surface-watching roles of these stations are therefore dealt with in this chapter.

The C.H.L. Stations

At the beginning of 1942 there were sixty-nine C.H.L. stations in operational use around the coast of the British Isles, forty-four having hand-rotated aerial systems and the remainder being automatically power-turned.[2] A further thirty-six C.H.L. stations were planned to complete the low R.D.F. cover, and of these twenty-two were commissioned during the 1942–1943 period.[3]

[1] Chapter 11 of this volume discussed the measure taken to counter the low-flying raiders.
[2] Air Ministry File C.S. 8143/II, Encl. 21A.
[3] No. 60 Group, O.R.B. The locations of the C.H.L. stations constructed during 1942 and 1943 are given in Appendix No. 19.

It will be recalled that many of the earlier C.H.L. stations had been constructed during the special " crash " programmes of 1940 and 1941. There had been a lack of standardisation about these stations. Three programmes involving major modifications to equipment were in progress at the end of 1941, and these alterations, completed early in 1942, were to bring the older stations up to the latest type as far as technical efficiency was concerned, and also to standardise the equipment.[1] The modifications comprised chiefly :—

(*a*) The conversion of the older C.H.L. transmitters to the latest type (T.3056), giving both increased power and range.

(*b*) The conversion of the separate transmitter and receiver aerial systems to a single common aerial array for both the transmitter and receiver.

(*c*) The improvement of the aerial rotating systems. The aerial framework and rotating mechanism had given some trouble and attempts were being made to increase aerial rotation speeds—a step considered to be essential for C.H.L. stations used for both normal raid reporting and for interception purposes.

C.H.L. Stations and Surface Reporting

Within the limitations of their range, the C.H.L. stations gave valuable information on surface craft, both hostile and friendly, to the Naval authorities. These shipping plots were passed directly to Naval Plot (or Control Room) and not to the Royal Air Force Filter Room. Some impression of the contribution made by the C.H.L. stations in this work may be gained from a letter, dated 31 March 1942, from the Flag Officer-in-Charge at Liverpool to the Secretary of the Admiralty, in which it was stated :—[2]

> " Six C.H.L. stations are directly connected by telephone to Liverpool Plot, reporting half-hourly day and night. In the past two months the efficiency of surface craft plotting has improved to a very high standard from all C.H.L. stations and great keenness and interest are shown by the R.A.F. operators.
>
> " The value of C.H.L. information has been clearly indicated and in the past month, during which haze or foggy weather in the Irish Sea has persisted, navigational assistance has been given to no less than twelve convoys, outward and inward bound, and on three occasions it was possible that disasters were prevented by issuing warnings to the escorts.
>
> " Confidence in the Liverpool Plot on the part of the Commanding Officers of the Liverpool Local Escort Vessels has been established, and it has not been unusual for several requests to be made for positions during night passages rounding the Chicken Rock and making the North Channel.
>
> " During the week ending March 28th, phenomenal ranges were obtained ; in one case Prestatyn plotted a convoy at a range of 60 miles and was able to give an accurate number of ships at that range. All stations have rendered valuable assistance."

Although C.H.L. stations on the west coast were able to offer so much useful assistance to the Naval authorities, similar stations in the south-east of England were not always able to give the very full information required by the Navy. In this area the almost incessant aircraft activity kept the C.H.L. stations

[1] Air Ministry File C.S. 8143/II, Encl. 20A.
[2] Air Ministry File S.3864/II, Encl. 160B.

fully occupied and it was often impossible to do full justice to the different types of information required by the Royal Air Force and the Royal Navy. However, the C.D./C.H.L. stations recently erected were taking over the Triple Service function from the C.H.L. stations in these vital areas. In addition the development of the centimetre equipment had progressed very favourably. Three Type 271 centimetre installations in the Army R.D.F. Chain together with the C.D./C.H.L. stations were able to take full responsibility for surface shipping in the Dover Naval Command by March 1942. It was laid down that, in future, reference by the Naval authorities to Royal Air Force C.H.L. stations was only to be made in the event of emergency, though these stations might be required occasionally to check the presence of I.F.F. on responses picked up by the centimetre equipments.[1]

C.H.L. Stations and Controlled Interception

Where hostile aerial activity was frequent over our South and East coasts there was an increasing demand made upon the C.H.L. stations for use in the controlled interception of enemy aircraft. With the increased speed of revolution of the continuous rotation of the aerial system instead of the older method of manually rotating or "sweeping," very accurate continuous tracking of aircraft could be carried out. In consequence, some C.H.L. stations were used very successfully for interception purposes, and ceased to form part of the normal raid reporting chain. This aspect of their activity is dealt with more fully elsewhere in this history.[2]

C.H.L. Stations on High Towers

One method of obtaining adequate warning of the approach of wave-hopping aircraft which was being explored was the use of C.H.L. stations on high towers, and towards the end of 1941 a decision had been taken to erect C.H.L. equipment on a 200-foot tower at Humberston as a prototype.[3] If this station proved successful, plans existed for further tower stations at West Beckham, Drone Hill, Happisburgh, Hopton, Dunwich, Cresswell and Bamburgh—all at sites selected because of the incidence of very low-flying raids in their areas.

The prototype C.H.L. (T) station at Humberston was operational during December 1941. A provisional report issued at the end of the year stated that it had been on the air since 10 December 1941. Activity since then had been slight and the assessment of very low-flying cover provided was not easy in consequence. The longest range then plotted over the sea was 143 miles. A theoretical performance chart then drawn gave the following pick-up ranges :—[4]

500 feet	32 miles.
1,000 feet	45 miles.
2,000 feet	60 miles.
4,000 feet	77 miles.
10,000 feet	110 miles.

These figures were, however, thought to be on the conservative side as the only information so far obtained was on limited activity, although some confirmation of these values was obtained by plots on a convoy at 30 miles and a pick-up

[1] Air Ministry File S.3864/II, Encl. 140A.
[2] Volume V, Part 3.
[3] Air Ministry File S.4039, Encl. 30A.
[4] *Ibid.*, Encl. 52B.

of 60 miles on an incoming bomber flying at 3,000 feet. Operations were rather erratic at first, but this was probably due to inexperience on the part of the operators, as later it was found that direction-finding was as good as, if not better than, that of other C.H.L. stations in the area. Direction-finding was found to be accurate at all bearings up to 60 miles. Test runs had not up to then been possible owing to prolonged unfavourable weather conditions.

Headquarters, No. 60 Group, summarised the findings to date at Humberston by stating that it did not appear possible to provide the ideal operational requirements under the high windage conditions which were likely to be experienced with power-turned C.H.L. stations on towers.[1] It was considered, however, that the additional coverage obtained by the extra 200 feet outweighed any limitations and that if power-turning gear could be operated in wind speeds up to 65 miles an hour, and if the rate of sweep could be controllable from 2 to 6 revolutions per minute under normal conditions, then erection of similar installations should proceed.

The desirability of being able to switch over instantaneously from the tower aerial on the new equipment to the ordinary 20-foot gantry aerial on the old equipment as a form of gap-filling became a subject of discussion. Fighter Command, in a letter to Air Ministry dated 28 January 1942, stated that though rapid switching facilities would be an attractive proposition, the primary operational role of the tower stations should not be allowed to suffer for the purpose of providing additional high-flying cover.[2] It was feared that this might be the case if the operator was able to switch rapidly from one aerial system to the other, owing to the danger of missing low-flying aircraft when using the gantry aerials. It was, in consequence, recommended that rapid switching facilities should not be provided on any tower station and that the gantry aerials should be regarded only as a reserve for the tower aerial array.

A complication arose in February 1942 regarding the erection of these towers, as it was thought that they might prove an obstruction to our own aircraft flying in the vicinity. In consequence, work was held up on five stations (Bamburgh, Cresswell, Hopton, Happisburgh and Dunwich).[3] The matter was referred for decision to the Deputy Chief of Air Staff, who ruled that these towers were necessary in order to give adequate warning of the approach of low-flying raiders, and that the operational necessity outweighed the possible risk of collision. Authority was therefore given on 4 March 1942 for the work to be implemented, subject to the provision of adequate safeguards, such as obstruction and warning lights on the masts.

Work therefore continued on the building of these towers and on the installation of their aerial arrays. The first to come into operation was Cresswell, commissioned in November 1942. Hopton and Happisburgh became operational the following month, and finally Bamburgh and Dunwich came on the air in April 1943.[4] Headquarters, 60 Group, commented in their monthly report that the new aerial array at Hopton gave very promising operational results, whilst Dunwich reported that their tower array gave them increased ranges on shipping tracks; this was confirmed by Happisburgh, who also reported increased ranges on aircraft.

[1] Air Ministry File S 4039, Encl. 50A.
[2] Headquarters, Fighter Command, File F.C/S.20424, Encl. 71A.
[3] Air Ministry File S.4039, Encl. 90A.
[4] No. 60 Group and Nos. 73 and 74 Wing, O.R.B.s.

Project abandoned on C.H. Cantilever Towers

Work on the station at West Beckham, where it had been intended to mount a C.H.L. station on a cantilever of one of the C.H. station steel towers, was suspended in November 1942 and the project abandoned. It was considered that the need for this station was no longer justified in view of the fact that

(*a*) Tower stations were being erected nearby at Hopton and Happisburgh.

(*b*) The use was impending of pre-amplifiers which would give a marked improvement on low-flying aircraft performances on existing stations.

(*c*) Installation was projected of a high-power 10-centimetre equipment at Hopton, and

(*d*) It had now become urgent, owing to the increasing calls for R.D.F. cover at home and overseas, to conserve operational manpower, installation effort and technical gear.

Work was for similar reasons suspended in December 1942 on the tower installation at Drone Hill C.H. Station. It was also considered undesirable to erect further ordinary C.H.L. (200 megacycles per second) stations owing to the jamming then being experienced from enemy sources, and the development of more efficient ultra-high frequency equipment.[1]

Termination of C.H.L. on High Towers Policy

Some criticism of the performance of the station at Happisburgh was made in April 1942, and consequently investigations into the performance of this and all other C.H.L. tower stations were made in the next few months. However, in a report made in February 1944, No. 60 Group Headquarters reported that their investigations carried out over a period of several months showed that the performance of the tower stations was well up to standard.[2] In all cases the results of test flights showed that adequate low cover was obtainable. It was recommended that no further research be undertaken into the performance of these stations in view of the fact that the high-power 10-centimetre chain was now coming into operation and these stations would be able to pick up any aircraft which might possibly escape detection by the C.H.L. tower stations.

The programme for C.H.L. on high towers was developed as an operational requirement, namely, to counter the very low-flying raider. It was expensive in installation and research man-hours. Subsequently the decision to erect further stations on the steel towers of C.H. stations had to be abandoned because the 10-centimetre R.D.F. equipment gave a better performance on a more economical basis. The C.H.L. on towers programme must be regarded as another example of a technique which became obsolescent as a result of progress in research. It was essential to make adequate provision against possibilities, some of which inevitably proved unnecessary in the long run. The C.H.L. (T) type of station was abandoned because the ultra-high frequency R.D.F. equipment supplanted some of its functions and it was thought at the time that it gave much superior results for considerably less outlay.

The Triple-Service C.D./C.H.L. Stations

Although the original scheme[3] for the C.D./C.H.L. Triple Service Stations was intended to be complete for our South and South-East coasts by the spring of 1941, and later to be extended all round the coastline, there had been considerable delay in implementing this project. The twelve stations, for the construction of which the Army had been responsible, were very much behind

[1] Air Ministry File S.4039, Encl. 140A and 141A. [2] *Ibid.*, Encl. 151A.

[3] The original scheme is illustrated by Map No. 3 and described in Chapter 11.

schedule. Unforeseen difficulties, not only technical but also such considerations as the provision of reporting telephone lines, approach roads and living accommodation, had prevented the inclusion of these stations in the full Royal Air Force reporting and operational system.

On 21 January 1942, however, the first Army station fulfilling the functions of a C.H.L. station was taken over by the Royal Air Force and became immediately operational. This was Bard Hill in North Norfolk, and it was followed at the beginning of April by The Needles (Isle of Wight), Goldsborough (near Whitby), Westcliff (Portland) and Bolt Tail (Salcombe, S. Devon). Three more came into operation in the following month: Marsden (South Shields), Oxwich (Gower Peninsula) and The Jacka (near Falmouth)), and by 31 May the remaining stations—Crannoch Hill (Elgin), Westburn (Aberdeen), The Law (Carnoustie, Angus) and Black Head (County Antrim)—of the original C.D./C.H.L. chain were operational. Thus a thin chain of stations, the nucleus of the final Triple Service Chain envisaged for the future, was complete, covering the South and East coasts of England and Scotland from The Jacka in Cornwall to Crannoch Hill in Banffshire, with one station to cover the approaches to Belfast Lough.

Though these stations were in use, much remained to be done before maximum efficiency was obtained, but it was felt that the need for maintaining a constant watch on shipping was so urgent that the stations should work with the apparatus already available; further improvements and modifications were to be made by No. 60 Group as opportunity arose.

The stations were operated by Royal Air Force operators from No. 60 Group, with a normal crew establishment as for a C.H.L. station, and in addition four Naval and four Army observers (ratings and other ranks—one each per watch) whose duties were to man the Naval and Army reporting lines respectively, and to pass to their appropriate Operations Rooms all relevant information. Shipping plots were generally reported at quarter-hourly intervals, although more frequently if the occasion warranted it.

The Development of Centimetre Equipment

The chief technical development during 1942 was in the field of very high frequencies, which led to an increasing use of equipment working on a 3,000 megacycles per second frequency (10 centimetres wavelength). The great advantages of centimetre stations were that they could be used equally effectively for the detection of surface objects and for the detection of the very low-flying hostile aircraft. Great advances were made in the period under review in this chapter by the setting-up and consolidation of a chain of centimetre stations—known as the C.H.E.L. Chain (Chain Home Extra Low)—used jointly by all three Services for surface watching and the detection of the very low-flying raider.

One other advantage of ultra-high frequency equipment, and an additional reason for hastening its development and production, was that as it employed a very fine beam it was very difficult to jam.[1] In common with other equipments, it was liable to jamming when " looking " in the direction of a jamming station, but this would only have an effect on, at worst, an arc of 10°. Jamming by the enemy had by this time become so troublesome to C.H. and especially C.H.L. stations that the installation of centimetre sets became imperative to ensure adequate R.D.F. cover at all times and in all conditions.

[1] Air Ministry File C.S. 16660/R.D.F.1, Encl. 48A.

From 1941 onwards the possibilities of applying the Naval Type 271 R.D.F. equipment to the problem of the efficient detection of the very low-flying raider were being explored ; its value in the detection of surface craft was already apparent.[1] This set worked on the ultra-high frequency band of the order of 3,000 megacycles per second and, employing the new magnetron valve, had a power of 7 kilowatts.[2] During the late summer of 1941 the Low Cover and Surface Planning Sub-Committee of the Inter-Service R.D.F. Committee had noted the advantages of the Type 271 equipment as :—[3]

(*a*) The detection of very small craft at long range. This was possible with an apparently greater consistency than was obtainable with C.H.L. equipment.

(*b*) Owing to its very narrow beam it could probe those areas which presented a clutter of permanent echoes on the C.H.L. display, and

(*c*) Its ultra-high frequency beam had a low-angle coverage on very low sites.

This last factor was of great importance as this was the only real weakness in the Home Chain raid reporting system at the time. In December 1941 authority was given for the development of the Type 271 set to meet the requirements of the Royal Air Force, and the first experimental equipment was installed at Ventnor in February 1942.[4]

The first experimental installation was modified to common aerial working, using a ten-foot parabolic reflector on the rotating aerial system, and a Plan Position Indicator was incorporated for the observer. First operational tests indicated that the cover obtained against very low-flying aircraft and surface craft was good.[5] Further tests were carried out in the spring of 1942 and comparisons between a mobile Naval 271 set at Selsey Bill, on a site approximately 30 feet above sea-level, and the modified set at Ventnor, 780 feet above sea-level, led to the conclusion that for the successful use of the Type 271 as an aircraft tracking device, continuous rotation of aerials and the use of a Plan Position Indicator were essential. It was thought that little or no advantage would be obtained by the installation of this equipment at a high-sited C.H.L. station, but that considerable advantages might accrue with regard to the tracking of very low-flying aircraft and surface craft, if the set were installed at a C.H.L. station on low ground.[6]

Additional tests and developments were carried out, bearing these considerations in mind, and using higher-powered equipment. The experiments at Ventnor showed that with the Type 271 set then in use, aircraft at flying heights of 200 to 50 feet could be tracked to approximately 30 miles, with a faint response on occasion to 45 miles. As an instance of the success of this set, on 23 May 1943 it detected aircraft at a range of 34½ miles, which were identified one minute later as hostile.[7] A 15-minute warning was given between first pick-up and landfall. The raid turned out to be twenty enemy aircraft, flying at 50 feet. Fighter aircraft were unsuccessful in interception, but A.A. defences destroyed two of the raiders.

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[1] This is described in Chapter 11.
[2] The magnetron valve advantages are discussed in Appendix No. 8.
[3] Air Ministry File S.8696, Encl. 16A.
[4] Air Ministry File C.S. 17288, Part 1, Encl. 8A.
[5] Air Ministry File C.S. 12138, Encl. 1A.
[6] Air Ministry File C.S. 17288/1, Encl. 20B.
[7] Air Ministry File C.S. 19224/1, Encl. 11A.

Transfer of Army Surface-Watching Stations to the Royal Air Force

The ultra-high frequency Naval Type 271 stations were giving better results on shipping than the C.H.L. stations. A scheme was therefore formulated in March 1942, whereby Army and Royal Navy C.D. No. 1, Marks IV–VI stations (using Naval Type 271, later modified to the high power Type 277 equipments) were to be installed on Royal Air Force C.H. or C.H.L. station compounds for surface-craft detection.[1] A further plan was devised in July 1942, whereby No. 60 Group was eventually to take over all Army surface-watching stations in the early warning Chain. This latter scheme embraced the former, but was a long-term policy measure, whereas the first plan was being implemented by the summer of 1942. When operational, the C.D. No. 1, Marks IV–VI stations were to take over surface-watching functions from the C.H.L. stations to which they were attached, these then being used only for stand-by purposes.

Siting and installation for the various stations were to be the joint undertaking of the Royal Navy, Army and Royal Air Force, each Service being responsible for certain specific sites. The Royal Air Force was to take on charge immediately all stations on existing Air Force sites, and eventually those manned by the Army. Crews were to be drawn from all three Services.

The scheme whereby all Army surface-watching stations were to be transferred to No. 60 Group was planned to take place in two stages. First, No. 60 Group was to be responsible for the maintenance of each station's equipment by a certain date, manning and administration remaining the responsibility of the Army or Royal Navy. Second, No. 60 Group was to take over complete responsibility for each station.

The three Services had each utilised differing nomenclatures for their equipment. This was a possible source of confusion when considering the various stations from the Triple Service aspect. Accordingly, on 25 August 1942, a summary of the various types of equipment was made by the War Office and confirmed by No. 60 Group.[2] This introduced a revised nomenclature for the equipments which was to be used by all three Services.

The programme at that date laid down a total of sixty-three coastal defence stations using centimetre equipment already installed or envisaged, covering between them the coastline of Great Britain and Northern Ireland. Sixteen of the stations were to be in existing C.H. or C.H.L. compounds, seven in C.D./C.H.L. (Triple Service) compounds, eight on C.D./C.H.L. (Dual-Service, Army/R.A.F.) sites, eight on existing C.H.L. stations, five on Naval stations in the Triple Service area and the remainder were to be on new sites remote from any existing R.D.F. stations. Of these sixty-three stations, installations were at that time complete on sixteen, and work in progress at several more.[3]

Operational Control of Triple Service Surface-Watching Stations

A meeting was held at the Admiralty on 27 August 1942, between their representatives and those of the War Office and Home Forces, to discuss the operational control of the R.D.F. Surface Chain. It was agreed that the Admiralty should assume operational control of altogether one-hundred and three stations, either in being or planned, and including all those stations

[1] Air Ministry File C.S. 12788, Encl. 92B.

[2] The Summary and Revised Nomenclature are given in Appendix No. 21. (Reference, Air Ministry File C.S. 12788, Encls. 71A and 92A.)

[3] *See* Appendix No. 20 for list of Air and Surface-Watching Stations at 31 December 1942.

mentioned in the previous paragraph.[1] The transfer was to be made area by area, as arranged between the Admiralty and Headquarters, Home Forces, subject to the following conditions :—

(*a*) The transfer was to take place when the stations had been taken over by the Royal Air Force for manning and maintenance.

(*b*) The Admiralty undertook to supply to Army Plots the information necessary to meet their requirements and to ensure that stations continued normal sweep during operations.

(*c*) The stations should operate solely for surface-watching over their allotted arcs of sweep. An additional set would be provided if stations were required to concentrate on individual targets for Naval purposes. (This set was not actually provided before 1944.)

The first eleven stations were taken over by the Royal Air Force by December 1942, followed by three more in May 1943. By December 1943 practically all surface-watching stations had been taken over for manning and maintenance by the Royal Air Force, operational control being exercised by the Navy.[2] A few stations, however, were retained solely by the Navy for their own particular needs, maintenance only being provided by the Royal Air Force, and these stations did not come into the normal reporting system of the Royal Air Force.

Value of Centimetre Equipment against the Low-Flying Raider

Added impetus to the more speedy adoption of ultra-high frequency R.D.F. equipment by the Royal Air Force was provided by the Air Officer Commanding-in-Chief, Fighter Command, who in September 1942 referred to the numerous attacks being made by the enemy on coastal targets in the South of England by very low-flying aircraft, frequently *Focke-Wolf 190* fighter-bombers, which came in at sea-level.[3] He stated that the existing C.H.L. stations on the South Coast, in spite of the fact that they were mostly high-sited, seemed quite incapable of providing adequate warning of such attacks. It did not seem to him that technical adjustment or improvement in operators' skill would make any substantial improvement in the detection of these aircraft, and other measures would be necessary.

As a solution, the Air Officer Commanding suggested the provision of 10-centimetre sets, similar to the Naval Type 271 sets but higher-powered, in all areas where very low-level attacks were likely to be made by the enemy, and as an instance he stated that a suitable equipment on trial at Great Orme's Head (the N.T. 273 medium-power 70-kilowatt equipment) had shown that an aircraft flying at 50 feet could be detected at approximately 35 miles.

Unfortunately, Plan Position Indicators were still unavailable in any quantity, and this lack meant that owing to the very narrow beam-width of 10-centimetre equipment the rate of sweep was so reduced that the arc over which efficient detection could be reasonably guaranteed was not likely to be more than 60°. The result of this would be that at any particular C.H.L. site at least two high-powered 10-centimetre equipments would be required in order to ensure that the coverage provided by this apparatus would be superior to that of the C.H.L. stations equipped with Plan Position Indicators (P.P.I.). The provision of a

[1] Air Ministry File C.S. 16640, Encl. 1A.
[2] Air Ministry Files S.12138/I, Encl. 112A, and S.16640, Encl. 15A.
[3] *Ibid.*, Encl. 36A.

suitable P.P.I. for use with 10-centimetre equipment was a matter of great urgency, but pending this development Fighter Command recommended that all C.H.L. stations between Land's End and The Wash be provided with two high-power 10-centimetre sets, to be reduced to one per site when effective P.P.I.s became available.

Difficulties of design made it impossible for this recommendation to be implemented in full, but developments were hastened on an Admiralty set, Type 273, Mark V, which it was hoped would help meet the need for low-flying cover. This set was undergoing tests at Ventnor and Great Orme's Head and was an improvement on the Type 271 set in so far as it was specifically designed to provide cover for aircraft and was not merely an adaptation of a surface-watching instrument.[1] As it was an Admiralty design, however, it was not anticipated that production would be available in quantity for the Royal Air Force before June 1943.

In order to give the Service operational experience with 10-centimetre equipment for aircraft cover, A.D.R.D.E.[2] was making the technical equipment for three C.H.E.L. stations for installation at Beachy Head, Happisburgh and Deerness (Orkney), these three sites being of high, low and medium altitude respectively. The equipment was similar to the experimental high-power set already in operation at Ventnor (known locally as the H.P.T.) comprising a ten-foot paraboloid reflector aerial system mounted on an Army type gantry over one-third of a standard Nissen hut, the latter being the Operations Room. The equipment was to be provided with a high-power 500-kilowatt magnetron valve, with both P.P.I. and range tube displays, and seemed to be the most satisfactory set yet designed for its purpose.

Reporting of Very Low-Flying Aircraft by Surface-Watching Stations on the South Coast

In order to give every assistance to Fighter Command Operations Rooms in the early reporting of very low-flying aircraft, the Radio Board recommended on 27 October 1942 that certain surface-watching stations should operate primarily for this purpose over their allotted arcs of sweep, but aircraft information observed by them should be relayed through C.H.L. stations to operational Filter Rooms and Sector and Gun Operations Rooms, providing that this did not interfere with the surface reporting function of the station.[3] If a station was required to concentrate on individual targets for Naval purposes (as, for instance, at Capel) then an additional set of equipment would be provided.

The Air Officer Commanding-in-Chief, Fighter Command, recommended that as a temporary measure these stations should be allotted a primary rôle of watching for aircraft during daylight hours and a secondary rôle of sweeping once in 15 minutes for surface watching. He further recommended that as many centimetre stations as possible should immediately be brought into action in the South of England and that P.P.I. displays should be provided at the earliest possible moment. As a consequence, Headquarters, Fighter Command issued orders on 18 February 1943 to Headquarters, No. 60 Group, repeated for information to the Admiralty and War Office (who later confirmed them to their own stations) that all ultra-high frequency stations on the South

[1] Air Ministry File C.S. 12138, Encl. 37A.
[2] (Army) Air Defence Research and Development Establishment.
[3] Air Ministry File C.S. 12138/R.D.F., Encls. 1A and 35A.

Coast should treat the detection of low-flying aircraft as a first priority. Naval and Army plotting rooms were to retain operational control and the right to order the full arc to be swept if and when considered necessary. Aircraft so detected were to be tracked and reported continuously to Royal Air Force Filter Rooms and Sector Operations Rooms through the associated C.H.L. telephone lines.

Provision of Further Cover against Low-Flying Aircraft

Instructions were given in February 1943 for the installation of eight special R.D.F. equipments in addition to already existing stations, their sole purpose being the detection of very low-flying aircraft. These sets were to be of the Type 273, Mark V, Admiralty pattern and six were, in fact, in operation by the end of March 1943, so great was the urgency of this requirement in view of the enemy's tactics to evade our early warning R.D.F.[1]

On 28 February 1943 the Director-General of Signals wrote to the Air Officer Commanding-in-Chief, Fighter Command, stating the action taken to provide special R.D.F. cover on the South Coast for the detection of low-flying raiders.[2] The Admiralty agreed to put temporarily at the disposal of the Royal Air Force three Naval Type 273 Mark V stations, to be sited on existing C.H. or C.H.L. stations at the discretion of the Royal Air Force, and in addition they promised that any information on very low-flying aircraft obtained by them at their new station at Capel (then undergoing test) should be placed at Air Ministry's disposal. Both the Admiralty and the War Office agreed that all Coast Defence Mark IV stations from Dengie to Start Point should be used primarily for aircraft detection during daylight. In the meantime the Telecommunications Research Establishment and the Admiralty Signals Establishment were pressing on with the development of suitable P.P.I. displays and power turning gear for the Type 273 stations. Two centimetre height (C.M.H.) Mark I stations which had been intended for use by the Admiralty in Orkney were also diverted instead to the South Coast to help to strengthen existing R.D.F. defences.

The ultra-high frequency R.D.F. technique was the only really successful method of obtaining early warning against the very low-flying raider, and so by April 1943 further low cover was provided using Royal Air Force Stations, Types 13, Mark I, and 14. The Type 13, Mark I station was the Air Force nomenclature for the Centimetre Height Set, originally designed for height-finding on C.H.L. stations. This equipment had proved rather unsatisfactory in performance and so was relegated to the rôle of watching for very low-flying aircraft. The Type 14 station, ultimately to replace all stations Type 13, Mark I, was the Naval Type 277 set. Installation details were as follows :—

(*a*) *Stations, Type 13, Mark I*, were provided at North Foreland, Kingsweir Beer Head and Fairlight. A note is made in the Operations Record Book of Headquarters, No. 75 Wing in No. 60 Group to the effect that the very low-flying cover was considerably improved by the addition of the two sets at North Foreland and Fairlight. The latter became operational on 18 April 1943, and five days later it was reported that the station had been able to keep continuous track of a raid flying at zero feet in mid-Channel at about 20 to 30 miles from the station.

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[1] Air Ministry File C.S. 12138, Encls. 59A, 72A and 87A. [2] *Ibid.*, Encl. 74A.

(*b*) *Stations, Type 14* were designed for the dual rôle of the detection of low-flying raiders during daylight hours and for detection of surface craft at long range during the night. Production of the Type 13, Mark I equipment had ceased in 1943 and it was intended that these should be replaced by Type 14 sets. The first Type 14 equipment was installed at Capel for the Royal Navy and during the spring of 1943 further stations, in mobile form, became operational at Beachy Head, Ventnor, Start Point and The Verne. It was anticipated that further equipment of this type, when available, would be installed on other south coast stations.

Operational Performance of Type 13 Mark I and Type 14 Equipment

The German practice of approaching our shores flying just above the sea to avoid detection by R.D.F. had initially achieved a high degree of success, but the new ultra-high frequency equipment could detect the approach of these wave-hopping raiders. The length of the warning was short, but gave sufficient time to permit interceptions to be made and also to warn anti-aircraft gun defences in the area likely to be attacked. The following specific instances give a picture of the effectiveness of the warning obtainable from Types 13, Mark I, and 14 stations :—[1]

(*a*) During an attack on Hastings on 23 May 1943, Fairlight T.13, Mark I station picked up a low-flying raider at 30-mile range, giving a warning period from pick-up to landfall of 11½ minutes. Four Typhoon aircraft intercepted and destroyed one *F.W.190.*

(*b*) On 25 May 1943, Beachy Head Type 14 station detected a formation of aircraft at a range of 22½ miles, with a warning period of 8 minutes (though only 3½ minutes warning after Filter Room gave a hostile identification). Five enemy aircraft were destroyed by A.A. guns and two by fighter aircraft.

(*c*) On the same day twelve *F.W.190s* set course for Folkestone and were picked up by Capel Type 14 station at a range of 18 miles. Immediate hostile identification followed and seven patrolling Spitfires sighted the formation and destroyed five raiders.

(*d*) On 30 May, Beer Head Type 14 equipment detected a formation at 26 miles range, and Kingsweir C.H.L. saw it only at 9 miles range. Nineteen miles of filter track were passed to Exeter Operations Room. The Air Raid Warning was given five minutes after the first plot, but unfortunately bombs were dropped on Torquay at the same moment, causing twenty-one fatalities. Thirty-two of our aircraft were airborne, including Typhoons which took off three minutes after the first plot. One enemy aircraft was destroyed by fighter aircraft and three were shot down by the A.A. defences around Torquay.

With a range of detection which may be seen from the above examples as between 20 and 30 miles the time factor for actioning such plots was of great importance. Every effort, therefore, had to be made to avoid any delay in both Filter and Operations Rooms.

Installation of High-Power Centimetre Equipment

To provide further cover in the Triple Service Chain, and in particular to counter the low-flying enemy aircraft which were making repeated raids along the East Anglian coast, it was decided in May 1943 to install high power

[1] Air Ministry File C.S. 19224, Part 1, Encl. 11A.

equipments on towers at six existing R.D.F. stations.[1] These stations were to be of the C.D. No. 1 Mark VI** (Tower) type, mounted on 200-foot towers using a high-power equipment known as the Naval Type 277—a high-powered version of the Type 271. The apparatus was to be installed in half-Nissen huts at the base of the towers, and 9-inch Plan Position Indicator tubes were ordered. The need for this low cover was so great that the project was awarded the highest priority. Rapid progress was made, and the first station, Hopton, became operational on 23 June 1943, followed two days later by Trimingham. Thorpeness and Winterton came on the air in July, Bard Hill in August, and Benacre on 13 September.

A further twelve Naval Type 277 stations were approved and a meeting was called at Air Ministry on 10 July 1943, to discuss their installation. Some discussion had already taken place on the desirability of installing the transmitter at the top of the tower, as at Hopton, or at the base, as in the case of Trimingham. Comparative tests carried out in July proved inconclusive. The meeting decided to carry out tests over a period of some months, and if later it was agreed that the performance of stations using a transmitter at the tower base was equal to that where it was mounted on top of the tower, then modifications could be carried out. Transmitting equipment was to be installed on top of the towers at Bard Hill, Bempton, Dimlington, Skendleby, Thorpeness, Beer Head, Hopton, Start Point, Winterton, Dengie and the Naval station at The Verne. Transmitter equipment at the base of the towers was scheduled for Benacre, Bamburgh, Cresswell, North Foreland, Pen Olver, Rosehearty and Trimingham. The reason for this was that the first batch of stations listed was equipped with Army towers and lifts ; the second batch built with Royal Air Force towers, was not so equipped ; and lifts were essential if the constant maintenance required by this gear was to be regularly carried out by the station mechanics.

A decision was taken in August 1943 to extend low-flying cover on the East coasts of Scotland and England by installing C.D. No. 1 Mark VI** stations on the 200-foot cantilevers of C.H. station steel towers.[2] The stations were Douglas Wood, Drone Hill, Dunkirk, Bawdsey and Danby Beacon, which were to be operated in the dual capacity of air and surface watching, and Great Bromley, to be used for aircraft detection only. Difficulties arose in November 1943 over the erection of the ten centimetre high-power sets on the C.H. towers at Douglas Wood, Drone Hill and Danby Beacon. Originally, it had been hoped that when operational they would render redundant the original C.D. stations in the area, but it was now decided that better inshore cover was provided by the existing stations at Lamberton Moor, Saltburn and The Law, so that no economy would be effected. Work was therefore held up pending a decision as to their suitability.

During late 1943 further extensions were planned to the chain of centimetre high-powered static stations, some for long-range surface watching only, the majority for air and surface-watching, as the need for detection of very low-flying aircraft still persisted. Types 277 and 277A equipment was to be installed using either a 200-foot wooden tower, or a 200-foot cantilever of the C.H. stations, or a 20-foot gantry aerial system on the higher-sited stations.[3] It was hoped to obtain a continuous rotation rate of at least four revolutions per minute.

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[1] Air Ministry File C.S. 12788/1, Encls. 123A and 149A.
[2] Air Ministry File S.12138/II, Encl. 3A.
[3] Air Ministry File C.S. 12138/II, Encls. 25A and 46A.

A summary of the C.D. No. 1, Marks VI* and VI** stations at the end of October 1943, revealed a programme of forty stations. Thirteen were operational at this date and good progress was being made on a further fourteen stations, which were due for completion by the New Year. Thirteen of the stations were high-powered on Army 200-foot towers, but the remainder were high- or low-powered and mounted on truncated towers, on gantries or in "Gibson Boxes."[1] The area covered was from the Moray Firth southwards to Pembrokeshire, with one station at Greystone in Ulster and another, Deerness, covering Scapa Flow.

Filter Room Instructions for Plotting on Low-Flying Aircraft

In an endeavour to hasten identification at Filter Rooms and to ensure immediate priority for any tracks suspected of being hostile, Fighter Command issued an Operational Procedure Instruction on 31 March 1943, which laid down that plots from R.D.F. surface watching stations (known as "K" stations) and from stations, Type 13, Mark I (Centimetre Height) and Type 14 (Naval Type 277) should be told immediately via the associated C.H. or C.H.L. station and given priority on the telephone line.[2] All such plots were to be prefixed with the letter "K" and were to take precedence over all others. Special display plaques were provided for use in the Filter Room so that Filter Officers and Controllers could see immediately which plots were from these stations. In addition, as each plot was passed the plotter was to call the attention of the Sector Controller to it by saying "K" Plot in a loud voice as soon as the information was received and displayed on the table. Controllers were instructed to treat all "K" plots as potential hostile tracks and to take appropriate action without delay.

It was realised that Stations, Type 14, would help materially in plotting our own fighter patrols, but the continuous tracking of friendly patrols could not be achieved at this time, and so it was inevitable that a number of the "K" plots passed would prove to be friendly aircraft, with numerous false alarms arising in consequence. Nevertheless, this fact was not to be allowed to delay intercepting action, as "K" plots might often be the only indication of attack before such action was actually in progress. Priority was given for providing these stations with adequate telephone facilities for reporting direct to all Operations Rooms concerned.[3]

Possibility of Low-Flying Raids at Night

A new factor had to be taken into consideration with the lengthening nights of the autumn of 1943—the possibility of the enemy sending over very low-flying aircraft by night as well as by day. This possibility was first envisaged in a letter dated 8 October 1943 by the Air Officer, Commanding-in-Chief, Fighter Command, to the Under-Secretary of State for Air. In this he stated that events had proved that there was a serious danger of hostile aircraft approaching this country by night at very low levels, particularly during moonlight periods, thereby evading detection by the normal R.D.F. reporting Chain.[4] If these raiders were to be detected it was essential that full use should be made of the anti-low-flying C.H.E.L. Chain (Chain, Home Extra-low) by night as well as by day, and for that purpose it was necessary that stations should be permitted to maintain a continuous rate of sweep so that no area should be left uncovered for even a short period of time.

[1] "Gibson Boxes" were small wooden transportable cabins.

[2] Headquarters, Fighter Command File F.C./S.27004/Ops. 2 dated 31 March 1942, and Air Ministry File C.S. 12138, Encl. 89A.

[3] Air Ministry File C.S. 12138/II, Encl. 56A.

[4] *Ibid.*, Encl. 32A.

The Naval requirements from C.H.E.L. stations included the plotting of hostile surface craft, the accurate and detailed plotting of friendly shipping, the conduct of sea strikes, and, in collaboration with the Royal Air Force, the conduct of air/sea strikes. For all these purposes the current Naval practice was to stop sweep every time an observation was to be made in order to take plots of surface craft from the range tube, using the range and bearing method of plotting. If adequate air cover was to be provided while surface craft were being plotted, it was necessary that a constant rate of sweep should be maintained and all plots read from a Plan Position Indicator tube. The Admiralty reviewed the position of their stations in view of Fighter Command's statements, and stated that the policy then in operation for High-Power Dual-Purpose Radar Stations, Type 14, was, in general, that stations watched for low-flying aircraft by day under Royal Air Force tactical control, and for surface craft by night under Naval control.[1] This made possible the development of two operational systems—the Royal Air Force method whereby stations swept continuously and read plots from a P.P.I. tube, and the Naval system where continuous rotation and P.P.I. readings were only adopted until it was necessary that concentration should be made upon specific targets. If continuous sweeping could be generally accepted, a great advance would be possible, because all distinctions in the tactical control of stations would disappear, and stations would sweep continuously and report whatever was seen to the correct quarter. A very considerable economy of high-power stations and crews would result with consequent simplification of the chain and of maintenance. Trials were, therefore, instituted by the Admiralty to decide whether the system of continuous sweep could meet all or any of the Navy's requirements. These trials were carried out in November at Hopton and Beachy Head.

The Army Commander-in-Chief, Home Forces, considered, after studying the results of these trials, that the dual-service use of high-power centimetre radar stations employing continuous aerial rotation with P.P.I. presentation (and a separate tube for surface watching) would be acceptable for all Army purposes, subject to certain safeguards when particular information on any target was required by them.[2]

The Admiralty, in consequence of the foregoing trials, agreed at the end of 1943 to the policy of continuous sweep, with the following provisos :—[3]

(*a*) That the local Naval Plotting Rooms should have power to interrupt the continuous sweep for counting or estimating size for a period not exceeding 20 seconds in any two minutes. Further, that this period might occasionally have to be extended, particularly at night, during the course of an action, or other special circumstances at the direction of the Flag Officer controlling the Operation. It could be accepted that these occasional protracted periods would only be ordered with the greatest discretion by the Flag Officers concerned and full arc sweeps would be interposed whenever the state of the action permitted. This requirement necessitated that adequate " inching " control should be fitted in the continuous sweep gear, so that the sweep could if necessary be stopped momentarily to investigate any particular response.

[1] Air Ministry File C.S. 12138/II, Encl. 47A.
[2] Air Ministry File C.S. 12138/II, Encl. 68A and 70A. [3] *Ibid.*, Encl. 85A.

(*b*) That each high-power radar station concerned should be fitted with a second P.P.I. tube, the range tube being flanked on either side by the Surface Watching and aircraft detecting P.P.I. tubes.

The whole matter was discussed at a meeting of the Radar Board in January 1944, and agreement was expressed with the Admiralty's proposals, with a recommendation that they should be adopted subject to further review should this prove necessary in the light of operational experience.[1] Consideration was also given to the proposals for providing extra P.P.I. tubes and facilities for reading I.F.F., and Air Ministry gave instructions to all parties concerned to implement this policy at the earliest possible moment.[2]

By the end of 1943, the counter to the enemy very low-flying attacks could be said to be operating successfully. The centimetre station had proved to be the answer to this problem which had faced our defences since 1941. The Home Chain ultra-high frequency stations could give cover both by night and day against the very low-flying raider. Out of the original Admiralty proposal, considered at the 16th meeting of the Inter-Service Committee on R.D.F. during January 1941 for a common C.H.L. Chain for all three Services, had now been developed an ultra-high frequency R.D.F. Chain with the original C.D./C.H.L. stations acting as stand-by equipment. On superficial considerations, three years may appear an unduly long period in which to achieve a satisfactory Coast Defence Chain. It must be appreciated, however, that in addition to the original C.D./C.H.L. Chain, the new ultra-high frequency technique had been adapted to Coast Defence requirements and equipment had been produced and installed.

The Triple Service Chain may be regarded as a triumph of technical liaison between the three Services. It provided adequate R.D.F. cover against the very low-flying enemy aircraft as well as surface-watching and was therefore a valuable adjunct to the C.H. stations—which, however, continued to give the broad picture of enemy activity on to which the reports from the centimetre stations had to be superimposed.

[1] The R.D.F. Board had been inaugurated at a meeting of the Radio Policy Sub-Committee on 27 February 1942, and held its first meeting on 4 March 1942. It became known as the Radar Board on 22 June 1943. Membership consisted of Service representatives from the branch of each of the three Service Ministries responsible for R.D.F. policy in their Service, under the chairmanship of Air Commodore V. H. Tait. Its terms of reference included the co-ordination of inter-Service action with regard to operational requirements, recommendations regarding the development, provision and allocation of R.D.F. equipment for home and overseas, the collection and dissemination of R.D.F. information to the Service Planning Staffs, and co-operation on R.D.F. matters with Dominion and Allied authorities.

[2] Air Ministry File C.S. 12138/II, Encl. 96A.

CHAPTER 16

GENERAL OPERATIONS OF THE HOME CHAIN DURING 1942 AND 1943

Although the heaviest attacks of enemy bombers on this country took place in 1941, and the subsequent years were marked by a decrease in the tonnage of bombs dropped, the decrease in the numbers of enemy aircraft was not accompanied by a corresponding simplification of the pictures presented on the cathode ray tubes of the R.D.F. stations. Bomber Command was steadily increasing the weight of its attacks, and the Home Chain stations plotted all such " friendly " activity, often being able to render valuable assistance for the safety of bomber aircraft and crews.

The period under consideration in this chapter is technically largely one of refinement of R.D.F. equipment in the C.H. stations, and of improvements in the apparatus embodied in the experimental progress of the 1941 period, with few major modifications in design. Methods of plotting and filter interpretation of the R.D.F. information were constantly under consideration because the maximum value was often not derived from the information available. To obtain a general picture of the problems which faced the Chain during 1942 and 1943, it is necessary to review briefly the type of aerial activity, both hostile and friendly, which it was called upon to plot.

Hostile Activity

1942 was notable for the number of attempts by the enemy to retaliate for the increasingly heavy bombing offensive actions undertaken by Bomber Command and later by the United States Army Air Force. There were approximately four classes of enemy raid :—[1]

(*a*) The early " Baedeker " raids on non-industrial targets of 25/26 April and 8/9 May 1942,

(*b*) The later " Baedeker " raids and other attacks which continued onwards from mid-May,

(*c*) Daylight " tip-and-run " raids by very low-flying fighter and fighter-bomber aircraft, and

(*d*) Daylight raids by twin-engined aircraft.

The year 1943 saw developments in the equipment and technical methods used by the *Luftwaffe* in attacks against the United Kingdom. On Hitler's orders an " *Angriffsfuhrer England* " had been appointed to take charge of bombing activities directed against this country. *M.E. 410* light bomber and bomber-reconnaissance aircraft were introduced in the summer, and the *Ju. 188* bomber in the autumn. Single-engined *F.W. 190* fighter-bomber aircraft were used by night as well as by day from April. A lesser tonnage of bombs was dropped than in the previous year, but attempts were made to get a higher return for this tonnage by an improvement in bombing accuracy, and to reduce losses by such tactics as mingling with the stream of returning British bombers, and by the use of faster aircraft.

[1] Headquarters, Fighter Command Intelligence Summaries and No. 60 Group O.R.B.

In the night raids of spring and summer 1943, the more accurate placing of flares and incendiaries by the leading enemy aircraft and the greater care by the Germans in the selection and briefing of their crews, produced a higher " raiding efficiency " than in the last half of 1942. This improvement was not maintained, however, and the enemy's battle casualties were considerable, and higher in proportion than in the previous year. Increasingly heavy casualties were imposed by our defences. By the autumn of 1943 such an ascendancy had been achieved that for the last three months of the year daylight flights over this country by any type of enemy aircraft were a rarity. " Tip-and-run " raids ceased at the end of the first week in June, partly because the enemy aircraft were needed in the Mediterranean, where a critical situation had arisen for the Germans as the result of Allied successes in the Tunisian campaign, and partly because the enemy found his raids too expensive both in men and machines.

Activity by Allied Air Forces, 1942–1943

Until 1942 the Chain had acted almost entirely in a defensive capacity, by giving warning of incoming hostile raids. This function it, of course, continued to fulfil, but in addition was now very much occupied in keeping track of friendly aircraft. Bomber Command's activities began quietly enough at the beginning of 1942, but its attacks became heavier and heavier as time went on. The development of R.D.F. as an offensive weapon, and the fitting of bomber aircraft with " Gee," " Gee-H," " H2S," and other forms of R.D.F. apparatus meant that more aircraft could be sent on raids at increasing range over enemy territory, with a greater accuracy of bombing. Production in this country was getting into its stride, and increasing numbers of aircraft were daily being delivered from the factories. The Royal Air Force training programme provided plenty of trained crews, enough to allow for new crews as well as replacements for casualties which were, unfortunately, mounting rapidly as the number of raids increased. Finally, by the middle of this period there was the valuable assistance of the United States Army Air Force, with its vast reserves of men and aircraft.

Activity gradually increased from 8 March 1942 when the first raid of aircraft using " Gee " was made, three hundred and fifty bombers going to the Ruhr, until 30/31 May 1942 when the " one-thousand bomber " raid directed against Cologne marked a turning point in our campaign. Intense activity at night continued throughout the summer, decreasing about November, when wintry weather brought its additional hazards. Daytime activity throughout the summer continued on an increasing scale, both day raids by bomber aircraft and offensive fighter sweeps keeping the coastal R.D.F. stations at concert pitch. Activity again increased from the spring of 1943. Stations which, early in 1942, thought themselves busy when one-hundred or more bomber tracks were plotted, were now regarding raids of five-hundred or six-hundred aircraft at a time as commonplace.

All this meant very considerable work for the Home Chain, particularly on the East and South-East coasts. Accurate tracks had to be maintained on the mass formations as they crossed the coast on the outward journey, with a constant watch for enemy fighter aircraft coming out to intercept them. Very careful watch had to be kept as our aircraft returned to base at varying times throughout the night and early daylight hours ; constant vigil had to be maintained for stragglers, for damaged aircraft unable to reach their home airfields and so returning by unexpected routes, and for aircraft in distress. Typical instances of the Home Chain co-operation with the Air/Sea Rescue services worthy of mention were :—

(*a*) On 4 June 1943, at 0329 hours, a returning bomber crashed in the sea ; a fade plot on the track given by a C.H.L. station marked the exact position. The station plotted four fighter aircraft guarding the spot for six hours until at 1010 hours the Rescue launch picked up all six of the crew. The associated centimetre station at the same time passed plots which were believed to be the dinghy and wreckage from the bomber.

(*b*) On 4 August 1943 St. Margarets, Type 14, R.D.F. equipment was the first station to pick up a response, later found to be a dinghy. Directed by plots from the station, a Walrus aircraft and twelve escorting fighter aircraft went to the rescue, and saved all the crew.

The C.H. Stations

The C.H. stations, which had proved their value during 1940–1941, were again the backbone of the raid reporting system throughout the period under review. The major portion of the C.H. station installation programme had already been carried out, and the years 1942–1943 were chiefly a time of consolidation. Twelve new C.H. stations were, however, completed in this period, filling gaps in coverage in the more remote parts of the British Isles, chiefly in Northern Ireland and North and West Scotland.[1] C.H. cover was now complete and adequate around the whole coastline of Great Britain and Northern Ireland. In addition, "Buried Reserve" equipments became operational and a "Remote Reserve" site was completed at St. Lawrence. An Intermediate C.H. station was commissioned at Broad Bay, near Stornoway, and two C.H.B. stations in the Western Isles of Scotland. These latter were stations using C.H.L. equipment plus a method of height-finding. They fulfilled the normal functions of C.H. stations but were placed in locations where siting difficulties made a full C.H. station impracticable. The great advantage of the C.H. stations was that they gave at all times a fairly complete picture of practically all aerial activity in their neighbourhood, the only real drawback being that very low-flying aircraft were beyond their scope. The C.H.L., centimetre, and G.C.I. stations all gave increasingly valuable help to our defences, but this was of a more specialised nature and only of full value when seen against the background picture depicted by the C.H. stations.

The extension of the C.H. Chain around the whole coastline, together with improved equipment and the provision to the majority of stations of adequate reserve equipment for use during maintenance and breakdown periods meant that Filter Rooms were always able to get a general idea of the activity in their area. C.H. stations again proved their worth particularly during periods of enemy jamming. Although they were often themselves affected, the enemy's attention appeared primarily to be directed towards the higher frequencies of the C.H.L. stations, which were sometimes rendered almost unserviceable. It was only rarely that C.H.L. and C.H. stations were jammed so intensively at the same time that adequate information could not be provided from either source.

[1] *See* Appendix No. 19 for all new station locations. These were taken from No. 60 Group, O.R.B.

The East and South-East Coast stations were particularly busy in these days, as here most of the Royal Air Force bomber activity was concentrated. Cathode ray tubes were often saturated with echoes when a heavy formation of bombers was plotted outwards over the sea, and frequently several hundred responses would be seen at a time, making individual tracking impossible and accurate estimation of numbers extremely difficult. After the one-thousand bomber raid on Cologne of 30/31 May 1942 one East Coast station's report read " tube was solid with echoes "—another report described it more enthusiastically as " literally dripping with echoes."[1] An indication of the activity displayed on the tubes is given by High Street's station report, which recorded on 4 August 1943, eight-hundred plus friendly aircraft as being seen at one time ; and on 30/31 of the same month they reported one-thousand aircraft. Despite the large numbers of aircraft seen, stations yet managed to pass readily intelligible information to Filter Room, and maintained a high standard of accuracy. A report dated March 1942 from the Headquarters, No. 75 Wing Operations Log stated that[2] " a fighter sweep and large formations of hostile aircraft were plotted at the same time. The accuracy of the plotting was directly instrumental in enabling Royal Air Force Station, Tangmere fighter aircraft to shoot down eight enemy aircraft without loss. Poling (C.H.) and Truleigh (C.H.L.) R.D.F. Stations saw most of these tracks."

An example of the increased range obtainable with improved equipment, allied to favourable weather conditions, was provided by Stenigot C.H. Station which, on 26 June 1942, plotted a high-flying photographic reconnaissance aircraft all the way to Bremen, a distance of 340 miles.[3]

Technical Improvements to C.H. Stations, 1942–1943

The main technical modifications to C.H. stations during 1942–1943 were concerned with the simplification of operation of the R.D.F. equipment, improved presentation to the Observer and more effective liaison between the Observer-Plotter and the Tracker, all leading to increased accuracy and speed of the R.D.F. information. Outstanding among these developments installed at the more important C.H. stations were :—[4]

(*a*) An improved C.H. station receiver, R.F.8, which included the new Electronic Range Marker (E.R.M.). This latter " electronic pointer " replaced the range marker mechanical coupling between the Observer and Tracker cathode ray tubes on earlier type receivers.

(*b*) A new Console, Mark III, containing major improvements to the Tracker and a much more practical lay-out of the controls of the radio portion of the Console (The Tracker Unit).

(*c*) The Automatic Message Recorder—a device for the teleprinted transcription of R.D.F. information observed at the Station, for the station's official records for onward transmission to the Operational Research Section at Headquarters, Fighter Command.

The decision as to the priority with which C.H. stations were to be fitted with this new equipment was taken by the Chain Executive Sub-Committee on 4 July 1942.[5] The work was well in hand by autumn 1942, but all stations

[1] No. 74 Wing O.R.B. [2] No. 75 Wing O.R.B. [3] No. 73 Wing O.R.B.

[4] The earlier types of range marker and tracker unit were described in Chapter 11.

[5] Air Ministry File C.S. 16358, Encl. 3A. Details of the Receiver R.F.8, the Console, Mark III, and the Automatic Message Recorder are given in Appendix No. 22.

could not be supplied with completely new receivers and consoles. Under the reverse Lease-lend agreement with the United States of America, some of the first new R.F.8 receivers off production were sent direct to America for use on their developing Pacific Coast Chain of R.D.F. stations. In order to avoid any delay occasioned by this diversion of new equipment, the existing R.F.7 receivers on some of the Home Chain stations were converted into R.F.8 design and the necessary modifications made to the existing consoles. During busy periods of enemy or friendly aerial activity the Automatic Message Recorder did not find favour with R.D.F. Operators, who preferred to use manual recording instead. The other C.H. station improvements, however, to the receiver and console did much to ensure the increased operational efficiency of the stations, and so enabled them to deal with the heavy aerial activity which fell to their lot during 1942 and 1943.

General R.D.F. Ground Station Policy for 1942–1943

Towards the end of 1941 Air Ministry reviewed the capabilities of the R.D.F. sets then in use, with a view to planning development and manufacture for the ensuing year. Ten basic sets were then in use by the Royal Air Force, divided into the following groups :—[1]

(*a*) C.H. (Chain Home), M.R.U. (Mobile Radio Units), A.C.H. (Advance Chain Home) and their overseas equivalents. These stations used masts or towers and the goniometer method of direction finding, giving radio " flood-lighting."

(*b*) C.H.L. (Chain Home Low) and G.C.I. (Ground Controlled Interception) stations, using beamed transmission or radio " searchlight " technique.

(*c*) The Naval Type 271 equipment, a beamed transmission using ultra-high frequency and parabolic reflectors.

(*d*) High powered Air-to-Surface Vessel (A.S.V.) equipment which used a beamed transmission adapted for highly mobile ground use.

It was considered that the development of the ultra-high frequency R.D.F. technique should be carried out as an adjunct to the existing C.H. and C.H.L. Chain systems. The former policy had been that the C.H. stations, using a " radio floodlight " technique, were the only satisfactory method of long-range warning and had the advantage of being able to estimate the heights at which aircraft were approaching. In 1940 this conclusion had been quite correct, as comparison of the " floodlight " technique with radio beam or " searchlight " methods had been made between the then existing C.H. and C.H.L. stations. By 1942 the newer centimetre (or ultra-high frequency) equipment gave several advantages, the chief being that it could detect surface objects and, in its specialised form (Type 13, Mark 1), could be used for height-finding by tilting the beam. By the beginning of 1942 there was no doubt that although the C.H. station Chain would continue to give effective long-range early warning on high-flying aircraft, the future development of R.D.F. lay in the perfection of beam systems used in conjunction with the Plan Position Indicator for detection at shorter range, surface watching and the plotting of very low-flying aircraft.

[1] Air Ministry File S.41234/II, Encl. 113B.

Summary of R.D.F. requirements

The Air Ministry appreciation of the requirements of R.D.F. at the beginning of 1942 was summarised in three types of R.D.F. ground equipment only :—[1]

(*a*) The C.H.L./G.C.I. general purpose set, its functions varying according to the type of set and being available in either permanent or hutted/mobile form.

(*b*) A special surface-watch/very-low cover set. This would use ultra-high frequency technique and would be an adjunct to existing stations already sited on high ground, or could be mounted on a tower when high land was unavailable.

(*c*) A very mobile set capable of going in a light vehicle and providing power for its own plant, for emergency use at home and also for providing cover to forces operating in the field in overseas theatres. This simplification of the requirements was to have a considerable influence on the production side. Too often in the past only " Crash " production and installation programmes had enabled reasonably adequate R.D.F. cover to be provided. The shortcomings of the equipment were only found when in operational use. Now the benefits of experience were beginning to show themselves in this standardisation of future requirements.

" Intruder " Aircraft

During 1941, when the enemy night bomber offensive had been at its height Fighter Command had developed a policy of " intruder aircraft " over enemy airfields. These " intruders " had awaited the return of the enemy bombers and attacked them as they attempted to land. The enemy adopted this method and adapted it to their own requirements during the 1942–43 period when the Royal Air Force bomber offensive was pressed home with increasing vigour. Their " intruder " aircraft flew in with our returning bombers, often escaping detection until they were right over one of our airfields. The first indication of their presence only too often was the arrival of a bomb or machine-gun bullet. Entries such as the following in the operational logbooks of the Chain stations are common.[2]

Stenigot C.H. 23 February 1942.—" Twenty-five bombers went out south of station. Returning bombers picked up at various ranges and were followed by a small number of hostile aircraft flying at same height."

Staxton C.H. 13 March 1942.—" During the evening hostiles came in with returning bombers. Incoming hostiles plotted. Twenty-three responses, seventeen hostiles."

73 *Wing Operations Report.* 12 December 1942.—" Random hostile activity. Enemy aircraft approached as our bombers returned, making identification very difficult."

In the vast majority of cases the problem was not one of non-detection but one of identification. The hostile aircraft were nearly always seen by the R.D.F. stations, but the numbers on the tubes were such that individual tracking of aircraft was impossible, and macroscopic plotting (or area reporting) was adopted instead. In this case a general plot was given of the front and rear edges of a formation, in the case of a C.H. station, with a mean height and an estimation of the numbers in the area. The C.H.L. stations passed plots on the four corners of the area raid. On the Filter Room table a four-cornered

[1] Air Ministry File S.41234/II, Encl. 113B. [2] No. 73 Wing O.R.B.

raid would be shown, with mean heights and estimated numbers, but within this area no individual tracks were filtered. Thus it was not always possible to identify hostile aircraft when their bearing and height were similar to that of the returning bombers and when they appeared in the middle of a formation. The chief contributory cause to lack of, or delay in identification, was the fact that so few of the British bombers showed I.F.F. All bombers were fitted with it, but many crews failed to switch it on when returning home, thus making the tasks of Filter Room and the R.D.F. stations even more difficult. Had all returning bombers shown I.F.F. then the intruder would have been easily spotted and a separate track could have been maintained. Constant complaints were made to this effect by the R.D.F. stations, and some improvement was noted, but the percentage of I.F.F. shown in a raid still remained insufficient.

As it was, it was very difficult in a mass raid to distinguish which particular aircraft were showing I.F.F. The introduction of Mark III I.F.F. made some improvement. When first introduced, this system proved by no means perfect, though providing more information than did the Mark II I.F.F., but constant research undertaken during 1942 to improve its stability and operational use had its effect and was shown by better performance. When single tracks only were on the tube it worked very well, but in a mass raid it was difficult to relate an I.F.F. response to any particular aircraft. The increased recurrence rate of Mark III however did to some extent simplify the R.D.F. Observer's job. Another great advantage was that it could be seen by all types of R.D.F. stations, and when more than one station was seeing a track, Filter Rooms were able to get confirmation of I.F.F. reports, thus assisting them in the difficult task of identification.

An Operations Research Section report reviewing hostile intruder action during 1943, stated that on the average there was one enemy attack per 4·5 friendly bomber nights.[1] Attacks were generally confined to the region of airfields, and the area most affected was to the East of a line Hull/Cambridge/Worthing, East Anglia being particularly affected. The following comments were made :—

(*a*) The operational limitations of tracking by the Radar-Filter Room system were such that recognition and tracking of a small number of hostile aircraft could not be expected in the following conditions :—

  (i) At the time and in the area when " area raid " technique was in operation.

  (ii) When numerous friendly aircraft were going out or coming in over a wide front and when there were more than fifteen tracks in any area 100 kilometres square.

(*b*) Early radar warning of hostile activity might have been given, but continued plotting of the hostile aircraft as far as the coast could not be relied on in the following conditions :—

  (i) When there was moderate or heavy density of friendly activity near the coast (*e.g.*, fighters in the Thames Estuary, or trainers in the Wash area).

  (ii) Whenever tracks near the coast were not coming straight in or out.

  (iii) When there was heavy friendly activity inland.

It must not be thought that the Home Chain failed completely with respect to the detection of these intruders. The job of the Chain was to pass details

[1] O.R.S. (A.D.G.B.) Report No. 13, 3 January 1944, and Air Ministry File C.S. 19224/1 Encl. 98A.

of tracks to Filter Room ; the identification of tracks and the use made of such information was the responsibility of Filter Room and Operations Room staffs. The whole trouble was that with heavy activity it was impossible for the Home Chain to pass satisfactory information on separate tracks, and even had they been able to do so, Filter Room would not have been able to deal with them all. The matter was discussed in August 1943 by the Deputy Chief of Air Staff in a report to the Chief of Air Staff. He stated that the failure to obtain adequate warning of these raids was due to faulty identification, which arose from a few hostile aircraft coming in mixed with homecoming bombers.[1] There was no evidence of any deterioration in the performance of the Radar Chain. It was further stated that the problem of identifying a few hostiles among a number of friendlies, and vice versa, had been occupying the attention of both the technical and operational staffs for some years and in neither case did there appear to be hope of finding a complete solution.

General Operational Efficiency of the Home Chain

The enemy raids which adopted a technique designed to avoid observation by our R.D.F. stations, namely, very low-flying attacks and "intruder" operations, had provided the major problems to the Home Chain during the 1942–43 period. Normal enemy activity in night raids between 10,000 and 20,000 feet in height continued on a reduced scale throughout these years, but was usually adequately reported by the C.H. and C.H.L. stations. Although the major R.D.F. effort had been directed against the very low-flying raider, a close watch was kept on the C.H. and C.H.L. Chain with a view to maintaining it at maximum efficiency. Some criticism of the operational efficiency of the Home Chain was made in Fighter Command's Operational Research Section's report dated May 1943, in which it was stated that stations were worse operated than in the Battle of Britain days. This criticism was felt to be unjustified by Headquarters, No. 60 Group, for the following reasons :—[2]

(*a*) At the time the report was written a considerable amount of re-fitting and installation was taking place on the E., S.E. and S.W. coasts, and a number of stations were using reserve channels in consequence.

(*b*) There was a high percentage of inexperienced operators in Numbers 9, 13 and 14 Groups, as these areas had been robbed in order to maintain a high standard in Numbers 10, 11 and 12 Groups, where activity was mainly concentrated.

(*c*) The Home Chain had been much diluted by withdrawal of operators for service on "Gee" and "Oboe" equipment in this country, and for general R.D.F. service overseas.

(*d*) The vastly-increasing numbers of stations meant a corresponding increase in the number of operators. Consequently it was not always possible to maintain the general level of efficiency which obtained in 1940, when operators were far fewer and could be "hand-picked" as a result.

(*e*) The estimation of numbers of aircraft in a formation, of which criticism was made, was very difficult and depended largely on the type of formation used by the enemy. On most offensive operations formations flew tightly packed and it was doubtful if stations could always estimate the number of aircraft accurately in such conditions.

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[1] Air Ministry File C.S. 19224/1, Encl. 67A. [2] *Ibid.*, Encl. 3A.

During the Battle of Britain the ratio of enemy tracks to friendly ones was relatively high and there was neither time nor staff to apply a meticulous analysis to station performance. The primary consideration was that of destroying the enemy and this aspect was satisfactory. There was at that time a very urgent need for a picture of aerial activity, however mediocre, and all information was thankfully received.[1] By 1942 the Chain's best performances were regarded as normal, and there was ample time and staff for any discrepancies or mistakes to be noted. The current performance could be compared to the past only when due allowance was made for the changed conditions. Invariably enemy aircraft approached our shores in a manner best calculated to defeat R.D.F. cover. The "50-footer" aircraft and the current trick of flying in to the verge of R.D.F. cover and then climbing to the height of 16,000 feet in six minutes or so were examples of his attempt to escape detection by the Chain.

Sir Robert Watson Watt in August 1943 stated that there was a tendency in Air Staff to use the term "R.D.F. failed to see X," when the facts were that "no filtered track corresponding to X appeared on the table." He was impressed by the number of investigated cases where the records of R.D.F. stations showed that adequate track data was provided but that it was mis-filtered. This accounted, amongst other things, for some of the many failures to deal adequately with low-flying aircraft. Sir Robert did not consider that the proportion of effort directed towards (*a*) improved filter room performance, and (*b*) improved station performance had ever been right, and he stressed the importance of maintaining the closest possible liaison between operating and filtering staffs.[2] Filter Rooms had many difficulties with which to contend and the only method of assisting them directly was in the simplification of the information presented from the Chain stations themselves. This approach was fully exploited by increasing the responsibilities of the supervisors on R.D.F. stations and arranging for closer team work between the C.H., C.H.L. and centimetre stations.

Improvements in Plotting Procedure to Filter Rooms

Directional Plotting.—C.H.L. improvements during 1941 and early 1942 made possible a speed of reporting which was far greater than any plotter at Filter Room could manage. The result was great congestion on the telling line to Filter Room and consequent confusion on the Filter Room table, with a loss of valuable information. In April 1942, therefore, an experiment was tried at Bawdsey in "Directional Plotting."[3] This was a method whereby the C.H.L. stations, instead of passing plots to Filter Room direct from the P.P.I. tube, plotted the tracks on a perspex map in their Operations Room. On every third plot, a filtered position with a direction of travel was passed to Filter Room. C.H.L. plots were so accurate that there was little margin for error in the filtering. Directional Plotting presented a very good picture of the activity and cut down congestion on the telling line. In June 1942, Headquarters, No. 60 Group decided to train all C.H.L. crews in Directional Plotting, and by the end of the year all stations from Beachy Head to Rame Head were reporting by this method. Later this form of plotting became current operational procedure at all C.H.L. stations.

[1] Air Ministry File C.S. 19224/1, Encl. 6A. [2] *Ibid.*, Encls. 53A and 66A.
[3] No. 60 Group File 60G/51/19/5/Ops.

Combined Directional Plotting.—With three types of stations reporting to Filter Room—C.H., C.H.L. and C.H.E.L. (Chain Home Extra Low—the Centimetre sets)—it was found by the end of 1942 that information was often duplicated. Directional Plotting, so successful on C.H.L. stations, could not be used at a C.H. station, where inaccuracies in bearing made filtered information from the stations unreliable. In January 1942, however, a new conception of plotting based on individual station filtering was suggested, and this eventually came into operation as "Combined Directional Plotting."[1] In this method, stations worked in teams, comprising one C.H. station, its associated C.H.L. station and the attached C.H.E.L. station. Within P.P.I. range (up to 90 miles from the C.H.L. station) all plots were passed by the C.H.L. teller to a Filter Room plotter sitting on the inland side of the Filter Table. A plotter at the C.H. station monitored the C.H.L. filter line and reproduced on a perspex map in the C.H. Operations Room everything passed by the C.H.L. If the C.H.L. station was plotting, then the C.H. station supplied only ancillary information on the same track, such as raid strengths and height, for transmission through the C.H.L. station to the Filter Room. C.H. station plots were only passed on aircraft not within C.H.L. or C.H.E.L. cover. Beyond P.P.I. range, plots were passed to a Filter Room plotter on the sea side of the table, on a line available either to the C.H. or C.H.L. station by throwing a switch. The C.H. station Supervisor was able to act as a co-ordinator of all information, and thus much of the filtering could be done at stations. This Combined Directional Plotting Method cut down the clutter on the Filter Room table and plotters were enabled to plot more easily, as their plaques were always within reach. This method was tested in January 1943 with the Branscombe–Beer Head teams, proving most successful. It was then adopted by Bawdsey, and by May 1943 the No. 11 Group area was covered entirely by C.D.P. units ; by the end of the year the method was in operation along the whole of the South and South-East coasts of England.

Restricted Plotting Area

The Combined Directional Plotting pre-filtered information dispensed with the need for having multiple information on each track. In June 1943 a system of Restricted Plotting Areas was introduced.[2] The Filter Table was divided into small areas (about ten to each table) and each C.D.P. unit was allotted up to about four of these areas. The boundaries were chosen so that each C.D.P. unit reported in the area of its best coverage, and generally not more than three units reported in each area. This allowed for concentrated plotting on tracks within the boundaries, but prevented confusion from long-range plots passed by stations outside the areas, and resulted in an appreciable improvement in the interpretation of R.D.F. information by the Filter Room.

Change in Nomenclature—" Radar "

In order to avoid differences in terminology between the Allies, the name " Radar " (Radio Detection and Ranging) used in the United States of America for radiolocation, was officially adopted instead of " R.D.F." in September 1943.

Radar Preparations Made for Anticipated Attacks by Enemy Long-Range Rockets

Early in 1943 Intelligence reports revealed that the enemy was working on new weapons, believed to be long-range rockets, and preparations were accordingly made so that the Home Chain would be equipped to meet this

[1] No. 60 Group File 60G/51/19/5 Ops. [2] Headquarters, Fighter Command O.R.B.

menace immediately it came into use. An Inter-Departmental Committee was set up in June 1943, under the chairmanship of Sir Robert Watson Watt, to discuss the possibility of the enemy using rockets to attack this country, and to make recommendations from the radar aspect.[1] In a report dated 12 June 1943 the Committee stated that as the firing points would probably be numerous it was most important that associated range and bearing data on each target should be obtained from individual radar stations. It was thought that this could be obtained, with a probable increase in maximum range for observation and with a subsequent improvement in immunity from jamming, by the installation at selected C.H. stations of an equipment developed at the Telecommunications Research Establishment in 1941 and known as Cathode Ray Direction Finding (C.R.D.F.). The equipment had been used experimentally at Dunkirk in 1942, when it was thought that it might be installed as a reserve equipment in the event of C.H. operations becoming impossible through German jamming, but had never come into general use on the Chain. The Committee felt that it could be of value in obtaining the special information required in rocket data, as it displayed instantaneously, visibly, and in a form suitable for continuous or intermittent automatic photography, range and bearing information for all targets within an angular sector of about 120° in front of the C.H. station.

The Committee therefore recommended that a prototype C.R.D.F. set held at the Telecommunications Research Establishment (T.R.E.) should be installed immediately at the C.H. station at Rye, linked to the Mark III aerial array, and that a second set also at T.R.E. should be sent to Pevensey. Improved models were to be developed and later installed at Poling, Ventnor and Swingate, and to supersede the equipments at Rye and Pevensey. It was further recommended that a second cathode ray tube should be incorporated to give a direct elevation display. Other recommendations from the Committee were the development of photographic recorders, the provision of extra telephone facilities, and the development and production of special recorders to give a range/time display. Instructions were also drawn up for radar operators in the area where bombardment was expected; it was anticipated that London would be the main target, with possibly subsidiary attacks on Portsmouth or Southampton. Two members of the Committee, Mr. A. F. Wilkins of the Operational Research Section at Headquarters, Fighter Command, and Wing Commander Jennings, Operations Officer at Headquarters, No. 60 Group, were detailed to visit all C.H. stations from Swingate to Ventnor (later the area was extended westwards to Branscombe) to initiate immediate discussions of the problem with the technical and operational personnel of the stations.

The "Bodyline" Watch

Although production and installation of the C.R.D.F. equipment was put in hand at once, it was apparent that it could not be operational for some months. It was felt, however, that the enemy might attack before that time, so that some form of special watch from the radar stations should be instituted immediately until such time as the C.R.D.F. equipment was installed. It was decided, therefore, to maintain a special lookout on the normal equipment at the C.H. stations, and this became known as the "Bodyline Watch." The strictest secrecy was maintained at all times; all radar personnel concerned

[1] Air Ministry File, C.M.S. 99/I, Encl. 2A.

at the stations had to sign a certificate of secrecy, and they were screened from posting away from their stations. The normal R.F.8 standby receivers at the C.H. stations were used. Besides the usual C.H. station crew two additional personnel were required, one to man the cathode ray tube and the other to read the range drum. A paper strip was placed over the range scale of the tube, to be marked with a vertical line coincident with the spot should an echo appear. Very accurate range and bearing records were required, and in order that times should be correct, a new system of synchronised time signals were issued from No. 11 Group Filter Room, and each station was issued with two stop-watches.[1] Very close and accurate observation was required of the "Bodyline" crew, as any response seen would necessarily be of very brief duration.

All C.H. stations from Swingate to Branscombe were maintaining a continuous "Bodyline" watch by 31 July 1943. It was then decided to extend the watch to C.H.L. stations in the same area; although their information was not likely to be as valuable as that anticipated from the C.H. stations, it was yet felt that no chance should be missed of getting all available data. Accordingly the C.H.L. stations were all maintaining the "Bodyline" watch by the beginning of September 1943. At the same time T.R.E. had undertaken to man a suitably equipped trainer for C.R.D.F. and this equipment, followed in September 1943 by a second similar outfit, made a tour of all the relevant stations giving practice to all operators in operational technique. Lectures and discussions were given by the officer-in-charge, and comment and criticism freely invited from the crews. On 8 September 1943 the Assistant Chief of Air Staff (Operations) issued an instruction to the effect that the "Bodyline" watch might be suspended only in the case of (*a*) the period during which a station was receiving training instruction, providing only one station at a time was being trained, and (*b*) during the installation in the Operations Room of the C.R.D.F. equipment.[2] The normal reporting functions of the stations were, of course, unaffected by this order.

C.R.D.F. Equipment

The standby R.F.8 receiver was modified so that two cathode ray tubes appeared in front of the operator and two control knobs. One tube displayed a normal range-time base, with the exception that echoes appeared both above and below the trace.[3] A bright spot appeared on this trace, controlled by the strobe knob, and by its use the appropriate echo could be indicated or strobed. On the second tube a "cursor" line was displayed along a diameter which could be rotated about the centre by means of the azimuth knob. This bearing tube also displayed the signal as a line so that the direction from which the signal was received could be read from a circular scale. When the strobe knob was turned so that an echo on the range tube was brightened a line of light appeared on the azimuth tube, the operator rotated the bearing knob until the cursor line lay in the same direction and the bearing was then read from the position where the bearing scale was cut by the cursor line. With practice, it was possible for the operator to obtain good D/F readings very quickly by this method. The speed of R.D.F. plotting by C.R.D.F. was much higher than that by the standard Home Chain equipment.

[1] Air Ministry File C.M.S. 99/1, Encl. 111A. [2] *Ibid.*, Encl. 100A.
[3] Air Ministry File C.S. 8688, Encl. 10A.

The prototype C.R.D.F. equipment from T.R.E. was installed at Rye in July 1943 and at first was manned only by a special watch. Installation at Swingate and Ventnor followed in September, and the new model at Rye, together with equipments at Poling and Pevensey, followed in October.[1] By 6 December the five stations had been calibrated and were fully operational, and by the end of the month the westward portion of the C.R.D.F. chain—Southbourne, Ringstead and Branscombe was operational too. The Remote Reserve station at St. Lawrence and the I.C.H. station at Dymchurch were found to be unsuitable for C.R.D.F., but they maintained a continuous watch for rocket incidents on the tracker tube of their normal set.[2]

An additional measure adopted to help in the accurate location of firing points was a special electrical high-speed tracker, with a photographic attachment which automatically recorded photographs of the trace on a continuous film. A record was made of range, rate of change of range and time bearing data. Authority was given in July 1943 for installation of this unit—Display Unit, Type 53, or "Oswald," as it was known—at Rye, Pevensey, Swingate, Poling, Ventnor, Southbourne, Ringstead and Branscombe.[3] The equipment was installed at Rye in August 1943, at Swingate on 28 August, at the remainder of the eastern C.R.D.F. chain later in the year.[4] Ringstead, Southbourne and Branscombe were not equipped until early in 1944. Completed film and all available information was to be sent to Operational Research Section at Headquarters, Fighter Command, where a special Computation Unit had been set up to correlate all information received on long-range rockets. At the end of December 1943, four supernumerary technical officers were posted to each "Bodyline" C.H. station, with a primary responsibility towards the maintenance of the photographic equipment and correlation of data obtained from the films.[5] A switchable camera was also fitted to the C.R.D.F. receiver itself, and this was referred to as "Willie." This recorded azimuth, range and time data and had a high rate of film consumption, "Oswald" recording at a much slower rate. The respective rates were 12½ feet per minute and 1·2 inches per minute. In order to economise in film, only "Oswald" operated continuously, "Willie" being brought into operation only upon detection of suspicious signals.[6]

Duties of C.R.D.F. Crews

The members of the crew on a C.R.D.F. station equipped with "Oswald" were four, assisted in the event of incident by the members of the normal reporting watch. The four special crew members were :—[7]

(*a*) Range Strobe Operator,
(*b*) Range Drum Reader and Recorder,
(*c*) Azimuth Cursor Operator,
(*d*) Display Unit Type 53 Operator,

and their duties, briefly, were as follows :—

Range Strobe Operator.—Strobed all new echoes in excess of 30 miles and in the event of an echo exhibiting "Bodyline" characteristics he made the C.R.D.F. camera switch and shouted "Bodyline." He held the strobe to the left hand of the echo, announced ranges and fades, and if the rocket had a "tail," announced and strobed it.

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[1] No. 75 Wing, O.R.B.
[2] Air Ministry File C.M.S. 99/2, Encl. 29B.
[3] Air Ministry File C.M.S. 99/1, Encls. 85A, 118A.
[4] Air Ministry File C.M.S. 99/2, Encl. 29B.
[5] *Ibid.*, Encl. 20A.
[6] Air Ministry File C.M.S. 636.
[7] Air Ministry File C.M.S. 99/1, Encl. 150A.

The Azimuth Observer.—Resolved all azimuths presented by the Range Strobe Operator by means of the cursor and in the event of incident called all bearings on it and on all subsequent announcements by the Range Strobe Operator.

The Range Drum and Recorder.—On each announcement of a " Bodyline tail," " range " or " fade," observed and recorded the figures shown on the range drum.

Operator on " Oswald."—Sat observing the high speed tracker tube and on witnessing a characteristic echo shouted " Bodyline " and pressed the camera switch which started the C.R.D.F. photographic recorder.

In the event of incident, the following normal crew members assisted as follows :—

C.H.L. Monitor.—Recorded the time sequence of an incident on the stop-watch.

C.H.L. Liaison Teller.—Was ready to provide a sequence of stop-watches and paper masks for the C.H.L. monitor and advised the C.H.L. that an incident was running.

C.H. Plotter.—Recorded the time of the incident to the nearest minute, recorded maximum signal/noise ratio and maintained accurate record of the sequence of events.

Long Range Teller.—When the Range Strobe or Type 53 Operator called " Bodyline " he warned the Filter Room by saying " Bodyline at . . ." and was additionally responsible for checking the stop-watches against Filter Room time signals.

Duties of the Recorder.—He was responsible for reloading the C.R.D.F. camera after every incident or otherwise as necessary.

Use of Stations, Type 12

In addition to " Bodyline " cover provided by the C.H. and C.H.L. stations, provision was made for mobile stations to be used for similar duties in the event of the C.H. stations being rendered non-operational through enemy jamming.[1] These stations, known as Type 12, were originally devised to use a beam technique, but were specially modified to " floodlight " use. Installation of the Type 12 stations was completed at Ramsgate, Hythe, Highdown Hill, Bexhill and Whitehawk in October 1943.[2] Crews were to be drawn from the neighbouring C.H.L. stations in case of necessity ; all such equipments were not continuously manned. They were maintained instead on a " Care and Maintenance " basis, but were able to be brought into immediate use should enemy jamming render this necessary, on the authority only of the Air Officer Commanding-in-Chief, Fighter Command.

All these preparations were made solely on the basis of intelligence information. There was no precise knowledge on which to build up new radar defences. Everything had been done which could reasonably be expected from intelligent foresight to prepare the Home Chain to meet this anticipated new form of bombardment, if and when it should occur.

[1] Air Ministry File C.M.S. 99/1, Encl. 130B. [2] *Ibid.*, Encl. 150A.

CHAPTER 17

R.D.F. RAID REPORTING IN THE LANDINGS IN NORTH-WEST AFRICA (OPERATION "TORCH")

After the French Government capitulated in July 1940 and the Axis sphere of influence extended in the central and western Mediterranean with the advent of Italy into the War, there were many strategical advantages to be gained by a military operation against French Morocco on the south-western Mediterranean sea-board. The western end of the Mediterranean was the key-point in the British blockade, and the strategic importance of the French North African Colonies in support of the blockade was not lost upon the British Government. In addition, the Chiefs of Staff feared a German advance southward into Spain and there was little prospect of serious Spanish resistance being forthcoming. Above all, there was the incentive of the moral victory which would be won if the French in North Africa could be roused to continue the struggle against the Axis.

With the fear of invasion threatening the United Kingdom and the acute shortage of war materials even at home, it was hardly possible at that time to launch a campaign of the magnitude required for a North African venture unless there was a guarantee of French support. Efforts were therefore made to rouse the French by offering considerable assistance should they decide to re-enter the War. These attempts, initiated in December 1940 by Mr. Churchill, were continued throughout 1941 whenever there were forces to spare or the political situation in Vichy France seemed to offer a chance of the French in North Africa attempting to escape from German domination. With the entry of the United States into the War, the policy of helping the French in North Africa to resume the struggle against the Axis was adopted at the Washington War Conference (December 1941–January 1942) as a combined Anglo-American operation.

Throughout 1942 various proposals for a "Second Front" were made. It was obvious to Chiefs of Staffs that the Allies could not launch a cross-Channel invasion that year, so the proposed help to the French in North Africa, which had been abandoned in March 1942, was revived. This time, however, the Allies were not merely desirous of assisting the French; they were determined that should the French not come over to their side, Morocco and Algeria would nevertheless be occupied. The Allied forces were then to seize Tunisia as expeditiously as possible. In addition to these basic aims, it was intended to establish a striking force in French Morocco that could ensure the control of the Strait of Gibraltar by moving, if necessary, into Spanish Morocco.

General Plans for Operation "Torch"

The Code Name "Torch" was given to this impending operation and the elements of the earlier plans were revived and revised.[1] There was a considerable period of negotiation between Allied Staffs before the places of assault were decided. Ultimately, on 31 August 1942, after several plans had been drawn up, Oran, Algiers and Casablanca were selected—D-day for the invasion of North Africa being fixed for 8 November 1942. Fresh plans and

[1] Prior to March 1942 planning for an operation against North Africa had been known successively as Operations "Cackle," "Gymnast" and "Super-Gymnast."

instructions had therefore to be compiled and forces embarked in a time-limit of just over two months, a stupendous task for the first large-scale amphibious landing involving British troops to be carried out since Gallipoli in 1915.

After such events as the British occupations of Syria and Madagascar, and the naval actions against the French Fleet at Oran and Mers-El-Kebir, it was thought that the French were more likely to co-operate in North Africa if Operation " Torch " had, externally, an American complexion. It was therefore decided that Oran should be attacked by American Army forces with British naval and Air Force units. Algiers was to be assaulted initially by Americans, to be followed up within the hour by a British force supported by British naval and air units. Casablanca was a wholly American undertaking.

Responsibilities of the Allied Air Forces

The air cover so essential for such an operation was to be divided between the American and British Air Forces. Both forces were given separate rôles and zones of responsibility.[1] The 12th United States Army Air Force, known as the Western Air Command, in an area bounded by the Atlantic coast of Morocco and a line north and south through Cap Tenes in Algeria, was to be responsible after the initial landings for assisting in the subjugation of the French forces if they offered resistance, and subsequently providing air support for the United States Army in the event of the occupation of Spanish Morocco becoming necessary. They were also to build up a force for a later move into Tunisia.

The rôle of the British Royal Air Force, which was called Eastern Air Command, was to—

(*a*) provide air cover and support for the initial assaults;

(*b*) protect the bases and communications against air attack and, in conjunction with naval forces, against attacks by submarines and surface raiders;

(*c*) disseminate propaganda by leaflet dropping;

(*d*) provide air co-operation and support for land operations subsequent to the assault;

(*e*) provide an offensive air striking force for strategic bombing;

(*f*) provide protection for Allied shipping convoys.

The initial assaults on Oran and Algiers were to be covered by carrier-borne squadrons of the Fleet Air Arm and that on Casablanca by shipborne aircraft of the United States Navy. To fulfil the rôle allotted to the British Air Forces, shore-based ground units of the Royal Air Force had to be provided for many varying tasks, not the least of these being the ground search R.D.F. units for early warning and the control of fighter aircraft.[2]

The plans as to size and composition of the forces required for the operation were governed almost entirely by the limitations of available shipping. Personnel and material considered to be required for the operation were available in quantities far in excess of the amount of shipping that could be escorted by the Navy in each convoy. This reduction of shipping capacity necessitated drastic cuts being made in the material requirements, and consequently had a considerable effect on the scales of supply of R.D.F. equipments in the initial

[1] Air Ministry File C.26023/45, Report on Operation " Torch " by Sir William Welch, para. 25.
[2] *Ibid.*, Appendix " B."

stages of the operation. When the bids were made for shipping space they were so cut that only 50 per cent. of the necessary vehicles could be taken in the early convoys.

General Plans for Ground R.D.F. in Operation " Torch "

As it was not clear as to whether the assault would meet with resistance or not from the Vichy French military forces in North-west Africa, two plans were originally prepared, but it was finally decided that the plan must be adopted which assumed full opposition by the French. Thus the system of loading based on this assumption had to be carefully worked out and a somewhat slow build-up in the theatre of operations became inevitable.

At the time Operation " Torch " was planned it was still assumed that the only way in which R.D.F. could be used satisfactorily was to group a number of dispersed R.D.F. stations round a central Operations Room, to which they might report, and to repeat this system at various intervals throughout the territory to be covered until they formed a chain basically similar in principle to that functioning in the United Kingdom. This system had proved a great success at home and in Libya, and, given time to become fully operational, might have proved invaluable at Singapore.

It is regrettable that the outstanding success of the improvised mobile C.O.L. stations used as Fighter Directors in the Western Desert by Headquarters, Middle East, could not have been exploited in this landing.[1] Instead of developing a mobile R.D.F. system along Fighter Direction lines which could move with advancing ground forces, and providing for a later build-up of raid reporting stations for the territory occupied when the military position had become stabilised, they continued to make provision for the formation of a static chain to extend the entire length of the Algerian coastline.

For the initial provision of R.D.F. cover to land with the assault forces on D-day, it was planned that Light Warning Sets were to be used. This new equipment had been developed at the Telecommunications Research Establishment (T.R.E.). There had long been a requirement for a portable R.D.F. warning set in the field. It will be recalled that such a need had been apparent in the Middle East in 1941, and that as a temporary expedient a number of pack-sets had been constructed using standard A.S.V. radio parts.[2] The chief drawback with this type of pack-set was its range, 15–20 miles on aircraft at 10,000 feet. Preliminary work had been embarked upon in January 1942, to produce an improved light warning set. The transmitter and aerials were developed at Metropolitan Vickers while T.R.E. had the responsibility for the development of a nine-inch Plan Position Indicator. Designs for the turning gear and aerials were largely taken over by T.R.E. The receiver was the orthodox equipment used in A.S.V. apparatus and the whole unit, working on a frequency of 176 megacycles per second, would pack into one 3-ton lorry and could be erected in a tent in a matter of an hour. The range of this equipment on aircraft at 10,000 feet was about 40 miles. Rough height-finding was possible by the comparison of signals from two Yagi aerials at different heights.

The Light Warning Sets to be available for Operation " Torch " were put together in Air Defence Research and Development Establishment workshops, as the contracts with Metro-Vickers had been delayed and production

[1] Chapter 12 of this volume describes this successful use of mobile C.O.L. stations.

[2] *See* Chapter 12 of this volume.

did not meet the dates demanded. A total of six hand-produced sets were demanded from A.D.R.D.E., some of which were to make their operational début in the North African Landings.

After the Light Warning Sets had landed in the D-day assault, the R.D.F. build-up was to begin with the arrival of C.O.L./G.C.I. mobile stations on D + 4, followed by a steady reinforcement of the territory gained by Allied ground forces of two similar equipments every fortnight.[1] This R.D.F. programme was worked out on the assumption that there would be a fairly slow Army advance due to resistance on the part of the Vichy forces.

Having decided on the general plan of the sequence of R.D.F. equipment to be used during the assault and build-up stages, the detailed plans for the American and British Zones were then evolved. These are described separately under their respective zones in the ensuing paragraphs.

Detailed Ground R.D.F. Plans for the American Zone (Western Air Command)

Planning for the Western Task Force and the Western Naval Task Force, which were to make landings at Casablanca, was done in Washington, and American R.D.F. equipment and personnel were to be used.[2] The remaining planning was carried out in London. One Royal Air Force officer was attached to the American planning staff at Norfolk House, and with a small group of American officers prepared the R.D.F. plans for the Centre Task Force which was responsible for the area from the Spanish Moroccan Border to Cap Tenes.[3] The intention was to provide R.D.F. cover as early as possible in the operation and then to begin a steady build-up of a chain of ground R.D.F. stations.[4]

One Light Warning Station was to be despatched in the Assault Convoy in company with a Wireless Unit, which consisted of a multiple collection of listening-watch receivers and observer units. These were to be followed by four C.O.L./G.C.I. stations in the Follow-up Convoy three days later. On D + 14 a second Wireless Unit was to arrive, and on D + 28 two Mobile Radio Units, similar to those used in the Middle East campaigns, and two more Light Warning Sets were to complete the ground search R.D.F. facilities for Operation " Torch " in the American zone of responsibility. All the sites, except those for the Mobile Radio Units, were chosen by the planning Staff in London with the aid of contour maps and aerial photographs ; the maps were rather old and unreliable. Tentative sites only were selected for the M.R.U.s as it was considered that there would be ample time to choose these at leisure as the sets were going in at a later date. The rest of the equipment was to be sited as follows :—

A.M.E.S. No. 890 to act as a C.O.L. Station at Cap Carbon.
A.M.E.S. No. 899 to act as a C.O.L. station at Cap Falcon.
A.M.E.S. No. 8000 to act as a C.O.L. station at Cap Ivi.
A.M.E.S. No. 8001 to act as a C.O.L. station at Cap D'Acra.
A.M.E.S. No. 675 Light Warning Set at Arzeu.
A.M.E.S. No. 6003 Light Warning Set at Cap Tenes.
A.M.E.S. No. 6004 Light Warning Set in reserve.

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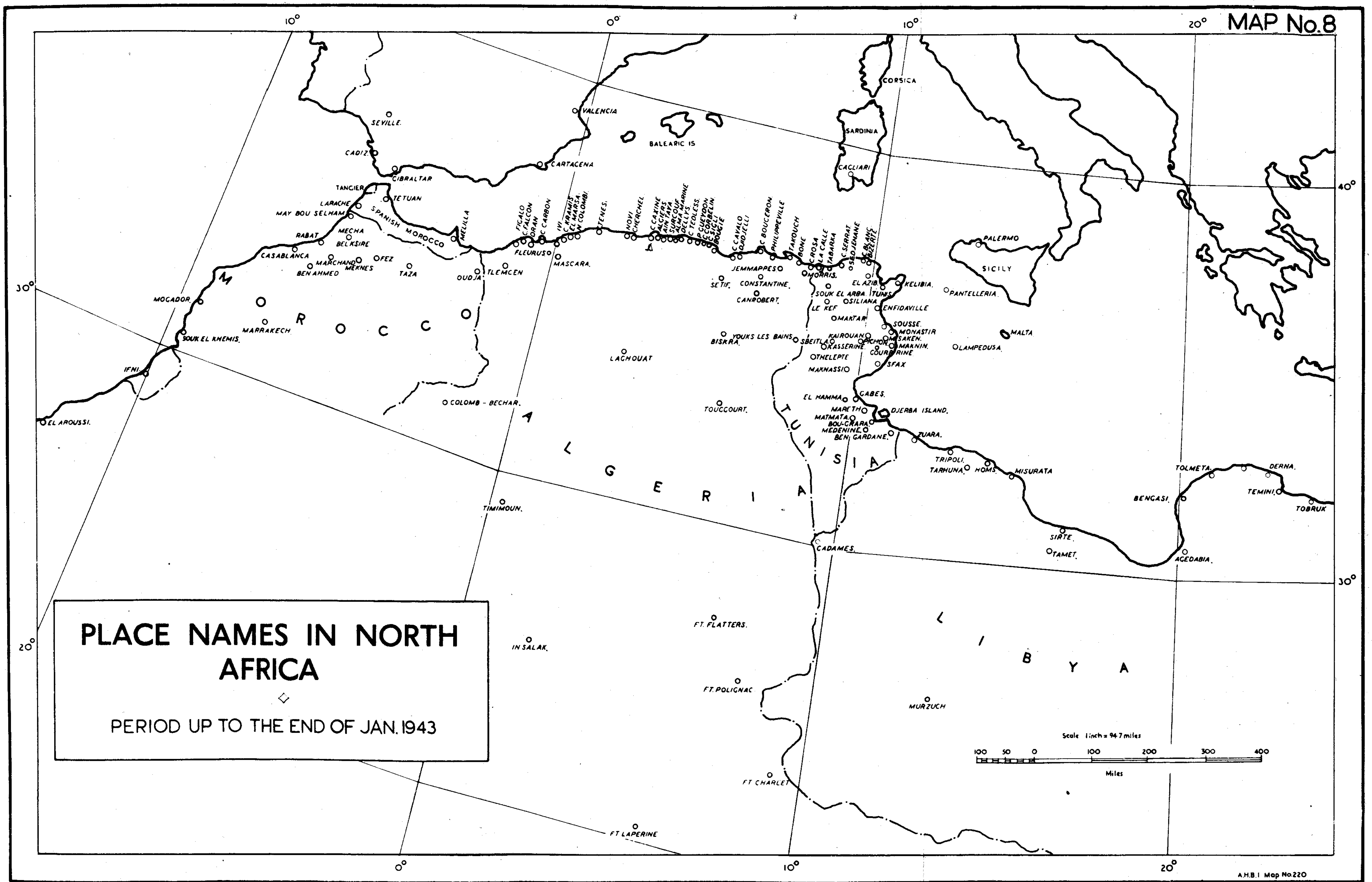
[1] No. 333 Group, O.R.B., Appendix " D," Signals Instruction.
[2] C.O.S. (43) 98 (0), 4 March 1943—War Cabinet Chiefs of Staff Committee, North Africa Operations, Lessons in Signals Communications, para. 2, sub-para. (*g*).
[3] Map No. 8 shows locations mentioned in this chapter.
[4] Narrator's interview with Wing Commander J. Swinney, Royal Air Force, R.D.F. Liaison Officer with U.S. Forces for Operation " Torch."

MAP No.8



PLACE NAMES IN NORTH AFRICA

PERIOD UP TO THE END OF JAN. 1943

The possibility of the Germans entering Spain and establishing bases there had to be borne in mind and provision was made to extend the ground R.D.F. cover to the west with the extra Light Warning Set. If the Germans were to enter Spain early in the operation it would be necessary to divert a C.O.L. station to the west and sites had been chosen in preparation for such a contingency at Cap Milonia and Cap Tarsa.

Detailed Ground R.D.F. Plans in the British Zone (Eastern Air Command)

The most important immediate objective in the assault on Algeria was the airfield at Maison Blanche, four miles south-east of Algiers. A landing was to be made on Surcouf beach. The aim of the forces landed there was to occupy the major airfield of Maison Blanche before dawn on D-day, 8 November 1942, and the two smaller airfields at Sidi Feruch and Blida, so that fighter aircraft could be flown in from Gibraltar at the earliest possible moment.[1] All Royal Air Force assault personnel were to be landed at " Charlie " beach, Surcouf, although several other landings were to be made. Two light mobile R.D.F. sets were to go in with the assault—later R.D.F. supplies would provide the setting up of a coastal chain similar to that operating in Libya.[2]

The Royal Air Force Commander and his staff were to be carried in H.M.S. *Bulolo,* the headquarters ship from which all operations were to be directed. Royal Air Force Signals section was to be a permanent part of the ship's company and was to be in contact with a small advance section of Headquarters, Eastern Air Command, in operation at Gibraltar, which in turn was to be in communication with the United Kingdom during the early stages of the campaign.

A Royal Air Force advance party, consisting of Nos. 322 and 323 Wings together with two Servicing Commandos, two A.A. Flights, four Signals Sections and two Light Warning R.D.F. Sets, were to travel with the Assault Convoy.[3] These units were to be disembarked from the transport ships in which they travelled into landing craft, and then were to follow the assault troops over the beach. Their rôle was to assist five fighter squadrons to operate from Maison Blanche airfield until the arrival of full Wing Operations facilities.

The immediate aim of the Royal Air Force Signals section in the assault was to provide facilities for the control of the aircraft in the Algiers area. To assist in this endeavour the two R.D.F. Light Warning Sets were to broadcast plots by W/T for reception at the airfield and elsewhere as required. A.M.E.S.s Nos. 6000 and 6001 were to take part in the landing.[4] The crews of each unit were to travel separately, that of A.M.E.S. No. 6000 in a United States personnel ship and that of A.M.E.S. No. 6001 in a British personnel ship. The drivers and two vehicles were to travel separately in two British motor transport ships. On landing, the personnel of A.M.E.S. No. 6000 in company with the other parties were to report to the embarkation staff, who in turn were to form units in as large groups as possible and order them to move to Maison Blanche. The exception to this was A.M.E.S. No. 6001, who were to report to the Advanced Headquarters and go into operation in that area as rapidly as possible. In general, it was decided that it was impossible to issue precise

[1] Air Ministry File C.26023/45, para. 54 of report. [2] *Ibid.*, Appendix " B."
[3] No. 333 Group, O.R.B., Appendices, Joint Operation Order for the Assault.
[4] *Ibid.*, Appendix " D."

orders for such an operation, the success of which must depend upon the individual unit officers acting with energy and initiative. Unfortunately there was no accommodation for an R.D.F. officer on the assault craft. Technical N.C.O.s were to be in charge of the Light Warning Sets.

The first units to commence operations were to be No. 2 Force Headquarters and A.M.E.S. No. 6000. These two units were to proceed sufficiently far inland to be clear of the beach and while the Force Headquarters opened W/T and V.H.F. R/T with the Headquarters Ship *Bulolo* on pack sets and Gibraltar on a T1190 transmitter, the Light Warning Set was to start operating and passing plots on enemy or friendly aircraft activity as soon as possible. When the road to Maison Blanche was reported clear by the Army, the two Advanced Landing Ground Sections and A.M.E.S. No. 6001 were to proceed to the airfield. A temporary Operations Room was to be established on arrival and A.M.E.S. No. 6001 was to become operational just adjacent to it, passing in R.D.F. plots on aerial activity by telephone to be provided from the land-line equipment carried by the Advanced Landing Ground Signals Unit, and also by W/T.

R.D.F. Build-up in British Zone up to D + 28—Plans

The first follow-up convoy was planned to arrive at Algiers on D+4. The R.D.F. equipment was to be increased by the following sets :—

A.M.E.S. No. 892 (G.C.I.).
A.M.E.S. No. 893 (G.C.I.).
A.M.E.S. No. 6002 (L.W.S.).

Also planned to be included in the signals facilities on this convoy was a Wireless Unit and a Wireless Observer Unit. These were to supplement the raid reporting organisation by passing plots to a central Operations Room where they would be co-ordinated with the R.D.F. plots. The Wireless Unit obtained its information through listening to enemy W/T and R/T transmissions, and the Wireless Observer Unit by visual methods similar to the Royal Observer Corps in the United Kingdom. By D+4 it was considered, too, that sufficient signals equipment would have been landed to warrant some form of servicing organisation—No. 301 Mobile Signals Servicing Unit was therefore formed to deal with minor repairs and emergency assistance beyond the capacity of the R.D.F. unit mechanics.

The instructions for the deployment of the R.D.F. reinforcements were in general terms. A.M.E.S. No. 892 and W.O.U. No. 87 were to report to the Chief Signals Officer on landing and he was to dispose of them in such a way that the best possible air raid warning system was provided for Algiers. He was then to arrange for A.M.E.S.s Nos. 893 and 6002 to proceed eastwards to provide R.D.F. cover for the advanced ground forces.

The second follow-up convoy was to arrive on D+14. The R.D.F. supply was to be supplemented by two more G.C.I. stations and two Light Warning Sets :—

A.M.E.S. No. 895 (G.C.I.).
A.M.E.S. No. 894 (G.C.I.).
A.M.E.S. No. 6004 (L.W.S.).
A.M.E.S. No. 6006 (L.W.S.).

A further W.O.U., No. 88, and a second M.S.S.U., No. 303, were to accompany this convoy.

The third and final convoy was due to arrive on D+28 and was to bring a further three G.C.I. stations and two Light Warning Sets :—

A.M.E.S. No. 896 (G.C.I.).
A.M.E.S. No. 897 (G.C.I.).
A.M.E.S. No. 898 (G.C.I.).
A.M.E.S. No. 6007 (L.W.S.).
A.M.E.S. No. 6008 (L.W.S.).

Two more M.S.S.U.s, Nos. 302 and 304, making four in all, and a second Wireless Unit, were scheduled to sail with this convoy. Arrangements for the disposal of R.D.F. equipment brought by follow-up convoys were to be made by the Chief Signals Officer to meet the needs of the prevailing situation.

The remaining ground search R.D.F. units were to arrive in Algerian and Tunisian ports by successive follow-up convoys at fortnightly intervals and were to be disposed of in accordance with the military situation obtaining at the time.[1] In the main, this equipment was to consist of G.C.I. stations and Mobile Radio Units, which were to be used to strengthen the R.D.F. coastal chain and extend it to the east. The supply of M.R.U.s was left to a later date as they were cumbersome to move and more appropriate to static and defensive warfare than to front-line movement.

Training of Ground R.D.F. Crews for the Invasion of North-West Africa

The crews for the three Light Warning Sets designed to go in with the assault troops on D-day were picked from the Home Chain R.D.F. stations and sent to the Combined Operations training centre, H.M.S. *Dundonald* in Western Scotland, for Commando training.[2] The crew of each set numbered twelve men with a senior technical N.C.O. in charge : the unit to be completely self-contained with its own R.D.F. and W/T operators, cook and motor transport driver. While at H.M.S. *Dundonald* the men were toughened up by means of physical training, daily Commando assault courses and hard living under field conditions. To complete their technical training as a team of skilled tradesmen it was intended that the Light Warning Sets to be used in Operation " Torch " should be sent up to H.M.S. *Dundonald* as soon as they came off production. This would have given the crews a chance to become fully acquainted with the new equipment before embarking on the invasion. Unfortunately these sets were not ready in time to be sent to the training camp and the first sight their crews had of this new and unfamiliar equipment was at West Kirby Personnel Despatch Centre. Here they were allowed three or four days only in which to practise setting up and taking down the gear. Owing to the rigid nature of the shipping time-table it was impossible to delay the despatch of the equipment in the convoys and therefore no extension of this far too brief technical training period could be allowed.

The training of the C.O.L./G.C.I. crews on the other hand was handled with much greater efficiency. It had been instituted by Headquarters, No. 60 Group, and was carried out at No. 21 Signals Training Unit, Renscombe Down, Swanage. The crews were given a training programme covering practice in assembling and dismantling the technical gear, driving heavy lorries, route

[1] *See* List of the units concerned in Appendix No. 23.
[2] Narrator's interview with Wing Commander Humphreys-Owen, R.D.F. Officer, Eastern Air Command.

marches, lectures and medical instruction. On completion of training at Renscombe Down the units were dispersed to R.D.F. stations in the South of England where they continued their training under operational conditions, living in the field in the neighbourhood of the Home Chain stations. Operators and mechanics often shared watches with the station personnel and in most cases this worked out extremely well. The major complaint was the cancellation of all leave during training, as the time spent at the Personnel Despatch Centre at West Kirby allowed for a maximum of only three days embarkation leave.

On the whole, this training system for the G.C.I. crews gave excellent results ; the men were keen and experienced and formed united teams. Good as the training was, however, these crews were trained in raid reporting and control functions purely for defensive operations, and at no time was any suggestion made that the units could or would be used for R.D.F. operations involving Royal Air Force tactical close support to the Army.

Embarkation and Voyage

Between 11 September 1942 and the end of that month, the R.D.F. units for the assault and build-up stages of Operation "Torch" for the Eastern and Centre Task Force were phased into the North-West Personnel Despatch Centres near Liverpool and Glasgow ; their technical equipment, fully packed and crated, being despatched separately with unit M.T. vehicles direct to the ports of embarkation.[1] The training period, short though it had been, was at an end. The personnel were embarked at various dates during October on shipping convoys from British ports, the assault forces sailing on 26 October 1942. Then followed the journey to the North African coast, a distance of approximately 1,500 miles, subject to U-boat attacks. The vessels on which the Assault R.D.F. units were shipped completed their slow convoy voyage safely, re-fuelling at Gibraltar, and arrived off their appropriate North African beaches before dawn on 8 November 1942, to await the beginning of the assault.

The Landings in the American Zones of Responsibility

The Western Task Force was to make landings at Casablanca, the Centre Task Force at Oran and Arzeu. The bulk of the American R.D.F. equipment in the assault convoy for the all-American Western Task Force was sunk during the journey from the United States. The American Signals Aircraft Warning Battalion of the mixed British–American Centre Task Force arrived without its equipment.[2] The assault convoy containing Royal Air Force R.D.F. equipment, however, arrived off Arzeu, East of Oran, in the early hours of 8 November 1942.

Before dawn the assault troops started going in and met with only light opposition from the French, which they soon overcame. By the afternoon the first staff officers of the 12th United States Air Force and the Royal Air Force R.D.F. liaison officer went ashore. They were taken within 40 yards of the beaches by landing barges and then left to wade ashore up to their chests in water, presumably to give atmosphere to the proceedings as there was no opposition by this time.[3] Accompanying them were the crew of one C.O.L.

[1] Royal Air Force Station, White Waltham O.R.B., September/October 1942.
[2] C.O.S. (43) 98 (0), 4 March 1943—War Cabinet C.O.S. Committee, North Africa Operations, Lessons in Signals Communications, para. 21, sub-para. (*a*).
[3] Report on Operation "Torch"—"R.D.F. used in the Centre Task Force" by Wing Commander J. Swinney.

unit, one Light Warning Set, and one Wireless unit. By the following morning the personnel had been formed into collective units but the only R.D.F. equipment aboard the ship, the Light Warning Set No. 675, took two more days to bring ashore. Therefore as far as the assault phase was concerned, ground search R.D.F. played no part in the landing at Arzeu. Every effort was made to get A.M.E.S. No. 675 into operation, but several setbacks in the form of an acute lack of spares, the usual teething troubles with newly-designed equipment, and difficulties with power supplies caused considerable delay. The station did not become operational at its appointed site near Arzeu until D + 6, 14 November 1942.

R.D.F. During the Period Immediately Following the Assault

On D + 3 a convoy arrived carrying four G.C.I./C.O.L. stations. Priority had not been given to R.D.F. equipment in the loading of ships and irate R.D.F. unit personnel had to stand by and watch much luggage being unloaded before their technical equipment could be taken off the ships. A.M.E.S.s Nos. 890 and 899 were two of the units in the follow-up convoy. The crew of A.M.E.S. No. 890 had made a wet-shod landing on D-day and were several days getting their R.D.F. equipment unloaded from three separate ships. They moved as soon as possible to their assembly point and found that a road would have to be constructed to their site at Cap Carbon. Heavy rains which turned the ground into a bog added to their difficulties. The morale of the R.D.F. personnel was high however and keen competition arose between the men of this unit and those of A.M.E.S. No. 899, who had docked at Mers el Kebir on 12 November 1942, as to which unit would become operational first. A.M.E.S. No. 890 finally was operational on 18 November 1942, beating A.M.E.S. No. 899 by a day, the latter losing their aerial vehicle in the mountains, which delayed them.[1] The two remaining C.O.L. units in the follow-up convoy, A.M.E.S.s Nos. 8000 and 8001, had similar trouble in collecting their equipment but after much perseverance became operational on 21 and 24 November 1942, at Cap Ivi and Cap d'Acra.[2]

The Filter Room

The provision of Filter Room facilities had been an American responsibility. On setting up this reporting centre for the R.D.F. stations, they found they had not sufficient radio equipment to receive information from all the R.D.F. units, so it was necessary to use some of the equipment and personnel of one of the Wireless Units. A temporary Filter Room was set up in the French Observer Stations Centre at Oran. The filter map had been drawn in London on a piece of white oil-cloth and only had to be pinned on a table. The Plotters and Filter Officers, who were American, were rather slow at first through the lack of experience in the job, but they soon improved. By D + 12 the Filter Room was operating well with four C.O.L. stations, A.M.E.S.s Nos. 890, 899, 8000, and 8001, one Light Warning Set, A.M.E.S. No. 675, and approximately ten Wireless Observer Unit Posts telling into it. On D + 14 the first enemy aircraft was plotted over Oran. The stations' plotting was accurate and as all the equipment was beam type there was no need for filtering, each station's plots lying practically on top of one another.

[1] No. 899 A.M.E.S., O.R.B.

[2] Nos. 8000 and 8001, O.R.B.

On D + 28 (6 December) two Mobile Radio Units and two additional Light Warning Sets were brought to Mers el Kebir. A.M.E.S. Nos. 285 and 286, Mobile Radio Units types similar to those used in the Middle East, took some considerable time to amass their equipment and repair the damages they had sustained during the long sea voyage. A.M.E.S. No. 285 finally became operational at the end of February 1943 at La Plage de la Bouliche, a sandy and well-drained site. A.M.E.S. No. 286 had trouble with bad weather, and flooding of their site delayed the erection of the equipment. They came into operation ahead of A.M.E.S. No. 285 on 16 January 1943 at El Marsa.[1]

A.M.E.S. No. 6003, a Light Warning Set, was attached to the 561st A.W. Signals Battalion, 12th Fighter Command, U.S. Army at La Senia airport. They found their equipment to be entirely different from that on which the unit had been trained. In the absence of secret documents, circuit diagrams or technical information of any kind, the erection and installation of the equipment presented a major problem. No wavemeter, an essential accessory with equipment fresh from production, was included but the equipment was put into operation with great difficulty for testing purposes.[2] Motor transport, and tents for sleeping accommodation were insufficient. In many small ways a lack of foresight was shown in the provision of non-technical equipment. Minor examples were the provision of nineteen inkwells for a unit totalling twelve personnel, five hundred duplicator stencils but no duplicator, and even the provision of Air Ministry Orders from 1918 to the current date lost some of its value in the absence of the relevant appendices. The unit moved to Cap Tenes, where the equipment had to be carried the last 150 feet to the site as the rocky nature of the ground precluded transport being driven over it. The personnel were billeted in a near-by lighthouse.

A.M.E.S. No. 6004, the Light Warning Set which had been in reserve, found itself in a sorry plight after landing at Mers el Kebir. No one could give it instructions where to go and no equipment could be found for it. Some days later when its crew were walking disconsolately through the docks they noticed a particularly ragged M.T. vehicle with the canvas torn and sides crushed in. This was A.M.E.S. No. 6004's equipment.[3] With great credit they became operational on 26 December 1942 at Cap Bacchus. Many breakdowns occurred, however, due to the set coming straight from production.

Trouble with the Technical Equipment

Considerable trouble was experienced with the technical components of the ground R.D.F. sets and it became increasingly apparent that a much more careful vetting of the equipment should have taken place before it was despatched in the convoys. The practice of having only one R.D.F. mechanic on the establishment of each unit led to chaotic conditions in the event of his becoming a casualty. Many of the mechanics had been used to relying on a Wing technical section during their previous experience on the Home Chain and consequently were inexperienced in servicing major faults. The lack of a first-rate R.D.F. mechanic on these isolated field units might mean a station becoming non-operational for far too long a period until the Mobile Signals Servicing Unit mechanics had been called in.

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[1] Nos. 285 and 286 A.M.E.S., O.R.B.
[2] No. 6003 A.M.E.S., O.R.B.
[3] No. 6004 A.M.E.S., O.R.B.

Motor Transport

The Light Warning Sets had one 15-cwt. motor vehicle only, which was quite inadequate to carry technical equipment, tents, domestic equipment and a crew of twelve. As these sets were primarily to be used for the assault phase they needed a high degree of mobility. Under the prevailing conditions in North Africa the personnel and equipment had to be moved alternately.

The C.O.L. stations fared better. They had ten prime movers but only one motor transport driver. This meant that M.T. maintenance could not be carried out efficiently and a total breakdown of any one vehicle caused delay to the entire convoy. Some of the lorries had been damaged in loading and unloading from the sea passage and many of the ancillary parts such as windshields, cabs, lamps, etc., were destroyed completely. Tow-bars for the trailers had been lost in transit,and some vehicles had been deck-loaded during shipment causing electrical leads to ignition systems and wiring to become unserviceable due to corrosion by sea water. Many of the vehicles were old before the operation began, one Wireless Unit Humber Utility Van had already covered 42,000 miles. They were consequently always coming to grief on the rough tracks and roads of the North-West African coast and were not adapted for transport in a tropical climate.

The Landing in Algiers in the British Zone

As originally planned, the airfield at Maison Blanche was occupied on D-day, 8 October 1942. This was mainly due to the fact that there was only temporary opposition from the French and no enemy air attacks on Algiers itself during that period. The assault operations proved a failure, however, as far as Royal Air Force Signals were concerned. The sea conditions at " Charlie " Beach at the time of the assault were a heavy swell and high rising wind, a combination of factors which precluded the landing of the equipment as planned.[1] Many landing craft were wrecked in attempts to beach them. Neither the point-to-point wireless stations nor the R.D.F. Light Warning stations could be landed. This resulted in a serious breakdown in communications and the provision of R.D.F. cover. No news was received of the progress of the operation subsequent to the initial landings until a small Army W/T hand-portable set was brought into operation. This made a link with the beach and the Command Ship H.M.S. *Bulolo*, which was lying off the main beaches to the West of Algiers and out of visual touch with " Charlie" Beach. Communications between Gibraltar and Algiers were conducted entirely through H.M.S. *Bulolo*, as was the early warning of enemy aircraft and fighter control, until these services were established ashore some days later. Officially, hostilities at Algiers ceased at mid-day on D-day and equipment from the assault vessels was brought into the harbour on D + 1, 9 September 1942.

The first of the Light Warning Sets to land, A.M.E.S. No. 6001, was left at the beach-head at Surcouf with the advanced Wing Headquarters while A.M.E.S. No. 6000 followed the Army advance to the airfield at Maison Blanche. Unfortunately they were of little use during this first phase of the landing due to the crew's complete lack of knowledge of their equipment and the slow and disorganised process of unloading the assault equipment. Not only were the packing cases difficult to find, and the case-openers packed inside them, but

[1] Air Ministry File C.26023/45, para. 58 of the report.

when located it was found that, due to the unsupervised packing of the equipment, the components were broken down to far too fine a degree. The aerial systems in particular were separated to the last screw. The crew, inexperienced and untrained on this equipment, found it an almost impossible task to piece their R.D.F. set together in order to get it operational. Consequently the Light Warning Sets which should have been ready to work within an hour of landing were not set up until the following day. This situation might have been alleviated if shipping space could have been found for one R.D.F. officer to accompany the sets during the assault.

Enemy Attacks on Ports and Shipping

On D + 1 no move was made owing to conferences on armistice conditions with the French. Enemy air attacks were made on Algiers and one ship was sunk off Cap Matifou. Twelve enemy aircraft were destroyed however by British fighter aircraft without the aid of any R.D.F. system, this proving to be the first and last time an attack was made on Algiers by day. On the following day information was received that the Axis had made an unopposed landing in Tunisia—small numbers of enemy troops had arrived at Aouina airfield on 9 November 1942, from Sicily. It therefore became all the more imperative to seize the airfields at Djidjelli and Bone to assist in a speedy occupation of Tunisia. After his attack on Algiers the enemy carried out bombing attacks on the ports of Bougie and Bone which were occupied on 11 and 12 November 1942 respectively. These air attacks for the most part were comparatively light, but there were further signs that the enemy was moving material and personnel into Bizerta and Tunis at a rapid rate, the Allied plan of anticipating the Axis in Tunisia thereby being placed in jeopardy.

Enemy air tactics during the early period underwent various changes. They began by attacks on the ports and shipping and then turned to the congested airfields, using *JU.88s* and fighter bomber aircraft in high and low-altitude attacks. Here again the lack of adequate R.D.F. cover was a serious deficiency in the defence system, and until a satisfactory warning system was established, standing aircraft patrols had to be maintained over the ports. Bone airfield in particular was subjected to frequent and heavy attacks while the port itself was raided intermittently. Some damage was sustained by the harbour and ships lying in it but it was never serious enough to prevent its use, vital to the build-up of the First British Army.

By 13 November 1942, the airfields at Algiers, Djidjelli, Blida and Bone were all occupied and squadrons quickly based on them to provide cover against enemy aircraft for convoys proceeding to and from the East, these convoys being the primary line of supply for Allied land forces. The same airfields provided the fighter defence of the ports in their vicinity. The operations of these squadrons were once more handicapped in the early stages by the absence of adequate warnings which only R.D.F. could give, and standing fighter aircraft patrols had to be kept over the convoys and ports, involving heavy flying hours for the limited number of aircraft.

R.D.F. During the Period Immediately Following the Assault

Once started, the advance to the East proved to be even more rapid than had been expected and by D + 9 the leading elements of the ground forces were less than 60 miles from Tunis, and Philippeville and Souk el Arba airfields had been added to Maison Blanche (Algiers), Blida, Djidjelli and Bone.

As a result, there was an acute shortage of all signals equipment. On D + 4 the main follow-up convoy had arrived. This should in theory have materially eased the situation. It was not, however, until 18 November 1942 (D + 10) that the first item of Signals equipment was collected from the ships nor was it until many days later that all the units were complete.[1]

One reason for this inordinate delay was the fact that all R.D.F. equipment had been stowed in the bottoms of ships and thus were the last of the cargo to be off-loaded. But the main cause of the trouble was the state of confusion resultant upon complete lack of organisation at the docks. Equipment was unloaded and then dispersed arbitrarily, not only over a large dock area, but also to various dumps all over Algiers. No attempt was made to ensure that vehicles bearing the same field unit's numbers should be sent to the same dispersal area, and no record was kept of the destination of individual vehicles, which were removed by the nearest man who could drive to whatever destination was favoured by the officer or N.C.O. supervising the unloading. The result was that the only practical way of concentrating a unit was to detail its personnel to wander about the docks and the better-known dispersal dumps, in the hope that from time to time they would come across their own equipment. It meant almost literally inspecting every packing case. No preferential treatment had been given to the highly-secret R.D.F. equipment, and it lay under a welter of barrack and domestic equipment, including mobile laundries and complete office furniture for the Headquarters staff.

Mobile R.D.F. Used in the Follow-up Stages

From 20 November 1942 onwards, the plan of deployment of R.D.F. stations agreed upon at Norfolk House ceased to be followed. This plan had been governed by the lack of shipping space available for R.D.F. in the early convoys and was based on a fairly gradual move forward of our forces eastward from Algiers. In actual fact the Army went straight forward into Tunisia and was only 16 miles from Tunis by the night of 24/25 November. Instead of a number of mobile R.D.F. sets being available to advance with the ground forces, there were only two L.W. Sets, and the promise of a steady but slow supply of C.O.L./G.C.I. stations arriving in fortnightly convoys, two at a time.

So short was the supply of the available equipment, that instead of it being sent to its planned positions to form a chain of stations along the North African coast, the plan was scrapped and the R.D.F. stations were sent wherever the need was greatest. Unfortunately this led to a high degree of chaos and confusion due to the inability of the operational and signals staff to agree on any one site. The R.D.F. stations consequently had a worrying time dashing up and down the countryside in response to contradictory signals. Here again the rigidity of shipping plans had to be adhered to and it was quite impossible to increase the flow of R.D.F. equipment to this theatre.

R.D.F. Units in Action

A.M.E.S. No. 893 arrived in Algiers on 13 November 1942. It took a week for the unit to collect its equipment and proceed en route to Bone.[2] But on 20 November 1942 the enemy made his first attack by night on Algiers. These attacks continued for five nights during the full moon, the maximum number

[1] Report on Operation "Torch" by Air Marshal Sir W. Welsh—(Air Ministry File C.26023) Appendix "B," Signals Instructions. [2] No. 893 A.M.E.S., O.R.B., 13 November 1942.

of aircraft used being about thirty. The R.D.F. warning system had not yet been developed and the only warning of approach of these raids was obtained from Naval R.D.F. on warships in the harbour. These attacks caused despondency amongst the civilian population.[1] A.M.E.S. No. 893, therefore, was turned back and on arrival at Algiers was ordered to proceed to Surcouf. The unit arrived here at 1600 hours on 23 November 1942, and with commendable efficiency and in the minimum of time, became operational at 2000 hours.

In order to carry out controlled interception satisfactorily it was necessary to have the R.D.F. not only on the ground in the form of the G.C.I. station but also in the aircraft, that was the A.I. (Air Interception) apparatus. Air Ministry had decided on security grounds that A.I. equipment was not to be fitted in aircraft flown into the North-West African theatre of war during the early stage of the campaign. This secret aircraft R.D.F. equipment was to come by ship and would consequently take some time to reach Algiers. Attempts to use both Hurricane and Beaufighter aircraft by night without ground control proved abortive, and when A.M.E.S. No. 893 finally became operational, attempts at "cat's eye interception" failed also.

Although these enemy attacks were delivered early in the operation, a Sector Gun Operations Room had already been set up near Maison Blanche. Complete control of the shore guns and fighter aircraft was effected from it except for the fact that there had been no G.C.I. control and the defence of Algiers had therefore to be left to the A.A. guns.[2] The damage caused during these raids to the harbour was negligible but General Eisenhower was concerned at the effect which might be produced on the civilian population. He therefore made urgent representations to the Chiefs of Staff to accelerate the provision of A.I. equipment. A rapid decision was made and a flight of Beaufighter aircraft fitted with A.I. was obtained from the Headquarters Middle East. When they arrived at Maison Blanche it was found that A.M.E.S. No. 893 still had no V.H.F. R/T control, but improvisations were made and on the night of 27/28 November 1942, a flight from No. 87 Squadron, in co-operation with A.M.E.S. No. 893, shot down five enemy aircraft. A greater number of enemy raiders had been anticipated by the Intelligence section, but after the first five leading enemy aircraft had been brought down the remaining enemy bombers evidently withdrew.

This successful operation showed that the German Air Force had not learnt its lesson from the night battle over Britain and its pilots continued to fly into the target at 15,000 feet in procession at five minute intervals. These tactics were perfect for G.C.I. interception. After this success the enemy did not renew his night attacks on Algiers for some weeks. Instead he turned his attention to ports further to the East. A.M.E.S. No. 893 remained at Surcouf for many months, as Maison Blanche was one of the main vulnerable points in the theatre. They made many successful interceptions but the *Luftwaffe* tactics changed and by the time they returned to the attack on Algiers they had adopted the low-flying approach to reduce the effectiveness of the R.D.F. cover.

The original tactics adopted by the enemy in his attacks on the ports were high and low-level bombing of ships at anchor in the bays. He had in the early days, as at Bougie, a measure of success but as it became possible to provide

[1] Air Ministry File C.26023, para. 133 of the report.
[2] *Ibid.*, paras. 135 and 136 of the report.

stronger fighter aircraft patrols, and as the R.D.F. and communications improved, he was forced to change his methods to torpedo-attack of ships in harbour and night attacks—neither of which was highly successful.[1]

The personnel and vehicles of A.M.E.S. No. 892 were disembarked at Algiers on 13 November 1942, but about this date a ship was sunk in Djidjelli harbour and A.M.E.S. No. 892 was ordered to re-embark without prior notice for Djidjelli on 17 November 1942.[2] With so little advance warning given, the minimum of equipment was put on a landing craft to be taken to the port by sea. Great hardships were suffered by the R.D.F. crew, and although most of the technical equipment arrived, none of the domestic articles were included, and indeed were never found. The unit became operational on the dock side to begin with, and suffered heavy bombing attacks which added to the considerable discomfort in which they already existed. Two nights later the unit moved to a second site, setting up as a C.O.L. station plotting to Djidjelli airfield, as suitable G.C.I. sites were practically impossible to find in this locality.

Four enemy aircraft were shot down on 28 November 1942 on the information given by A.M.E.S. No. 892 and several other successful interceptions were brought about later. It did not have such a success as A.M.E.S. No. 893, as Djidjelli airfield was only a small private flying field and could not accommodate fighter aircraft.[3] Once again the same mistake had been made of sending R.D.F. to a port without realising it only has a really useful function when used in close conjunction with fighter aircraft. Occasionally Beaufighter night-fighter aircraft would be flown from Maison Blanche to be controlled by Djidjelli but after the first week or so Djidjelli became of secondary import and it was considered more advisable to control aircraft from Maison Blanche. Later, day fighters based at Philippeville flew patrols over to Djidjelli and A.M.E.S. No. 892 remained on its site to become part of the final coastal chain.

The Light Warning Set A.M.E.S. No. 6002 which arrived with A.M.E.S. No. 892 and 893 was sent to a French airfield inland at Youks le Bains. It was of no actual use there and the airfield was not being attacked—its move was due rather to political representations at a high level. Meanwhile it was decided to resite the Light Warning Set A.M.E.S. No. 6000 on some high ground in the Bois du Boulogne area near Algiers—to give low cover. A.M.E.S. No. 6001 was taken from Surcouf where it had been encamped and was resited at Maison Blanche. A temporary Filter Room was set up in the maintenance buildings belonging to the French civilian airline, *Air France*, which lay adjacent to Maison Blanche airfield.

Start of the Ground Search R.D.F. Build-up for the Coastal Chain

By D + 14, R.D.F. equipment was coming in through the ports fairly steadily, although there were still considerable delays in assembling and moving it forward. A.M.E.S. No. 894 proceeded to Bone and was set up on good flat ground about 15 miles east of the town, becoming operational on 2 December 1943. To a large extent the story of A.M.E.S. No. 893 at Surcouf was repeated. Enemy night attacks on Bone had begun before the G.C.I. convoy arrived there, and despite the fact that most of the crew had only a little G.C.I. experience as the unit had been intended for use as a C.O.L. station, morale and keenness were very high. On the third night of operation, when night fighter aircraft were available for the first time, three enemy aircraft were

[1] Air Ministry File C.26023, paras. 127 and 129.
[2] No. 892 A.M.E.S., O.R.B.
[3] No. 893 A.M.E.S., O.R.B.

shot down.[1] The port of Bone remained a vital target for the *Luftwaffe* throughout the campaign as it was the nerve centre for supplies to the British First Army under General Anderson. Thus A.M.E.S. No. 894 always had plenty to do and the total claims of night fighter aircraft operating under its control from December 1942 to early summer 1943, were approximately seventy enemy aircraft, thirty-four being shot down in the first month of being operational.[2] The toll taken of enemy raiders proved so devastating that the German Air Force abandoned the attacks for some time and never renewed them in force.

A.M.E.S. No. 895 arrived at Algiers on 22 November 1942. There was some disagreement between R.D.F. technical officers and Operations staff officers as to whether it should be sited at Bone or Cap Takouch. Eventually it was agreed that it should remain near Philippeville and it became operational at Herbillon near Cap Takouch on 6 December 1942 as a C.O.L. station. Generally the siting of C.O.L. stations on this terrain proved to be far from easy. There were few roads and the site at Cap Takouch was a typical example of some of the difficulties which had to be overcome. The selected location lay in a lighthouse and although there was a sort of road to the foot of the lighthouse, the site lay a further hundred feet up. Six-wheeled lorries had to be half-dragged, half-driven over hard, rough rock that formed the approach to the lighthouse compound.

Of the two Light Warning Sets that accompanied A.M.E.S. Nos. 894 and 895, one could not find its equipment and the crew were therefore dispersed amongst other stations and the other was put near Cap Gros close to La Calle, about 60 miles east of Bone. This advance position was useful for early warning in conjunction with A.M.E.S. No. 894.

A.M.E.S. No. 896 was on its way to Philippeville, but soon after its arrival a state of emergency arose in Algiers necessitating a C.O.L. station to back up A.M.E.S. No. 893. A.M.E.S. No. 896 was therefore turned back and was finally sited on high ground slightly west of Algiers in the grounds of the observatory at Bouzereah, for a straightforward C.O.L. function, becoming operational on 29 December 1942.[3] The site was only fair, as the R.D.F. view was impeded by permanent echoes on the cathode ray tube for a radius of 10 to 20 miles from the station. The missing Light Warning equipment finally turned up and the station was set up on the highest site in the cork forest, west of Algiers, as an experiment for the resiting of A.M.E.S. No. 896.

At the end of December 1942 Bone was being heavily attacked by air. This port was in range of enemy fighter and fighter-bomber aircraft and it constituted the most forward port available to the Army, so was used to a maximum capacity. The R.D.F. coverage was poor at Bone owing to the configuration of the country, so A.M.E.S.s Nos. 897 and 898 which had arrived at Algiers in early December to supplement the R.D.F. early warning system were sent to Bone.[4] A.M.E.S. No. 897 became operational as a C.O.L. station at Cap Gros in order to extend the advance warning against Bone, and No. 898 set up as a reporting G.C.I. at Souk-el-Khemis on 2 January 1943, just east of Souk-el-Arba. These sites covered a group of makeshift advanced inland airfields, used for the support of the Army, which were being attacked by German fighter-bomber aircraft, necessitating standing fighter patrols being

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[1] No. 894 A.M.E.S., O.R.B.
[2] Air Ministry File C.26023, para. 136 of the report.
[3] No. 896 A.M.E.S., O.R.B.
[4] Nos. 897 and 898 A.M.E.S., O.R.B.

kept throughout the hours of daylight. In planning the R.D.F. programme the main object had been to protect ports and shipping. Full appreciation had not been given to the fact that the stations could be used for protecting the airfields. Used in this way, they would give sufficient warning to Allied fighter aircraft to scramble, thereby eliminating the necessity for standing patrols. The Light Warning Set could have been usefully employed for this purpose, but at that time they were being used as gap-fillers for the C.O.L. and G.C.I. stations.

The End of the Initial Race for Tunisia

At the beginning of December 1942 the weather had broken and the period of heavy rains began. The narrow lowlands of the North African coast became a glutinous sea of mud. Thus rainy weather was the worst enemy of all at that time, making it increasingly difficult for the ground forces to advance or withdraw. The Axis forces in Tunisia had been steadily building up by reinforcements brought in across the Sicilian narrows and the enemy resistance became too strong. The British First Army, having advanced nearly 550 miles from Algiers to within 16 miles of Tunis, had to withdraw to a more easily defended position at Medjez el Bab because of the difficult supply problem and the stiffening enemy opposition. The immediate aim in the race for Tunisia had not been achieved and it was impossible to capture the whole of Tunisia by a single stroke.[1] The weather, by bogging down transport and airfields, frustrated Allied plans, and a battle for supplies of both sides began. The Axis forces had the easier supply route of some 100 miles only from Sicily compared with the arduous sea passage of the Allied supply routes, followed by either 500 miles of road or rail, or a sea journey along the North African coast.

Establishment of the North-West African Coastal Chain

The Allies could not hope to resume major operations in the north until the middle of March 1943 when the weather would have improved. Consolidation of the territory occupied included the improvement of the R.D.F. coverage and raid reporting organisation of the coastal chain of stations. By 21 December 1942 the R.D.F. position was as follows :—[2]

A.M.E.S. No. 890 was operational at Cap Carbon.
A.M.E.S. No. 892 was operational at Djidjelli.
A.M.E.S. No. 893 was operational at Surcouf.
A.M.E.S. No. 894 was operational at Bone.
A.M.E.S. No. 895 was operational at Herbillon, Cap Takouch.
A.M.E.S. No. 896 was operational at Algiers, supporting A.M.E.S. No. 893.
A.M.E.S. No. 897 was operational at Cap Gros, Bone.
A.M.E.S. No. 898 was operational at Souk-el-Khemis, Bone.
A.M.E.S. No. 899 was operational at Cap Falcon.
A.M.E.S. No. 8000 was operational at Cap Ivi.
A.M.E.S. No. 8001 was operational at Cap D'Acra.
A.M.E.S. No. 675 was operational at Arzeu.
A.M.E.S. No. 6000 was operational at Bois de Boulogne.
A.M.E.S. No. 6000 was operational at Algiers.
A.M.E.S. No. 6001 was operational at Maison Blanche.
A.M.E.S. No. 6002 was operational at Youks les Bains.

[1] Air Ministry File C.30435/46, Commander-in-Chief's Despatch on North African Campaign, pp. 16/17.
[2] Air Ministry File C.26023, R.D.F. Appendix to the summary of lessons learned in Operation "Torch." These locations are shown on Map No. 8.

From that date R.D.F. units started arriving from the United Kingdom in far greater numbers. They were soon piling up in the base areas, as they were intended for the provision of a chain of stations along the entire Tunisian coast. New G.C.I. stations with power-rotated aerial systems were brought to Algiers, and Mobile Radio Units, which had been sent later as their masts had to be broken down in detail, also began to arrive. Two of the ships in one convoy were torpedoed and some equipment was lost, the R.D.F. personnel fortunately suffering only one casualty.

All the units had great difficulty in amassing their equipment. The ship in which the technical equipment for A.M.E.S. No. 387 was being carried had been forced to return to the United Kingdom on account of bad weather. Several other units had minor parts missing and had to obtain them locally. A.M.E.S. No. 389, despite the fact that it had several vital pieces of equipment missing, claimed to be the first M.R.U. to become operational east of Algiers on 18 January 1943. The following are points of interest relating to the other Mobile Radio Units in this theatre :—

(*a*) The crew of A.M.E.S. No. 372 was embarked on the flagship S.S. *Strathallan*. Throughout the voyage a W/T watch from this unit's personnel was operated and was congratulated on its efficiency by the ship's officers. At 0230 hours on 21 December 1942 the ship was hit by a torpedo when approximately 68 miles out of Oran.[1] The unit was transferred to a destroyer and subsequently disembarked at Algiers on 23 December 1942, becoming operational on 19 January 1943 at Jemmapes near Bone. They were a highly complimented station subsequently, the peak of their success being a track picked up at 90 miles due south on 26 March 1943. This track was plotted across the station and out to a range of 234 miles, making a complete run of 318 miles. It was later verified as a friendly aircraft attacking the docks at Tunis and enemy concentrations at Cap Bon.

(*b*) *A.M.E.S. No.* 318 became operational a month after its disembarkation at a site name Lac des Oiseaux on 25 January 1943.[2] It was on level ground back from the sea on the edge of a 12 miles swamp, backed by mountains.

(*c*) The ship on which the crew of *A.M.E.S. No.* 392 were travelling was torpedoed on 21 December 1942. The unit was disembarked at Oran just before the ship blew up.[3] They re-embarked for Algiers on 23 December 1942 and were operational at Alma Marine, east of Algiers, by 29 January 1943.

(*d*) *A.M.E.S. No.* 388 was put as far east of Bone as possible and slightly inland in the hope of catching enemy aircraft reconnoitring Bone from Bizerta airfields.[4] An objection was made to the site by the Army as it lay next to an ammunition dump, but the objection was over-ruled and the station became operational on 4 February 1943.

(*e*) *A.M.E.S. No.* 387 had to wait six weeks for a further supply of technical equipment as its original load had returned to the United Kingdom and the station consequently did not become operational until the middle of March at Port Gueydon to give advance warning to Bone.[5]

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[1] No. 372 A.M.E.S., O.R.B. [2] No. 381 A.M.E.S., O.R.B. [3] No. 392 A.M.E.S., O.R.B. [4] No. 388 A.M.E.S., O.R.B. [5] No. 387 A.M.E.S., O.R.B.

(*f*) The crew of *A.M.E.S. No.* 226 were aboard H.M.T.P. 15 which was torpedoed on 21 December 1942.[1] The personnel were taken off by a destroyer and landed at Algiers on 23 December except for one corporal who was missing and whose body was later washed up at Djidjelli. On finding their technical equipment, it was discovered that most of the masts were missing. After considerable trouble they obtained spare parts from local sources, but so great was the delay that it was not until 1 April 1943 that the station ultimately became operational at Djidjelli.

Five mobile G.C.I. stations, A.M.E.S.s Nos. 8002–8006, were distributed between Philippeville and Bone, the idea being to site them as far up with the advanced front of the Army as possible.[2] A.M.E.S. No. 8002 did good work as a G.C.I. station at Cap Cavallo reporting in to A.M.E.S. No. 892 at Djidjelli as it had no Filter Room telephone line of its own. Its maximum range on enemy aircraft reached 183 miles. A.M.E.S. No. 8003 gave a creditable performance, located in a vineyard just outside Philippeville, helping to destroy six enemy aircraft in the first six days of being operational from 21 December to 27 December 1942. A.M.E.S. No. 8004 had a spectacular position on the summit of a marble mountain at Col de Bes Best.

A.M.E.S. Nos. 8005 and 8006 were diverted at the request of the American authorities to Tebessa and Biskra to give R.D.F. cover to two of their inland airfields on the edge of the desert. On 14 January 1943 A.M.E.S. No. 8000 was removed from its site at Cap Ivi and rushed to Cazes airfield preparatory to setting up as a G.C.I. for the protection of Casablanca. The setting up of A.M.E.S. No. 8000 at a point 6 miles east of Fedala coincided with the arrival of Mr. Winston Churchill and the President of the United States of America for the Casablanca Conference and the unit was subjected to the visits of numerous high-ranking and important officials.

The Americans had very little R.D.F. of their own and few trained personnel. Their supplies had been depleted considerably by the loss of ships in their assault convoy for the Western Task Force. The Type 270 was an example of the equipment they erected in the Oran and Casablanca areas. It was a heavy static set with two Cathode ray tubes indicating range and bearing only, and worked on a frequency of 106 megacycles per second. These sets had originally been used in Iceland. Experience gained in Operation " Torch " demonstrated the difficulty of preparing in the United States a seasoned and well-equipped air warning system ready for immediate deployment in a very distant theatre of war. The loss of equipment in transit and damage in shipment and landing necessitated considerable replacements and servicing as soon as the units reached dry land. Furthermore, replacement personnel arrived with a very limited amount of practical field experience, precluding their use in an active theatre. It was therefore suggested that the Casablanca area should be used as a location for a training school to be established, combined with an installation and maintenance reception centre.

By 30 January 1943 there were thirty-nine Allied ground search R.D.F. stations operating along more than 1,100 miles of North African coastline from the Casablanca area to Western Tunisia, excluding the relatively small

[1] No. 226 A.M.E.S., O.R.B.

[2] *See* Deployment of R.D.F. Stations, Appendix No. 24. Nos. 8000, 8002–8006 A.M.E.S. O.R.B.s, give these details.

portion of the Spanish-Moroccan sea-board.[1] In spite of all set-backs, the Coastal Chain had made good progress during the twelve weeks since Operation " Torch " had begun.

R.D.F. Lessons Learned in Operation " Torch "

The North-West African coastal R.D.F. chain could be regarded as reasonably adequate at the end of January 1943. Many valuable lessons had been learned by then of the application of R.D.F. to a campaign of this nature. Perhaps the strongest impression created from the R.D.F. and Signals aspect was that in any future similar operation the equipment and crews should sail together in the same vessel, and that as far as possible the equipment should not merely be transportable, but actually mobile, being fitted in a vehicle and adequately waterproofed.[2]

All R.D.F. equipment required skilled setting-up before it could be brought into operation. It was therefore a bad policy to issue untried equipment such as the new Light Warning Sets immediately prior to the voyage from the United Kingdom. The crews required experience on these sets before they could be regarded as adequately trained for such an operation. This situation might have been alleviated to some degree by the presence of an R.D.F. specialist officer, well versed in siting and technical supervision. On future occasions an R.D.F. officer should accompany each equipment in the assault stages and be with the station at all times while it is operational. The officer should be supplied with a light vehicle and it should be equipped with R/T equipment to enable the R.D.F. officer to keep in touch with all stations.[3]

Even had the Light Warning Sets worked immediately, their limitations made it imperative that sufficient long-range equipment of the G.C.I. type should be available at each assault area to cover vital focal points.[4] These would also require V.H.F. R/T ground-to-air facilities with them so that the night defence of the assault areas could be quickly organised in conjunction with A.I. equipped night fighter aircraft. As it was, in Operation " Torch," three Royal Navy ships were lost while attempting to provide this initial R.D.F. local cover.

The G.C.I. stations, though mobile, were very cumbersome, including trailers for aerial systems and power supplies. With the beginning of the rainy season in North West Africa the G.C.I./C.O.L. Units were practically immobilised by the mud. All vehicles should have been prime-movers so that rapid movement to new sites was always possible and never dependent on weather conditions.[5]

In the initial stages, the Army swept rapidly forward leaving a very large and important tract of country behind it ; within a very few days of the first landings the area of combat had moved over 300 miles from the landing places. The R.D.F. stations at that time were required to provide cover over ports and airfields behind the battle area. The scale of provision of R.D.F. equipment in the operation was insufficient for any to be spared for Army support in the very forward areas. It was all absorbed for the vital task of building the coastal chain. In addition, practically no inland R.D.F. reporting system could be set up either, giving rise to a need for airfield R.D.F. sets for purely local warning only.

[1] *See* Deployment of operational and non-operational R.D.F. stations in North Africa, Appendix No. 24.

[2] C.O.S. (43) 98 (*o*), 4 March 1943—War Cabinet Chiefs of Staff Committee, North Africa Operations, Lessons in Signals Communications, para. 21, sub-paras. (*c*) and (*e*).

[3] *Ibid.*, para. 21, sub-para. (*d*).

[4] *Ibid*, para. 21, sub-para. (*g*).

[5] *Ibid.*, para. 2, sub-para. (*b*).

Specialist tradesmen, particularly R.D.F. operators, quickly lose efficiency if they do not work regularly. Since the unit equipment was packed and shipped long before the embarkation of the personnel, additional equipment for continuous training should have been made available in the United Kingdom and special measures taken for daily training on board ship, particularly when the voyage was to be of so great a distance as that covered by the invasion troops of Operation " Torch."[1]

A much more thorough maintenance organisation for R.D.F. equipment should have been planned and organised in advance.[2] Spare replacement parts should have been received in the theatre of operation in greater quantities and at a much earlier date. Light Warning Sets should have been furnished with a greater percentage of spare parts to accompany each set as the maintenance organisation could not be expected to function in the early days of the assault.

Finally a plan for the installation, maintenance, and operation of the Air Warning Services should have been made under the control of the Royal Air Force Commander charged with the fighter defence of the area, and an R.D.F. staff officer should have been assigned to work under him. This would have obviated a lot of unnecessary wrangling about the disposition of the stations and enabled the units to settle down quickly and efficiently to the task for which they were intended.[3]

Although there had been deviations from the original R.D.F. plans for Operation " Torch " at the beginning of the operation, occasioned by both the inability to land the Light Warning Sets at the beaches because of the heavy sea, and also the landing of R.D.F. equipment at the unorganised docks, nevertheless, in the main the scheme of building a coastal R.D.F. chain was carried out successfully. By January 1943 this chain was fulfilling its functions, namely, giving R.D.F. warning of enemy air attacks on our coastal convoys, ports and coastal airfields, and G.C.I. cover for night attacks on these important targets. In addition, two G.C.I. units had been spared for the night defence of two inland airfields. The R.D.F. requirement in North Africa had become remarkably similar to the original requirement in the United Kingdom—a coastline had to be covered and certain targets had to have local sets—there was a definite R.D.F. " frontier " following the coast and the stabilised battle-line by January 1943.

The end of the race for Tunis in December 1942, in which the British First Army failed only by the narrowest of margins, saw the end of the first major phase of the North-West African campaign. The junction of General Von Arnim and Field Marshal Rommel's forces, and the approach of the British Eighth Army to the Mareth line fused the two separate theatres of war east and west of Tunisia into one. The Allies therefore re-organised during the latter part of January and February 1943 to achieve a unified command which was to lead to the final defeat of the Axis forces in North Africa.[4] The part played by the Royal Air Force ground search R.D.F. units in the concluding phases of the pincers movement in the culminating stage of the campaign is dealt with in the next chapter.

[1] C.O.S. (43) 98 (*o*), para. 5, sub-para. (*d*). [2] *Ibid.*, para. 21, sub-para. (*j*).
[3] *Ibid.*, para. 21, sub-para. (*k*).
[4] Air Ministry File C.30435/46, Commander-in-Chief's Despatch on North African Campaign, p. 37.

CHAPTER 18

R.D.F. RAID REPORTING IN THE FINAL PHASES OF THE TUNISIAN CAMPAIGN (JANUARY–MAY 1943)

On the fusing of the two separate theatres of war in North Africa, it was decided to achieve a unified command in the Allied land, sea and air forces. The first of the re-organisations to become effective was that of the air forces, with the creation of Mediterranean Air Command on 17 February 1943 under Air Chief Marshal Sir A. W. Tedder.[1] The new Command established a unified control over all Allied Air Forces, French, American and British, which were based in the Middle East, North-West Africa and Malta. The chain of command they established is shown below :—

Mediterranean Air Command

- Malta Air Command.
- North-West Africa Air Force.
  - Tactical Air Force.
    - No. 242 Group, Royal Air Force.
    - United States XII Air Support Command.
    - Desert Air Force.
  - Coastal Air Force.
  - Strategic Air Force.
- Middle East Air Command.

Under the Mediterranean Command, the North-West Africa Air Force was formed to unify the diverse activities of the Western Desert Air Force of the Middle East, the British Eastern Air Command and the United States Twelfth Air Force. It consisted of three separate combat elements—the Strategic Air Force, the Tactical Air Force and Coastal Air Force. The Strategic Air Force, under General Doolittle, was composed mainly of American heavy and medium bombers and had as its mission the destruction of enemy naval and air bases, communications and convoys. The Tactical Air Force, under the command of Air Marshal Sir Arthur Coningham, consisted of fighter and bomber aircraft from No. 242 Group, Royal Air Force, United States XII Air Support Command and the Desert Air Force. Its particular mission was the close support of Allied ground troops.[2] Air Vice Marshal H. P. Lloyd commanded the new Coastal Air Force, composed of the United States XII Fighter

[1] A.H.B./IIJ15/4, Report on Operations, The Western Desert Air Force.
[2] Air Ministry File C.30435/46, Commander-in-Chief's Despatch, N.W.A.A.F.

Command and of certain Royal Air Force elements from Eastern Air Command, with the task of defending Allied ports and convoys, conducting continual reconnaissance and carrying out both shipping and anti-submarine patrols.

These changes in the Command of the Air Forces in North Africa led to a re-organisation of the entire R.D.F. system, including the raid reporting and control organisation. The two Forces with which the history of ground search R.D.F. in North Africa is mainly concerned were Coastal Air Force (N.A.C.A.F.) and Tactical Air Force (N.A.T.A.F.).

Ground Search R.D.F. in N.A.C.A.F.

The Coastal Air Force was made responsible for the defence of the coastline from Casablanca to Tabarka, and was to embody the following R.D.F. equipment :—[1]

Eight Mobile Radio Units.
Fourteen C.O.L./G.C.I. Units.
Twenty-two S.C.R. 270s (American Units).
Three S.C.R. 516s (American Units).

With the attack on Casablanca on the night of 30/31 December 1942 by enemy aircraft which could only have come from bases in Southern France, it was decided that the Information Centres should be re-organised and that some rapid landline communication among the various centres in the whole of North Africa would do much to increase the effectiveness of the air warning network.[2] As an example, the returning bombers from the raid on Casablanca could have been engaged by Allied fighter aircraft from Oran if prompt and continuous contact between the Information Centres and Casablanca had been available. There later developed a scheme for dividing the entire coastline from Casablanca to Tripoli into twelve areas, each to be regarded as a Sector.[3] Each Sector, covering approximately 150 square miles, was to be given a series number and an Operations Room was to be sited in a convenient position within the Sector, combining in the same building a Filter Room connected to the R.D.F. screen within the area.

As the American R.D.F. equipment differed from the British in the major respect that its reliability in operational conditions was untried, it was decided that the static area West of Algiers should be equipped mainly with U.S. " Radar " stations.[4] However, as long as the Royal Air Force Beaufighter aircraft were the only aircraft available for controlled night fighter interceptions, a British G.C.I. station with crew had to remain sited in the Oran and Casablanca area. As soon as American night fighter aircraft arrived, with their own controlling staff, then the Royal Air Force G.C.I. stations were removed and their function taken over by the American G.C.I. units.

American R.D.F. Equipment used for Ground Control Interception

Owing to the lack of United States R.D.F. equipment with Plan Position Indicators in this theatre, the resources of the Royal Air Force were heavily strained in providing ground controlled interception facilities throughout the

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[1] N.W.A.A.F., O.R.B., " Outline History of R.D.F. in N.W.A.A.F." The R.D.F. Units involved are given in Appendix No. 25 of this volume.
[2] A.H.B./IIE/176, Minutes of Air Warning Conference, 1 January 1943 (Air Ministry Signals Branch Folder).
[3] N.W.A.A.F., O.R.B., Appendix " B," Signals Plan No. 3, 27 March 1943.
[4] " Radar " was already the American term for R.D.F. at that time.

area.[1] In order to free mobile C.O.L./G.C.I. sets to some extent, for use with N.A.T.A.F., a decision was taken in March 1943 to order eleven S.C.R. 588 equipments from the United States of America. These sets were an American fixed radar based in principle on the Royal Air Force " Intermediate " transportable G.C.I. equipment and were the only P.P.I. apparatus in production in the U.S.A. at that time, no mobile sets then being available. Sites were planned to reach as far east as Bone.

Ground Search R.D.F. in N.A.T.A.F.

The Tactical Air Force's area was the battle front and the immediate hinterland. No. 242 Group provided air support for the British First Army in the northern Sector, from the coastline to the important river crossing at Medjez el Bab and the central region down the Eastern Dorsale to Pichon.[2] No. XII Air Support Command (U.S.) supported No. II Corps in the Southern Sector. The nature of the terrain in Northern Tunisia had imposed certain limitations on the use of the R.D.F. Up to the changeover of Command these limitations had more or less been accepted, and no effort had been made to get R.D.F. early warning of enemy air activity in the battle area. There was an excellent R.D.F. layout in the rear areas and along the coast, but the front line had been neglected. The conditions obtaining on the formation of N.A.T.A.F. were as follows :—[3]

No. 242 Group.—Little R.D.F. equipment was available for the battle area. The four stations which were already in operation, one C.O.L., one C.O.L./G.C.I., and two L.W.S.s were sited to give fairly full protection for the defence of airfields in the Souk el Arba area at La Calle, Souk el Khemis and Oued Zarga, the latter site being close behind the Allies forward positions. The Operations and Filter Rooms were housed in two converted omnibuses situated in the Souk el Arba area. The R.D.F. stations were working well and personnel were keen, but to exploit the advantage of R.D.F. to its highest extent a far more comprehensive screen was necessary. In addition, the Controllers were inexperienced—which did not help in overcoming the difficulties caused by lack of R.D.F. cover of all possible enemy approaches.

XII Air Support Command (*U.S.*).—No form of systematic fighter control existed in this area, and the few American L.W.S.s sited here were merely acting as air-raid warning devices for the airfields at Tebessa and Thelepte.

The whole R.D.F. layout was therefore re-organised and augmented, the object being to look over the Tunis coastal plain as far as the mountainous ground permitted ; the gaps in the cover were made good by the extensive use of Light Warning Sets. As its role was to be mobile, N.A.T.A.F. was allotted the following R.D.F. units :—[4]

One Mobile Radio Unit.
Five C.O.L./G.C.I. Units.
Thirteen Light Warning Sets.
Nine S.C.R. 602 (American Light Warning Sets).

[1] N.W.A.A.F., O.R.B., " Outline History of R.D.F. in the N.W.A.A.F." (A.H.B./IIM/A.36/IM–IBB).
[2] A.H.B./IIJ15/26, Report on the Tunisian Campaign, N.A.T.A.F.
[3] A.H.B./IIJ15/27, Report on the Tunisian Campaign, N.A.T.A.F.
[4] *See* Appendix No. 26 for Unit Numbers.

Ground Search R.D.F. in the Desert Air Force

In addition, the Desert Air Force, which came under the command of Tactical Air Force but which was made responsible for its own battle-line and back areas, brought its own R.D.F. units into the Tunisian battle area.[1] These were some of the tough little units which had given excellent performances during the advance, retreat and final advance of the Western Desert Forces. They had a minimum number of personnel, displayed a high degree of initiative in all things and competed keenly for the most advanced sites. They were, namely :—

Three Mobile Radio Units, A.M.E.S.s Nos. 214, 216 and 274.
Two C.O.L. Units, A.M.E.S.s Nos. 510 and 522.
One C.O.L./G.C.I. Unit, A.M.E.S. No. 889.
Three Light Warning Sets, A.M.E.S.s Nos. 602, 609 and 629.

The R.D.F. system in this area was well established to operate on a narrow front. Good cover in depth existed, provided by the above stations. A.M.E.S. No. 510, with associated L.W.S.s, was employed with a forward sub-sector Operations Room, known as Sector " A."[2] The sub-sector Operations Room and the remainder of the R.D.F. stations reported directly to the main No. 211 Group Operations Room, there being no associated Filter Room.

Organisation for Maintenance and Supply of R.D.F. Equipment

At the time of the creation of the North-West Africa Air Force, a combined organisation called North-West Africa Air Force Service Command (N.A.A.S.C.) was inaugurated. Some time elapsed, however, before N.A.A.S.C. was able to function in any other manner than as an initial supply agency from the United Kingdom and the United States, and in the meanwhile the R.D.F. and Signals maintenance organisation, existing before the fusion of the Air Forces, continued in a modified manner, as follows :—

Nos. 301, 302 and 304 Mobile Signals Servicing Units were allocated to N.A.C.A.F.

No. 303 Mobile Signals Servicing Unit was allocated to No. 242 Group, N.A.T.A.F.

Air Headquarters, Western Desert, brought up its own Signals maintenance organisation, which included an advanced R.D.F. party from the Radio Installation and Maintenance Unit and which was claimed to be indispensable by the Air Officer Commanding.[3]

Prelude to the Enemy Retreat to Mareth

It will be remembered that in January 1943, the British Eighth Army and supporting Royal Air Force elements had the Axis forces well on the run in the Western Desert. Details have already been given of the R.D.F. ground units which followed up with the advancing elements of the Western Desert Forces when they were driving the enemy troops back along their previously victorious route.[4] As they approached Tripoli, the way became increasingly arduous. Roads were mined and bridges blown, giving rise sometimes to difficult diversions over large tracks of desert. The edges of the desert became boggy traps during

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[1] N.W.A.A.F., O.R.B., Outline History of R.D.F.

[2] Sector " A " was an advance echelon of No. 211 Group Headquarters, containing all essential Fighter Control elements and associated telecommunications. These details are given in the Report on the Tunisian Campaign, N.A.T.A.F. (A.H.B./IIJ15/27).

[3] Air Ministry File C.S. 8251/II, Middle East Report from the Senior R.D.F. Officer, Encl. 12A, para. 5.

[4] *See* Chapter 12 of this volume.

the winter rains, into which the heavy R.D.F. vehicles sank and were only dug out with difficulty. The rough tracks slowed up the pace of the convoys ; the R.D.F. aerial array mounted on its trailer was too cumbersome for speed, and the weight of the transmitter was sufficient to break the springs of the Crossley vehicle under injudicious driving.[1]

A.M.E.S. No. 880, a C.O.L./G.C.I. station was the first R.D.F. unit to become operational in Tripoli.[2] It arrived at 0500 hours on 26 January 1943, three days after the town had fallen to the British Eighth Army, and went on the air at 0800 hours the next day. A landline was laid to Navy House and the A.A. battery for early warning, and A.M.E.S. No. 880 did some valuable work reporting enemy aircraft raiding the town and harbour.

A.M.E.S. No. 274, a Mobile Radio Unit, became operational a day later, on 28 February 1943, having been held up on the road outside Tripoli by the advancing Highland Division. An experiment of controlling fighter aircraft on interceptions was carried out between A.M.E.S. No. 274 and fighter aircraft of No. 73 Squadron, but effective results were practically impossible as the identification equipment—I.F.F.—had been removed from the aircraft.[3] Air Ministry had stated that since it could not be guaranteed that I.F.F. switched on over enemy territory did not assist the enemy, it would be advisable to restrict its use to certain areas. It was therefore removed from all fighter aircraft operating in the mobile area of the Western Desert—which made positive identification of aircraft impossible.[4]

As the R.D.F. stations moved forward, several of them dropped out of the mobile race after the enemy, becoming static stations at the vital key-points on the route — for the defence of the Libyan and Egyptian coast-line. It was no easy task to build semi-permanent sites unaided, and a great deal of hard work had to be got through before technical and domestic efficiency was achieved. Stations were sited by their commanding officers, in the absence of instructions from higher authority.[5] One station became operational with the heavy transmitter mast standing on two legs only, rather than admit to unserviceability. Fortunately they had a breathing space some time later for the mast to be righted. Ingenuity and resource was the normal order of these days, and what the units had not got they improvised, from repairing transport with parts taken off abandoned German vehicles, to keeping operational for three months with a transmitter coupling-condenser knocked up from a pickle jar lined inside and out with lead foil.[6]

Several of the units were bombed, but there were few fatal casualties. A.M.E.S. No. 510, the original mobile C.O.L. which, with A.M.E.S. No. 522, took the lead in the advance on Tripoli, found itself amidst heavy enemy air activity at Tamet.[7] An officer of one of the armoured cars which were used in the defence of A.M.E.S. No. 510, was killed when two German aircraft, *Me. 109s*, strafed the camp from a height below 50 feet.

As the forward landing grounds were cleared, Allied fighter and bomber aircraft were able to move up from rear positions and both day and night friendly sweeps added considerably to the air activity already plotted by the forward R.D.F. stations.[8] Their constant mobility precluded the laying of landlines, so that all aircraft plotted had to be reported by W/T.

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[1] No. 510 A.M.E.S., O.R.B.
[2] No. 880 A.M.E.S., O.R.B.
[3] No. 274 A.M.E.S., O.R.B.
[4] Headquarters, Middle East, O.R.B., 18 January 1943.
[5] No. 274 A.M.E.S., O.R.B.
[6] No. 215 A.M.E.S., O.R.B.
[7] No. 510 A.M.E.S., O.R.B.
[8] A.H.B./IIJ15/4, Report on Operations of the Western Desert Air Force.

A.M.E.S. No. 510 was congratulated by Headquarters, No. 211 Group, with whom it operated, on the speed and efficiency with which the unit handled the heavy air activity under adverse circumstances.[1] At Ber Dufan on 19 January 1943 it operated from a site adjacent to the landing ground. The following day the unit was ordered to move as near to Tarhuna as the military situation permitted. On 21 January 1943, after travelling 110 miles over the desert, this mobile C.O.L. arrived on the outskirts of Tarhuna and camped within sight of the battle going on down the road. On 23 January 1943, it was in Castel Benito, 15 miles from Tripoli, and was operational within half an hour—despite the bad shaking during the journey over crude tracks and uneven ground, and the overdue need of a technical overhaul.[2]

By early February 1943 there were four Mobile Radio Units operational in Tripoli, two C.O.L./G.C.I. stations, one acting as a C.O.L. and one as a G.C.I., and the two mobile C.O.L. units, A.M.E.S.s Nos. 510 and 522 taking a well-earned rest on the outskirts of the town and giving their overworked equipment its much needed maintenance by day, although Tripoli was raided every night.[3]

The Enemy's Withdrawal to the Mareth Line

Laborious as the British advance had been into Tripolitania, the enemy, too, had made a long and difficult retreat. Not only had he to be ready to meet a further advance by the British Eighth Army, but he had also to hold powerful Anglo-American forces in Tunisia, and all this with a line of communications across the sea from Italy and Sicily. In the air the enemy was at a disadvantage, since he had to face the Western Desert Air Force and at the same time to oppose strong Allied air forces, strengthened by unification, on his right flank in North-West Africa.

After the fall of Tripoli on 23 January 1943, the enemy began to withdraw to the Mareth defences. Tripoli now became the main port and supply base of the Eighth Army, and as such it was expected to become the target for considerable air effort at night by the enemy. To counter these attacks a flight of Beaufighter aircraft of No. 89 Squadron was moved forward on 27 January 1943, the day after the port was opened, and, controlled by A.M.E.S. No. 880, took part in combating the enemy night raids. Some time later this unit became the target of an enemy raid.[4] The receiver vehicle was destroyed and thirteen casualties were incurred, seven fatal.

While the preparations for the re-deployment of the Western Desert Forces were proceeding steadily, if slowly, against the enemy Mareth Line defensive positions, an attempt had to be made to hamper the enemy's supplies and reinforcements. It was known that his more urgent requirements were being transported by air in *Ju. 52* aircraft and it was thought that these lines of supply were employing the direct air route from Sicily to Bizerta across the Gulf of Tunis. In order to attack these transport aircraft effectively, it was decided to extend the R.D.F. early warning cover as far as possible and provide night and day fighter control facilities as far forward as ground conditions would permit. It is therefore necessary to digress from the main story of ground R.D.F. units in direct support of the land battle to consider the offensive operations against the enemy air transport supply lines.

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[1] No. 510 A.M.E.S., O.R.B. [2] *Ibid.*
[3] Report on Operations of the Western Desert Air Force (A.H.B./IIJ 15/4).
[4] No. 880 A.M.E.S., O.R.B.

R.D.F. Controlled Offensive Operations against the Enemy's Air Transport Supply Lines

With the falling off of night attacks on the Allied-occupied ports and with the removal of the ban on using A.I. aircraft over enemy territory, it was now possible to use the Royal Air Force night fighter aircraft on offensive operations against the enemy night air traffic between Sardinia, Sicily and Tunisia.[1] To this end, a G.C.I. station and a C.O.L. station were to be established in a lighthouse compound at Cap Serrat, which lay in front of the British First Army forward defences, overlooking the bay.[2] A.M.E.S.s Nos. 8010 and 8009 were selected for this task and were the first G.C.I. units in North Africa to be equipped with power-turned aerial systems. They had arrived at Algiers on 17 January 1943 and had been sent on to Bone, where once again opinions differed at Headquarters as to their ultimate deployment.[3] Such difference of opinion between Signals and Operational staff were characteristic of the siting of R.D.F. units throughout the North-West Africa campaign.

It was finally decided on 2 February 1943 that the units should make their way to Cap Serrat, despite the fact that it was expected that this area would fall to heavy enemy ground attacks within four or five days.[4] Both units were ordered to proceed with all haste to Tabarka and, once there, to disperse in the cover of the woods, eight or nine miles east of the town. A.M.E.S. No. 8009 had a comparatively uneventful journey, although harried by considerable air activity.[5] Rivers were crossed by means of temporary bridges thrown over by Army engineers, and vehicles encountered very difficult conditions, the road merging into a rough track which was sheer bog in many places. The way from the woods to the lighthouse was little better than a cart track and the whole surrounding area was a sea of mud. The vehicles had to be taken one by one through the mud, each one being hauled with the greatest difficulty from one tree to another by means of a winch. The unit finally set up in the lighthouse compound as a C.O.L. station on 4 February 1943.

A.M.E.S. No. 8010, on the other hand, was not so fortunate, and on 4 February 1943, on the way to Sedjenane, the transmitter vehicle towing a diesel power trailer, went off the road and overturned. Fresh equipment was brought up from A.M.E.S. No. 8005 and the unit sited in a partially dried bog, offering good concealment, about one and a half miles south-south-east of the lighthouse.[6] On 8 February 1943, the A.M.E.S. No. 8010 became operational as a night-operating G.C.I. working in conjunction with A.M.E.S. No. 8009. On 12 February the first enemy aircraft was shot down by a Beaufighter aircraft. However, the site was not satisfactory technically, and an alternative site was selected half a mile away at the foot of the lighthouse hill.

The Army front in this area was ill-defined and the British First Army Commander was unable to place sufficient troops in front of the R.D.F. stations, so a detachment some 350 strong of the R.A.F. Regiment was sent to augment a small garrison of *Corps Franc D'Afrique du Nord*, who were continually in skirmishes with the Italians on the Cap Serrat–Sedjenane road.[7] A small advance Headquarters was formed at Combined Headquarters, Tabarka, to provide a link with the lighthouse and the outside world. This Headquarters

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[1] A.H.B./IIE/176, Minutes of Meeting held at N.W.A.A.F. H.Q., 23 January 1943, para. 5 (*c*).
[2] No. 242 Group File 242G/550/Sigs., Encl. 23A.
[3] No. 8010 A.M.E.S., O.R.B., 1 February 1943.
[4] File 242G/550/Sigs., Encl. 66A.
[5] No. 8009 A.M.E.S., O.R.B.
[6] No. 8010 A.M.E.S., O.R.B.
[7] No. 8009 A.M.E.S., O.R.B.

was responsible for provisioning the two R.D.F. units, and organised mule and camel train to bring supplies along the coast as the road was no longer passable. It also had to liaise with the Royal Navy in order, when possible, to run a tank landing craft at night with supplies, and to maintain continuous contact with the Army, as the position in this sector was extremely fluid and it was essential that the Cap Serrat garrison should keep in touch with enemy movements.

This area was used for bombing practice by the enemy—which added not a little to the discomfort of the inhabitants. It was also overlooked by reconnaissance planes and reconnoitring Italian forces in the hills opposite. Consequently camouflage had to be as near perfect as possible. Personnel had to remain motionless during the day, either keeping under cover of the building or sitting in slit trenches and beneath bushes. It had been planned to use the C.O.L. station by day so that attacks could be made on the enemy air transport traffic of *Ju. 52* aircraft passing between Italy and Tunisia. Owing to the proximity of enemy observation posts, the station could only be operational during the hours of darkness. The aerial vehicle, elaborately camouflaged, was towed into position for operations at dusk and towed back into concealment behind the buildings before first light each day. The technical vehicles in the courtyard were camouflaged by whitewash to match the surrounding walls and buildings, being screened from view by high walls, and thus were reasonably inconspicuous from the air.

Operationally A.M.E.S. No. 8009's site was a very good one, on a cliff edge at between 600 and 700 feet above sea-level. Buildings immediately to the south and a buttress south-west of the aerial position screened the beam in these directions, but from 270° to 130° the sweep was unobstructed. Ranges were good, a maximum of 160 miles being obtained over the sea—this gave good cover over enemy-occupied Bizerta.[1] Shortly after the stations had been established, however, there was an almost complete cessation of enemy night activity and it was never possible to prove the efficiency of the scheme.

During the period, a matter of some three weeks, that the equipment was at the lighthouse, the stations were subjected to frequent enemy fighter-bomber attacks—sixty-seven attacks in all taking place, the first raid starting on the day A.M.E.S. No. 8009 became operational. By 19 February 1943 supplies were getting short. Owing to adverse wind and weather conditions, for over a week the Royal Navy had been unable to get their tank landing-craft up to the lighthouse. Reserves of food were almost exhausted and the only supplies getting through were those brought up from Tabarka by mule and camel; these were subjected to almost unceasing enemy air attack. On 26 February 1943, A.M.E.S. No. 8009 suffered a heavy air attack; telephone cables were cut and superficial damage sustained. Heavy gunfire could be heard in the vicinity and enemy gun positions could be seen being dug in the headland east of the Cap. An enemy attack inland was confirmed by French stragglers who took refuge in the lighthouse.[2] A message was received that Fort Monopole had fallen and 500 enemy soldiers were camped about the fort. The Brigadier commanding the local Army Brigade informed the Commanding Officer of A.M.E.S. No. 8009 that the Brigade were withdrawing to a position west of Sedjenane. They were therefore unable to offer help to the R.D.F. units at

[1] No. 8009 A.M.E.S., O.R.B.

[2] No. 8010 A.M.E.S., O.R.B.

Cap Serrat, and although there was no need to take immediate action, the position was obviously serious and a plan of evacuation was prepared in readiness.[1]

The following day the lighthouse was attacked by enemy aircraft which were mistaken for Spitfires expected over the station. Slight damage was done to the receiver vehicle. The Spitfires arrived later and, controlled by A.M.E.S. No. 8010, strafed enemy positions on the hills overlooking the valley in which the unit was situated.[2] On 28 February the tension had slackened and guards were dismounted, but by 1 March 1943, the enemy had captured Sedjenane and both units were ordered to evacuate. All secret documents were destroyed and secret apparatus was sent down to the jetty for despatch by motor torpedo boat. The only means of evacuation was along the coast to Sidi Mecherig and thence by mountain road to Tamara. As there was a danger of the enemy ambushing this defile, a further R.A.F. Regiment squadron of 200 strong was called up to hold the pass until Cap Serrat personnel had got through safely.

Both units proceeded to a rendezvous close to A.M.E.S. No. 8010's domestic site, carrying arms, ammunition and the minimum amount of kit possible. Personnel were split into small parties and made their way on foot to Sidi Mecherig. Enemy aircraft were frequently overhead and it was necessary to take cover continually. Sidi Mecherig was reached however without any casualties, and from there the parties were sent on to Tabarka by motor transport. The most secret parts of the technical equipment were evacuated by sea, but these consisted mainly of the smaller items. The remainder, including the technical vehicles and airmen's personal equipment, were destroyed by fire, detonators, and some of the more indestructible parts were jettisoned into the sea.

Royal Air Force Ground R.D.F. Units during the Enemy's Attack on Central Tunisia

While the Western Desert Forces were preparing for an onslaught on the enemy Mareth Line positions, the astute German Commander, Field Marshal Rommel, realising that an early attack by the British Eighth Army was unlikely, decided to take the initiative and strike at the American forces in Central Tunisia.[3] On 14 February 1943, despite adverse climatic conditions, the Axis opened an offensive in the southern sector of Tunisia directed against the Sidi Bou Zid and Kasserine areas. These attacks were held, but only after the enemy had materially improved his positions by securing the high ground from Gafsa to Pichon and the passes through the Dorsale.[4] By this action the enemy succeeded in reducing the Allied threat to the corridor joining Rommel's forces in Eastern Tunisia to Von Arnim in the north. In the air, the enemy air forces were largely having their own way. The American XII Air Support Command was being forced back by the enemy advance to Kasserine from the Thelepte plain.

At the beginning of the year, two Light Warning Sets, A.M.E.S.s Nos. 6002 and 6008 and one C.O.L./G.C.I., A.M.E.S. No. 8006, had been sent to Tebessa on temporary loan, to give cover to the American airfield at Youks les Bains,

[1] No. 8009 A.M.E.S., O.R.B. [2] No. 8010 A.M.E.S., O.R.B.
[3] A.H B./IIJ/15/4, Report on Operations of the Western Desert Air Force.
[4] Report on the Tunisian Campaign, Part I (A.H.B./IIJ/15/27).

15 kilometres north-west of Tebessa.[1] Communication facilities were bad and there seemed no possibility of A.M.E.S. No. 8006 being used to its fullest advantage. It was therefore decided that, in view of the military situation and the fact that the equipment was cumbersome to move in the event of an emergency, the unit should be removed to a safer area at Dellys, near Algiers. The Light Warning Sets were left behind to carry on.[2] With only a Senior N.C.O. in charge, these small stations had to fend mostly for themselves. Great difficulty was experienced with communications as they had no means of laying landlines and W/T plotting was poor due to the screen of surrounding hills. Contact with the airfield Operations Room became practically impossible after the hours of darkness and, due to unfamiliarity with the uses of an R.D.F. early warning system, a constant listening watch was not kept at the American airfield end.[3] To add to their troubles shortage of transport proved a great hindrance when getting out of tight corners in a hurry.[4] The Douglas Petrol Electric Generators were the chief source of technical trouble. They were the only means of electrical power supply that the Light Warning Sets had and they were continuously breaking down. To add to these difficulties, the fuel was sabotaged by local natives.

A.M.E.S. No. 6008 had arrived at Tebessa by train as they could not transport their men and equipment in one lorry. They had become operational in early January near Tebessa giving cover over the American air base and plotting to the base Operations Room and heavy A.A. battery nearby. A.M.E.S. No. 6002 had also been sent to Tebessa originally but had finally become operational at Thelepte in early February.[5] Both stations were busy but really needed 100% spares to maintain complete R.D.F. cover. Enemy air activity was practically continuous, and throughout the first half of February the heavy raids associated with the Kasserine Pass battle were plotted by A.M.E.S. No. 6008. By 17 February 1943, Thelepte was in the hands of the enemy and A.M.E.S. No. 6002 had been evacuated two days before to A.M.E.S. No. 6008's site, with its equipment badly damaged, its single vehicle destroyed, and one airman seriously injured.[6] By 20 February 1943, the enemy had captured the Kasserine Pass and had begun to strike out to the north and south towards Tebessa and Thala, but these onslaughts were checked, and on 23 February 1943 the enemy withdrawal began.[7] This proved to be the turning point in the Tunisian campaign. With the withdrawal of the Axis forces, Tebessa became a fairly safe area and A.M.E.S. No. 6008 remained on its site, later to be joined by several other R.D.F. ground search units. In the north of Tunisia, however, General Von Arnhim followed up the Axis advance in Central Tunisia with a powerful diversionary attack against Medjez el Bab and Beja.

General Von Arnhim's Attack in North Tunisia

On 26 February 1943, Von Arnhim launched a well-aimed thrust between Cap Serrat and Dj Mansour, achieving the high ground north of the Beja-Medjez road and the capture of Sedjenane, thus strengthening his defensive hold in this area. Once again, in the air the enemy were initially on top. No. 242 Group airfields in the Mejerda Valley were frequently unserviceable

[1] Nos. 6008 and 8006 A.M.E.S., O.R.B.s, and No. 242 Group File 242G/550/1/Sigsr., Encl. 25A. [2] Nos. 6008 and 8006 A.M.E.S., O.R.B.
[3] Mediterranean Air Command H.Q., O.R.B., "The Report on Signals Aspects of Reorganisation in North-West Africa." [4] No. 242 Group File 242G/550/Sigs., Encl. 54A.
[5] *Ibid.*, Encl. 80A. [6] *Ibid.*, and No. 6008 A.M.E.S., O.R.B.
[7] A.H.B./IIJ/15/27, Report on the Tunisian Campaign, N.A.T.A.F.

through rain, while low cloud conditions in the mountainous area enclosing the valley imposed a further restriction on Royal Air Force air operations. The enemy meanwhile operated ceaselessly from all-weather airfields in the Bizerta, Tunis and Kairouan areas.

There were four ground search R.D.F. units giving overland cover in this area in addition to those at Cap Serrat : A.M.E.S. No. 898 at Souk el Khemis, just east of Souk el Arba, A.M.E.S. No. 897 four miles west of La Calle, A.M.E.S. No. 6006 at La Calle and A.M.E.S. No. 6001 at Medjez el Bab. Lack of spare parts and consequent lack of technical maintenance had reduced the latter equipment to a totally unserviceable state, and it was therefore withdrawn to No. 303 M.S.S.U. on 11 February 1943 for a complete overhaul. A.M.E.S. No. 6006 was sent for from La Calle and was directed to take the place of A.M.E.S. No. 6001 at Oued Zarga. This unit was also in a state of disrepair, but instead of getting a badly-needed technical overhaul at the M.S.S.U. it was pushed into the forward area immediately and became operational on 13 February 1943.[1] Operationally the unit became extremely busy, and plots were even obtained on shells from enemy heavy artillery a few miles away. On 26 February 1943 some instructions were received from Souk el Khemis Operations Room for the unit to move out immediately. On applying to No. 303 M.S.S.U. for extra transport to make the journey possible, the sergeant in charge was told to keep the equipment operational. However, the following day a passing Army Transport officer took pity on them and advised them to clear out as quickly as possible in view of the local military situation. So piling their R.D.F. and W/T equipment and personnel on to their one and only lorry, the men made their way to Souk el Arba. There was persistent air activity throughout the move but the vehicle reached No. 303 M.S.S.U. without mishap, and the following day the N.C.O. i/c the station and two airmen returned to Oued Zarga and retrieved the domestic items which had been left behind. The remaining stations, A.M.E.S.s Nos. 898 and 897 gave excellent performances on the heavy Allied raids on Tunis and Bizerta and the enemy raids on Bone.[2] The rapid successes of the enemy in Tunisia had given rise to anxiety among the High Command in North Africa, and the aid of the Western Desert Forces was enlisted.[3]

Diversionary Attacks by the Western Desert Forces

During the enemy's temporary success in Central Southern Tunisia it became evident that any further similar enemy tactical moves might well jeopardise the whole Allied position, and General Montgomery received an urgent request from General Alexander to do everything in his power to draw the enemy's attention towards the British Eighth Army front. It was therefore decided that the Eighth Army should stage an immediate demonstration in force and the Desert Air Force was ordered to exert maximum pressure on both enemy air and land forces. On the day the attack opened, 23 February 1943, Fighter Wings of the Western Desert Air Force moved to forward airfields in the Medenine area, and were controlled by an Advanced Headquarters of No. 211 Group, while the remainder of the Fighter Force was controlled by Rear Headquarters, No. 211 Group, from Castel Benito. In the meantime, the

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[1] No. 6006 A.M.E.S., O.R.B. [2] Nos. 897 and 898 A.M.E.S., O.R.B.
[3] A.H.B./IIJ/5/4, Report on Western Desert Air Force Operations.

forward R.D.F. units of the Desert Air Force had been moving up after their short respite at Tripoli where their greatest pleasure had been the luxurious washing facilities.

A.M.E.S. No. 889 was the first R.D.F. unit to cross the Tunisian border. It occupied a suitable G.C.I. site at Ben Gardane on 19 February 1943 and set up at night with the aid of the moon.[1] A.M.E.S.s Nos. 274 and 510 were also moving up and had great difficulty in Zuara, half-way between Tripoli and Medenine. The former unit tried to find a site amidst the flat marshes which had been made considerably worse by heavy rains and bad weather. On the way it encountered A.M.E.S. No. 510, bogged on the track to El Assa. By prospecting all day, a fairly passable track to a site inside a minefield was found and the equipment set up as soon as possible, with the domestic camp made in a nearby former enemy fort and barracks. Meanwhile A.M.E.S. No. 510, having got out of the bog, moved to a reasonably good site at El Assa and erected its equipment in the face of a severe dust storm. During the afternoon fighter aircraft moved into the nearby landing ground and A.M.E.S. No. 510, now joined by A.M.E.S. No. 522, gave highly satisfactory cover to the standing patrols over the forward troops.[2] On 23 February 1943, A.M.E.S. No. 510 moved off to Medenine. Delays were caused by vehicles becoming bogged again and by the manœuvring of a pontoon bridge, but by the evening the unit was operational on a site two kilometres south-east of the town. W/T contact was established with No. 211 Group Rear Headquarters at Castel Benito, Tripoli, and despite the distance, the signal strength was extremely good. A landline was connected to Sector " A," No. 211 Group Advanced Headquarters, three miles away. The site proved to be good despite rather heavy permanent echoes to the north, and it appeared that the equipment gave better results when sited inland than on the sea edge.

On 25 February 1943, A.M.E.S. No. 522 became operational 10 kilometres east of Medenine. On the same day A.M.E.S. No. 274 left El Assa for Medenine. The road was densely packed with troops moving up, and after the frontier was crossed the congestion became worse. Two days later they were operational at Medenine, having had great difficulty in driving the stakes into the stony ground for guying-up the masts. At the same time A.M.E.S. No. 889 was instructed to move alongside A.M.E.S. No. 522 at Medenine.[3] A.M.E.S. No. 214 took over A.M.E.S. No. 274's site at Zuara and A.M.E.S. No. 216, an old campaigner from Tripoli, Syria, arrived at Zuara on 24 February 1943, two months after it had vacated its Syrian site. The following day the unit moved up to A.M.E.S. No. 889 at Ben Gardane and from there tried to reach its pre-selected site at Djerba Island. This proved to be impossible, so it joined A.M.E.S. No. 522 at Medenine and was sited nearby at Adjim on 1 March 1943.

By 25 February the British fighter-bomber offensive was in full swing, the main targets being Bordj Touaz, Gabes West and El Hamma airfields. The enemy was very active at first and launched a series of low-flying attacks on the British forward landing grounds.[4] The plotting of the forward R.D.F. units was good, so these enemy attacks had but little effect. On 26 February 1943, A.M.E.S. No. 510's site was ground-strafed by two enemy groups of *Messerschmitts*. An airman of the Armoured Car Corps escort was injured but the station guns fired back and the Operations Room helped to bring down

[1] Nos. 274 and 889 A.M.E.S., O.R.B. [2] Nos 510 and 522 A.M.E.S., O.R.B.
[3] Nos. 216 and 889 A.M.E.S., O.R.B.
[4] A.H.B./IIJ/15/4, Report on Operations, Western Desert Air Force.

six enemy aircraft and one probable.[1] The following day the No. 1 Armoured Car Corps took up a more advantageous position on top of a ridge above the R.D.F. site, in order to attack further hostile aircraft which assailed the unit. Excellent tracks were plotted by the mobile C.O.L. station and much information was given to Operations at Sector " A " on enemy aircraft over the Gabes area.

The Desert Air Force made attacks on Gabes airfield and town and on concentrations of enemy troops and armour in the Mareth area, all plotted by the forward R.D.F. units. By 27 February 1943 it was apparent that the plan had succeeded, as the enemy was withdrawing from the ground he had taken in Central Tunisia and was once again concentrating against the Eighth Army front.[2] In order that a similar enemy blow to that dealt to the Allied forces in Tunisia should not then be directed against the Eighth Army, it was arranged for the Allied Air Forces in North and Central Tunisia to attack the enemy airfields in the Gabes area and the movements or concentrations of his land forces behind the Mareth lines. This policy of switching the attack, adopted in turn by the Axis forces and the Allies, meant that the forward R.D.F. units were continually on the move, and often their sites were directly threatened by the enemy. On 1 March 1943, A.M.E.S. No. 889 moved to a pre-selected site north of Bougrara and camp was set up. One hour after their arrival, however, an urgent message was received instructing them to return immediately to A.M.E.S. No. 522 at Medenine as an Axis attack in force had commenced east of Mareth and it was vital that the C.O.L./G.C.I. equipment should not be captured.[3] The unit packed their equipment and moved back to Medenine in the dark.

Meanwhile, A.M.E.S. Nos. 510 and 274 were receiving some attention from the enemy and were being shelled on their sites at Medenine. A.M.E.S. No. 274 were ordered to evacuate on the evening of 1 March as the enemy were believed to be grouping armour which might develop into a thrust in the direction of Medenine. There was no moon that night and with difficulty they dismantled their Mobile Radio Unit and retired.[4] Some withdrawal of the whole forward R.D.F. screen appeared necessary at that time, and A.M.E.S. No. 510 were instructed to move off their site and to proceed to No. 211 Group. The unit waited for the following morning and moved off early, only to be told two hours later to return. Operations were set up again, but the following day warning was given of another impending move. This occurred on 6 March when the unit moved to a site one and a half miles east of Sector " A " and ten miles east of their previous site.

During this general withdrawal of the forward R.D.F. units, A.M.E.S. No. 522 was able to remain at Medenine. On 1 March 1943 there was an air of suspense on the station, the personnel being aware of the proximity of the enemy, and on 2 March 1943, having watched A.M.E.S.s Nos. 216 and 889 depart for the comparative safety of Ben Gardane, the unit maintained its defences in a state of emergency.[5] They held on, and by 3 March 1943 were the most forward Royal Air Force unit. Enemy air activity was intense and the unit's defences were in action most of the time. On 6 March 1943 the enemy attacked to the north-west, with armour and lorried infantry from Hallouf and Toujane, aiming first at cutting in between two strongly-held

[1] No. 510 A.M.E.S., O.R.B.
[2] A.H.B./IIJ/15/4, Report on Operations, Western Desert Air Force.
[3] No. 889 A.M.E.S., O.R.B.
[4] No. 274 A.M.E.S., O.R.B.
[5] No. 522 A.M.E.S., O.R.B.

features in the Medenine area, and a fierce battle went on a few miles away from the R.D.F. unit all day and night. The following day bombs were dropped by *Me. 109's* from 100 feet, striking within 50 yards of the technical vehicles but doing no more damage than making the transmitter trip. No. 522 mobile C.O.L. station continued plotting from its exposed location, giving invaluable information on the hostile air activity at that time.

Having arrived back at their original site at Ben Gardane, A.M.E.S. No. 889 were instructed two days later to find a C.O.L. site between their present position and Medenine and they became operational on 5 March 1943 at Neffatia landing ground. The latter was subjected to severe bombing attacks and nearby roads were heavily strafed, A.M.E.S. No. 889 being congratulated on its coverage of the raids.[1] On the 14th of the month, the unit was told to report to No. 211 Group Advanced Headquarters at Medenine to carry out experiments in the possible use of R.D.F. units for controlling tactical reconnaissance and bomber aircraft.

R.D.F. Aid to Direct Support Aircraft

Visits to the Western Desert by an Operational Research Section expert had shown that there was a case for the employment of ground search R.D.F. units as navigation aids for aircraft engaged in offensive operations over the battle area. The unrelieved panorama of the desert provided few distinguishing landmarks of navigational assistance to pilots. After considering the character of the operations, the type of aircraft concerned, and the available R.D.F. equipment, it was decided to use a C.O.L. or G.C.I. equipment in conjunction with an R.D.F. beacon carried in one or more aircraft of a formation ; such a beacon could be easily produced by simple modifications to existing I.F.F., Mark IIG, IIN, or American I.F.F. sets.[2] Preliminary tests were held in Egypt using different aircraft, beacons and R.D.F. stations ; and after the final series of tests it was proposed to use the system immediately in the desert air operations then proceeding.

Several test flights were carried out with aircraft of the Desert Air Force, and on the success of the last of these an operational trial was arranged with A.M.E.S. No. 889. A Spitfire aircraft of No. 40 S.A.A.F. Squadron was fitted with the beacon previously used in a Hurricane aircraft on non-operational tests. The flight was successful ; the aircraft carried out a sortie in the Gabes–Mareth region and was continuously plotted by A.M.E.S. No. 889 as soon as it had gained sufficient height.[3] The filtered track agreed exactly with the pilot's report of his positions. It was considered from these tests that, in conjunction with the use of R/T control, this R.D.F. operational technique might be used for the close control of fighter, fighter-bomber and light bomber sorties to what was loosely called the "target area."[4] It was pointed out that for individual bombing, however, visual indication was still essential. The R.D.F. plot accuracy was certainly not adequate enough for "blind bombing."

The Assault against the Mareth Defences (Operation "Pugilist")

Meanwhile, preparations were complete during the third week of March 1943 for the major attack by the Western Desert Force on the enemy Mareth Line positions. The Allied forces in eastern and southern Tunisia were also to attack

[1] No. 889 A.M.E.S., O.R.B. [2] A.H.B./IIE/173, Radio aids to direct support aircraft.
[3] *Ibid.*, and No. 889 A.M.E.S., O.R.B.
[4] The report on R.D.F. aids to direct support aircraft is given in full at Appendix No. 27.

almost simultaneously. By means of this three-pronged pincers movement it was hoped finally to expel the Axis forces from the Cap Blanc peninsula. Briefly the Eighth Army plan was to deliver a frontal attack on 20/21 March 1943 against Mareth with the whole of the Western Desert Air Force effort devoted to its support. The New Zealand Corps was to make a turning movement round the enemy's western flank and cut off his means of escape across the Gabes–Matmata road.[1] In order to allow the Western Desert Air Force to give its undivided attention to the British Eighth Army, the North African Air Forces under No. 242 Group and the American XII Air Support Command were to endeavour to neutralise and divert the attention of the enemy air forces from the Eighth Army front by attacking enemy airfields, including those in the Gabes area, by day and night.

Ground Search R.D.F. Plans for Operation "Pugilist"

Good R.D.F. cover was required over the battle area before Mareth for the protection of forward landing grounds and the special flanking operation by the New Zealand Corps.[2] The two most experienced mobile C.O.L. stations, A.M.E.S.s Nos. 510 and 522, were to accompany the advancing troops, A.M.E.S. No. 510 to move with Sector "A" of No. 211 Group in the forward area and A.M.E.S. No. 522 with the Main No. 211 Group Section. Thus direct control of tactical aircraft was possible at both Operations Centres, employing the R.D.F. technique which had been developed by the Western Desert Air Force.

To complete the raid reporting R.D.F. cover over the whole battle zone and beyond, the Mobile Radio Units were re-deployed. A.M.E.S. No. 274, located on a height-finding site near No. 211 Group, was to leap-frog forward in conjunction with A.M.E.S. No. 216, whenever No. 211 Group advanced.[3] A.M.E.S. No. 214 was to move to a point on the north coast, near Djorf, to give long-range R.D.F. warning over the Gulf of Gabes, and to remain on that site as long as required, plotting to No. 211 Group by W/T or landline if available. In addition, A.M.E.S. No. 606 was to move with Sector "A," A.M.E.S. No. 629, with the Main No. 211 Group for possible airborne operations and A.M.E.S. No. 609 was to be held in readiness at No. 211 Group to accompany the New Zealand Corps in their flanking operation, if required.[4]

In Northern and Southern Tunisia R.D.F. stations were being re-deployed also to assist the Allied Air Forces in their offensive on the enemy airfields. It was decided that a much wider R.D.F. cover was necessary in the No. 242 Group area if fighter aircraft were to be controlled over the battle zone, and as soon as the equipment became available sitings were made in addition to those already existing, as follows :—[5]

(*a*) One M.R.U., A.M.E.S. No. 388, was moved to Le-Kef for medium and high cover, with height-finding facilities, to the east and north-east.

(*b*) One C.O.L./G.C.I., A.M.E.S. No. 8005, was sent to Maktar providing cover to the east over Kairouan and the enemy airfields.

(*c*) Three Light Warning Sets, A.M.E.S. Nos. 6001, 6010 and 6011, were placed at Ras Rajel, near Tabarka, El Aroussa and Siliana.

[1] A.H.B./IIJ/15/27, N.A.T.A.F. Report on the Tunisian Campaign, and A.H.B./IIJ/15/4, Report on Operations, Western Desert Air Force.

[2] *Ibid.*, Appendix "J."

[3] Nos. 214 and 274 A.M.E.S., O.R.B.s.

[4] A.H.B./IIJ/15/4, Western Desert Air Force Report on Operations, Appendix "J."

[5] A.H.B./IIJ/15/27, N.A.T.A.F. Report on Tunisian Campaign, Nos. 388 and 8005 A.M.E.S., O.R.B., and No. 242 Group File 242G/550/Sigs., Encl. 106A.

This created a fairly complete chain over the whole No. 242 Group area. Meanwhile, improved Filter and Operations Rooms were opened in a farmhouse at Souk el Khemis, and preparations were put in hand for building a mobile Filter/Operations System.

In the XII Air Support Command (U.S.) area, the arrival of the American Third Defence Wing in early March provided a basis on which a fighter control system could be organised. The equipment of the Third Air Defence Wing consisted of two Mobile Operations Rooms with associated V.H.F. " homing " and " fixing " apparatus. Their information for the Operations Room was provided by the 561st Air Warning Battalion, whose equipment consisted of two Transportable Filter Rooms and 12 Light Warning equipments of American make (Type SCR. 602). This R.D.F. equipment, consisting only of Light Warning Sets, was inadequate to provide long-range R.D.F. cover in depth, on which large-scale control of fighter aircraft could be carried out.[1] The following British units were therefore provided to complete an effective R.D.F. network for fighter control :—

Three C.O.L./G.C.I. Units—A.M.E.S. No. 890 at Tebessa.
A.M.E.S. No. 899 at Thelepte.
A.M.E.S. No. 8004 at Dernaia.

Five Light Warning Sets—A.M.E.S. No. 675 at Tebessa
A.M.E.S. No. 6003 at Tebessa.
A.M.E.S. No. 6005 at Thelepte.
A.M.E.S. No. 6008 at Tebessa.
A.M.E.S. No. 6009 at Thelepte.

R.D.F. Movements during the Battle (Western Desert Air Force)

In the Western Desert the Main Operations Room and the R.D.F. units followed the line of the main British Army advance along the coast. From 13 March 1943, A.M.E.S. No. 510 was almost continuously on the move. On several occasions the unit had narrow escapes from enemy bombs, and on reaching El Hamma it moved into a site which was immediately shelled by enemy heavy artillery. Two days later, on their way to a site near Gabes, a transport hit a mine and the R.D.F. officer from No. 211 Group was killed.[2] A.M.E.S. No. 522 did exceptionally good work at the Main No. 211 Group area and later moved up with the Group, once more finding itself the most forward unit at its site ten miles north of Gabes, on 7 April 1943. Although subjected to constant enemy attacks, the crew and equipment remained unscathed and on 15 April 1943 arrived at Gourbaine, only to find A.M.E.S. No. 890 from Tebessa already installed there. This was the first occasion on which R.D.F. units of the North-West Africa Air Force linked up with the Western Desert Air Force stations.

A.M.E.S.s Nos. 274 and 216 moved up according to plan and by 12 April 1943 A.M.E.S. No. 274 had reached Sfax and No. 216 was at Moknine in the Monastir area.[3] The latter unit had an extraordinary welcome from the civilian population as the town, which had only just been evacuated by the enemy, had been by-passed by the forward ground troops. Landlines which were installed to No. 211 Group were continually sabotaged, however, by local

[1] A.H.B./IIJ/05/27, N.A.T.A.F. Report on the Campaign, Nos. 890, 899 and 8004 A.M.E.S., O.R.B., and No. 242 Group File 242G/550/Sigs., Encls. 122A and 127A.

[2] Nos. 510, 522 and 890 A.M.E.S., O.R.B.

[3] Nos. 216 and 274 A.M.E.S., O.R.B

natives, for whom the wire had a great attraction. A.M.E.S. No. 214 obtained extremely good technical results from their site at Djorf. Throughout the Mareth Line battle they provided valuable information and were repeatedly congratulated by the Controller at the Operations Room. Aerial activity was on a very heavy scale, particularly on 25–28 March, when the enemy was forced to abandon the Mareth Line positions and the *Luftwaffe* attempted to give cover to the enemy ground forces.[1] As more and more Royal Air Force units followed the Eighth Army into Northern Tunisia the work of No. 214 M.R.U. decreased in importance and on 12 April 1943 the unit also packed up and proceeded to Msaken to give general R.D.F. early warning cover over the forward area once again.

R.D.F. Movements during the Battle (South and West Tunisia)

Most of the movement occurred in the XII Air Support Command (U.S.) area. The two main directions covered were a thrust north-east from Thelepte to Sbeitla and towards Kairouan with a sub-sector Operations Room, and a thrust south-east from Thelepte to Gafsa, and thence east to Maknassy with main Filter Room and Operations Room at Thelepte.[2] A.M.E.S.s Nos. 899 and 8004 followed the strike to the north-east. The former unit was placed well forward and plotted considerable hostile activity, the most notable being intruder enemy aircraft which followed Allied returning escorted bombers back to their base.[3] Although the site was not outstandingly good, excellent R.D.F. plots were obtained, raids over the Gulf of Gabes being plotted to ranges of 105–115 miles. After 9 April 1943 the unit was mobile until it joined up with the Desert Air Force and was attached to No. 211 Group. A.M.E.S. No. 8004, after a bad start with their transmitter vehicle hitting a landmine, transferred the complete transmitter and vehicle body to the chassis of a general purpose Crossley vehicle and carried on to Feriana, where it gave a good account of itself on an almost ideal site.[4]

At all stages, the Light Warning units were used as a forward R.D.F. screen for the longer-range C.O.L./G.C.I. equipment. Being smaller, more mobile, and taking far less time to become operational after arrival on site, the L.W.S.s were better able to take advantage of rapid military gains which were occurring.[5] In addition, being a smaller and less valuable equipment, the permissible margin of security was less. The forward siting of Light Warning Sets on C.O.L. type sites thus provided the best possible low cover over the battle area at all stages. A.M.E.S. No. 675 was congratulated on its performance at Medjez el Bab, where it was operational day and night without a break. Some idea of the hard work of this unit may be gained from the fact that in the period 6–30 April 1943 it passed 12,148 plots on 2,669 aircraft tracks by W/T. A.M.E.S. No. 6008 was put too far forward initially at Thelepte, and was pulled back just in time.[6] A.M.E.S. No. 6009 managed to get permission from the American colonel at La Miskiana to transfer its technical equipment from the special tent provided with the equipment to a lorry to increase its mobility. The idea had been suggested to No. 242 Group on several occasions but the British Service had been loth to make any radical changes during an operation.

[1] No. 214 A.M.E.S., O.R.B.
[2] A.H.B./IIJ/15/27, N.A.T.A.F. Report on Tunisian Campaign.
[3] No. 899 A.M.E.S., O.R.B.
[4] No. 8004 A.M.E.S., O.R.B.
[5] A.H.B./IIJ/15/27, N.A.T.A.F. Report on the Tunisian Campaign.
[6] Nos. 6008 and 6009 A.M.E.S., O.R.B.

The merging of the former North African and Western Desert R.D.F. units continued, and on 15 April 1943, A.M.E.S. No. 6009 encountered a C.O.L./G.C.I. a Light Warning Set and two mobile C.O.L. units from the Western Desert at Msaken. The unit was attached for a time to A.M.E.S. No. 510 to compare results with the mobile C.O.L. equipment. They were much the same, except for the important difference of the greater reliability of the C.O.L. unit power supplies, which were given by a Diesel generator, as compared with the small Douglas petrol-electric generator of the Light Warning Set.

Ground Search R.D.F. in the Final Phase of the Campaign in North Africa

With the convergence of the two armies in North Africa and the subsequent joining up of the various R.D.F. units, redistribution of equipment was carried out, and siting was arranged to cover to the fullest extent possible the enemy bridge-head remaining after his withdrawal to defensive position on a line Cap Serrat–Medjez el Bab—Pont du Fahs—Enfidaville. This area was too large for effective control by one Operations Room and too small to accommodate three without confusion and waste of effort.[1] It was therefore decided that the battle area should be divided into two areas by the Miliane river under No. 242 Group and No. 211 Group respectively and the available R.D.F. units were allocated accordingly, in order to provide all possible cover over the battlefield during the closing stages of the campaign. In each section sufficient stations were allotted to hold some in reserve to leap-frog forward and take speedy advantage of the territory gained. The main movements of the final phase took place in the No. 242 Group area. Advances were made by the available C.O.L./G.C.I. stations along a generally north-easterly trend from Pont du Fahs and Medjez el Bab. On the northern coast, Cap Serrat was occupied by a C.O.L. station as part of the permanent North African Coastal R.D.F. Chain, as soon as the site became available. Two C.O.L./G.C.I. stations moved with the advance from Medjez el Bab and were usually sited as a C.O.L. and a G.C.I. together, thus providing long-range low cover and G.C.I. cover with height-finding facilities simultaneously.

At this period it was considered advisable to adopt one standard map grid for all Royal Air Force and United States Fighter Defence operations throughout the entire area for which the Mediterranean Air Council was responsible.[2] It was to be known as the "Mediterranean Area Fighter Operations Grid" (M.A.F.O.G.)[3] and came into use at the R.D.F. units deployed in North Africa on 20 April 1943. As a further measure of co-ordination of the various commands involved, the Standard Air Warning Code,[4] already in use in the United Kingdom, was introduced throughout North Africa on 15 May 1943.

At the fall of Bizerta and Tunis on 7 May 1943 rapid advances were made to coastal sites by the Light Warning equipments. The heavier C.O.L./G.C.I. sets were then moved up to certain of these positions to form part of the permanent North African Coastal Chain, plotting to No. 242 Group Advanced Operations Room established at La Sebala.[5] Certain sitings of a temporary nature were made to cater for any prolonged resistance by the enemy on the Cap Bon peninsula and against any speedy night bomber reaction to the Allied occupation

[1] A.H.B./IIJ/15/27, N.A.T.A.F. Report on the Tunisian Campaign.
[2] N.W.A.A.F., O.R.B., "Outline History of R.D.F. in N.W.A.A.F."
[3] Instructions in the use of M.A.F.O.G. are given in Appendix No. 28.
[4] Appendix No. 29 gives a full description of Standard Air Warning Code.
[5] A.H.B./IIJ/15/27, N.A.T.A.F. Report on Tunisian Campaign.

of Tunis and Bizerta. Such sitings included a G.C.I. station at Ras el Mekki and a G.C.I. station at La Sebala. The end was not far off, however, for all enemy resistance terminated in North Africa on 13 May 1943. The role of the R.D.F. units then became defensive—that of early warning and controlled interception of enemy bombers.

Completion of the Ground Search R.D.F. Chain in North Africa

During the period April–May 1943, the enemy had been concentrating attacks against the ports in North Africa, making his raids at last light or during the night, with aircraft approaching at approximately 8,000 feet. Mobile G.C.I. and M.R.U. coverage was therefore provided at these ports and the remainder of the coast was covered by C.O.L. stations.[1] Towards the end of this phase, as the enemy's approach at medium heights was proving expensive to him, he started to come in flying very low and climbing to make his attacks. It was decided in consequence to site C.O.L. stations along the North African Coast as high as possible, in order to obtain the maximum amount of coverage against low-flying raiders. On 26 May 1943, No. 242 Group was transferred complete with its R.D.F. units, some of which had been original Western Desert units, to the North African Coastal Air Force so that N.A.C.A.F. became responsible for the complete R.D.F. coverage of the North African Coast from the Casablanca area to the Tripolitanian border. This coastal R.D.F. scheme was to form a background to the defences of North Africa against enemy attacks on the Allied build-up of equipment for future land/sea operations which were shortly to take place from those shores.

[1] A.H.B./IIJ/1/99, " Mare Nostrum," a review of M.A.C.A.F. operations.

CHAPTER 19

PLANS AND PREPARATIONS FOR GROUND SEARCH R.D.F. IN THE LANDINGS IN SICILY (OPERATION "HUSKY")

In order to appreciate fully the Allied grand strategy which lay behind the invasion of Sicily, it is necessary to recall to mind the high level discussions at the Casablanca Conference of January 1943. At Anfa Camp on the outskirts of the town, the Combined Chiefs of Staff, in session with Mr. Winston Churchill and President Roosevelt, made the momentous decision that landings should be effected on the shores of Sicily. The conference had met to determine the basic war strategy for the year 1943, and although both American and British Joint Staffs were agreed that priority must be given to the effort to destroy the European members of the Axis before an all-out effort could be made to conquer Japan, it was by no means clear at that time what particular major operation would serve the purpose best.[1]

Rommel was retreating from Egypt and Tripolitania, but victory in Tunisia had yet to be achieved. The Russians had turned the tide of the war in the east at the River Don and had completed their 100 miles advance to Donetz. It was agreed on all sides that something must be done as soon as possible to relieve the strain on Russia and it was clear that an operation against Sicily could be mounted much sooner than any effective invasion of the European Continent via Northern France because of the present availability of both shipping and manpower in the North African theatre. Tentative plans had been made for an operation against Sardinia as the less heavily defended target. Unless such an attack were followed up by an immediate assault on Corsica, with the further object of approaching Italy from the flank, it would not have weighed very heavily in the scales of Allied effort against the Axis at a time when it was essential to divert as much German strength as possible from the Russian front. An additional argument was that with Sicily still in Axis hands, the threat to the Allied shipping routes in the Mediterranean remained materially unrelieved.

The Combined Chiefs finally came to an agreement on 19 January 1943 that offensive action should be undertaken in the Mediterranean in 1943 for the conquest of Sicily with the object of—

(*a*) making the Allied line of communications in the Mediterranean more secure,

(*b*) diverting as much German strength from the Russian front as possible, and

(*c*) intensifying the pressure on Italy, hoping that such results might create a situation in which Turkey could be enlisted as an active ally.

Despite the uncertainty of the general military situation at that time and the tremendous complexity of planning a major amphibious operation, the conference decided on the exact period when the assault was to take place. The target date was provisionally set for a day between 10–14 July 1943, assuming that North Africa would be cleared of the enemy forces by 30 April 1943: in actual fact cessation of hostilities in Africa did not occur until 13 May 1943.

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[1] Air Ministry File C.32153/46.

On 23 January 1943, detailed planning for operations against Sardinia was stopped and a directive was issued giving General Eisenhower Supreme Command of Operation " Husky." At the same time the Combined Chiefs of Staff decided to explore the possibilities of an even earlier date for the invasion, and on 19 February 1943 insisted that the period 10–14 June must be the target set and that all preparations had to be pushed with utmost vigour to achieve it. General Eisenhower, however, was left free to judge whether, in the course of studying his plans, he found that such an early date would make the operation impossible, and on 13 April 1943, on his recommendation, the Combined Chiefs of Staff reverted to their original choice of 10 July 1943.

In the meantime, General Eisenhower had realised that the occupation of the two Islands, Pantelleria and Lampedusa would greatly assist the Allied invasion of Sicily by providing additional air bases and removing a further enemy threat to Allied shipping convoys. Despite primary opposition on the ground of wastage of material the Combined Chiefs finally acknowledged the wisdom of the Supreme Commander's suggestion and preparations went ahead for Operation " Corkscrew."

Plans for the Subjugation of Pantelleria (Operation " Corkscrew ")

At the end of May 1943 it was determined that the capture of the Island of Pantelleria was an essential preliminary to the assault on Sicily.[1] Its airfields would provide another air base in addition to Malta, from which one hundred fighter aircraft could operate in protecting shipping and the beaches in the assault phase against Sicily. It would also mean that the enemy would be denied the use of his R.D.F. stations on Pantelleria and Allied R.D.F. cover could be established there. A combined operation was therefore planned to achieve this object, the date selected for the assault being 11 June 1943.

It was appreciated that an invasion of the Island would be impracticable if the garrison offered a determined resistance, on account of the strong fortifications and the restricted beach landing areas. Consequently the main structure of the plan was that the garrison should be weakened by continuous bombing on an increasing scale prior to the main assault. In addition the beach defences in the landing areas were to be neutralised by air attacks and naval bombardment, and a blockade of the Island was to be maintained. The final assault by land forces was then to be carried out by one British Division.

Ground Search R.D.F. Plans for Operation " Corkscrew "

The North African R.D.F. Coastal Chain was still in a transitionary stage. The final link up of the Western Desert R.D.F. units with the Tunisian stations had only recently occurred with the defeat of the Axis forces at Cap Bon and Western Desert R.D.F. units were being embodied into the North African Coastal Air Force for subsequent re-deployment. Although both early warning and R.D.F. fighter control would be available from the North African stations for Operation " Corkscrew," nevertheless plans had to be laid to increase this cover by landing R.D.F. units on Pantelleria as early as possible. The purpose of these ground search R.D.F. stations was threefold :—[2]

(*a*) to provide cover in the north of the Island as soon as possible to enable early warning of enemy aircraft attacking from Sicily.

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[1] A.H.B./IIJ/1/20, Report on N.A.T.A.F. Participation in the Capture of Pantelleria and Lampedusa.
[2] Air Ministry File C.S. 20051, Encl. 5A.

(*b*) to provide cover for high and low-flying aircraft over as large an area as the available equipment and the local terrain would permit.

(*c*) to provide R.D.F. information in such a manner that it could be used for control of fighter aircraft for interception purposes.

There were only four ground search R.D.F. stations available for this landing, two American Light Warning Sets and two Royal Air Force C.O.L./G.C.I. units, A.M.E.S.s Nos. 897 and 8000. In the Signals instructions issued on 1 June 1943, ten days before D-day, alternative executions of the above plan were outlined. The deciding factor as to which should be used was dependent on the availability of an L.C.T. to carry a C.O.L./G.C.I. station in the assault phase. The original plan allowed for one American Light Warning Set to go in with the assault force, collect its technical equipment and become operational at its pre-selected site as soon as possible. A second American L.W.S. was to follow on D + 5 and both sets were to remain operational until relieved by the C.O.L. stations which were to arrive on D + 8. The smaller units were then to proceed to their final sites.

The second plan, which was eventually put into practice, arranged for A.M.E.S. No. 897 to travel with one American L.W.S. in the assault convoy, and A.M.E.S. No. 8000 to follow with the second L.W.S. on D + 5. No. 1 SCR 602 (American Light Warning Set) was to become operational until relieved by A.M.E.S. No. 897, when it was to set up at a further site until once again relieved by A.M.E.S. No. 8000, after which it was to proceed to its final site. Both types of R.D.F. stations were to report to the Operations Room which would be set up on the Island, using Directional Plotting and the MAFOG Grid.[1] The Operations Room was to receive information from Malta Filter Room and La Sepala (North Africa). Although W/T equipment was to be carried as a standby reporting system, no difficulty with landline communications to the deployed R.D.F. units was expected as the distances involved were so short.

It was hoped that a Mobile Radio Unit would become available for despatch about D + 12. Until such time as its arrival, there would be no R.D.F. height measurement or calibration on the island and the C.O.L. stations were to endeavour to obtain estimated heights for the Operations Room and for the G.C.I. Controllers who were later to be attached for interception work. Heights on friendly aircraft were to be given to the C.O.L. stations from Operations, whenever possible, to check estimations. The commanding officers and crews of the R.D.F. units concerned were warned that jamming might be expected from enemy radar counter-measures stations (" *Karl* ") situated in Sicily and Sardinia, as several jammers had been located on those islands.

The Floating Filter Room aboard the Headquarters Ship H.M.S. " Largs "

During the assault phase of operation " Corkscrew " a floating Filter Room on board H.M.S. " Largs " functioned operationally for the first time.[2] Continuous watch was maintained from 1300 hours on 10 June 1943 (D — 1) when the ship lay off Sfax until it returned to Sousse on 12 June 1943 (D + 1). At all times the Filter Room was able to present a fair picture of the air situation, many of the tracks being good enough for interception and being used successfully for informative direction of aircraft. They would have been sufficiently accurate for normal Royal Air Force methods of fighter control had

[1] For details of MAFOG, *see* Chapter 18 and Appendix No. 28.
[2] A.H.B./IIE/184, Report on Operation " Corkscrew."

the usual V.H.F. D/F facilities been available. They were able to give warning to the ship's bridge of the approach of hostile tracks and to give the controllers the position of some, at least, of covering fighter aircraft. Plotting in the MAFOG Grid worked very satisfactorily with both Naval and shore-based reporting units. The Filter Room picture was, however, often incomplete. Some of the largest bomber raids were not plotted until within visual range of the Headquarters Ship. The sources of information were as follows :—

(*a*) The Sousse–La Sebala Sector Operations/Filter Room W/T Link, which broadcast filtered plots from information by the North African Coastal R.D.F. Chain.

(*b*) Filtered R.D.F. plots on hostile aircraft from the Malta broadcast.

(*c*) The 286 P.Q. (Short-range R.D.F. warning set on board H.M.S. *Largs*).

(*d*) The supporting cruisers, whose reports started after W/T silence had been relaxed.

None of the three W/T reporting channels used were at any time saturated, the capacity of the operators being a minimum of four plots a minute, and they could always have handled more information than they received. Lack of output by the reporting sources was not a cause for complaint. They all did well, but the main problem arose when W/T silence was broken ; this naturally occurred at the critical stage of the operation and the interference of the transmitters on board the Headquarters Ship prevented repetition of any but a small part of the plots sent to the ship. The cruisers were at the same time set free to report to the Filter Room by W T, but reception from them was subject to the same obstacles, and the R.D.F. picture as a whole suffered. The 286 P.Q. on board operated well, but the range of the set was extremely limited and its chief value was in the positioning of Allied fighter aircraft.

It was possible for the Filter Room to identify correctly all the hostile tracks plotted, and no instances of attacks on friendly aircraft either by H.M. Ships or other friendly aircraft were reported. Bomber lanes used were well adhered to. So far as it was known, all the hostile aircraft came from Sicily, thus all the friendly aircraft were normally to the west of Pantelleria and all the hostile aircraft to the east of the Island while General Spaatz's order restricting anti-aircraft fire over the island reduced the Filter Room's responsibilities at the meeting point. Where the system worked less well was when the hostile aircraft were known to be in the vicinity of the convoy or the beaches and several tracks were being plotted. On these occasions the only practical procedure was to make all tracks not showing I.F.F. into unidentified raids.

No instructions were issued with regard to local air raid warnings but a system was developed whereby the Filter Room advised the officer of the watch on the bridge as to the probability of air attack. This system was brought into use when the ship was unsuccessfully dive-bombed on 11 June 1943. With this very simplified version of a ground R.D.F. early warning system to provide cover for them, the R.D.F. units selected for shore-based operation on Pantelleria moved into their selected sites.

Ground Search R.D.F. Units in Operation " Corkscrew "

A.M.E.S. No. 897 was given orders to dismantle its equipment and move from La Calle to Bone on 28 May 1943. On its arrival at Bone the officer commanding, in company with the officer commanding A.M.E.S. No. 8000, was briefed for Operation " Corkscrew " at Headquarters, N.A.A.F. Plans were changed and A.M.E.S. No. 897 was instructed to proceed to Sousse where vehicles were waterproofed and preparations made for the short sea passage to Pantelleria.[1] The L.C.T. carrying the unit left Sousse at 1300 hours on 10 June 1943 arriving in the vicinity of the Island by the following morning and disembarked the C.O.L./G.C.I. station at Pantelleria harbour in the late afternoon. The unit made its way to a site about one mile inland and became operational at 0330 hours the following morning. The ease and speed with which the transfer of this unit from North Africa to the Island was effected was due largely to the lack of opposition from the enemy occupying forces, proving that the intensive bombing operations, maintained against the Axis garrison troops prior to the operation, had been totally effective.[2]

The story of A.M.E.S. No. 8000, however, is quite different. The unit remained at Bone and on 5 June 1943 the vehicles were shipped aboard the merchantman " Fort Guinevere " at the docks.[3] Once the wagons were on board, the drivers were sent ashore and were not allowed to travel with their transports. No information was given as to when the " Fort Guinevere " was scheduled to arrive at Pantelleria but it was understood that the ship would make her way to Sousse, where the vehicles of A.M.E.S. No. 8000 would probably be transhipped on to an L.C.T. Meanwhile the officers and crew travelled to Sousse. They arrived on 10 June 1943 and were attached to the 734th Signals Air Warning Company, U.S. Army, with whom they bivouacked on the Monastir Road. They were heavily bombed but sustained no casualties. Five days later, they embarked on L.C.T.s, and were put ashore at Pantelleria harbour the following morning. There was no sign of the technical vehicles, and temporary accommodation was found in the ruins of an old house. By 22 June 1943 the unit's equipment had still not arrived so the officer commanding and four drivers, on the authority of the General Commanding Pantelleria took the next boat back to Sousse—somewhat of an anticlimax for the unit's first " Invasion " operation. At Sousse it was found that the vehicles were due to be unloaded that day from the " Fort Guinevere," but it was not until 25 June 1943 that the unit drivers had the satisfaction of driving their lorries on to the " Empire Dace," from which they disembarked at Pantelleria Harbour on 26 June 1943—ten days behind schedule.

During the vigil of the R.D.F. crew awaiting their equipment on the island, the station site was altered three times ; the original position, which had been chosen by the R.D.F. officer of No. 242 Group was changed by the G.C.I. Controller who had accompanied the station to Pantelleria and again by instruction emanating from the American R.D.F. officer at Headquarters, N.A.A.F. In order to avoid a repetition of this unsatisfactory state of affairs, a ruling should have been given as to the proper authority to issue instructions. The unit finally became operational at Puntal Del Duce as a controlled C.O.L. station on 26 June 1943, reporting to the Filter Room at Pantelleria airfield.

Both stations were operationally busy and received letters of commendation from General Strickland, the American Commander.[4] This standard was maintained during the occupation of the island, and A.M.E.S. No. 8000 also received congratulations from the Senior Controller on the expert handling of unusually heavy volumes of traffic during the subsequent occupation of Sicily.

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[1] No. 897 A.M.E.S., O.R.B.
[2] A.H.B./IIJ/1/20, Report on N.A.T.A.F. Participation in the Capture of Pantelleria.
[3] No. 8000 A.M.E.S., O.R.B.
[4] Nos. 897 and 8000 A.M.E.S., O.R.B.

He had never seen such accurate plotting and pinpointing. This was doubly satisfying considering that the stations were heavily jammed each night by enemy " railings " interference,[1] apparently coming from either the Marsala or Trapani area.

In May 1943 shortage of R.D.F. equipment generally had necessitated the withdrawal of Mobile Radio Units and G.C.I. stations from Iraq and Mombasa and it was decided to allocate one of these units for installation on Pantelleria.[2] A.M.E.S. No. 233 therefore was removed from its site at Habbaniya (Iraq), and was reformed at the R.I.M.U., Middle East, on 26 May 1943. On 27 June 1943 it left this location and, travelling by road, reached Sousse on 13 July 1943.[3] Two days later it embarked by L.C.T. for Pantelleria, arriving in the early morning of 16 July 1943, without incident. By the following evening the men were installed in the domestic site and, with the aid of American bulldozers, work had begun on levelling the ground for the installation of masts and equipment on the technical site. The unit was within one and half hours of becoming operational on 23 July 1943 when an instruction was received from Tunis Fighter Sector to discontinue installation and prepare for an immediate move. Consequent upon this order, masts were lowered, dismantled and all equipment ready for the move by the evening. On the last day of the month, however, a signal was received to re-install the equipment on the original site. So once again the unit set to work and this time continued uninterrupted until operational on 3 August 1943, plotting to the American Filter Room of the No. 2690 Air Base Command. On 14 August 1943 the officer commanding this R.D.F. unit also assumed command of the British garrison of Pantelleria.

The Capitulation of Lampedusa

Having found that the Allied Air Forces had bombed to good effect in the case of Pantelleria, the bomber effort was switched to the island of Lampedusa at mid-day on 11 June 1943 and a total of one hundred and seventy-nine bomber sorties and two hundred and forty-two fighter sorties was undertaken against the comparatively small target up to 1710 hours on 12 June 1943.[4] At this hour the garrison capitulated and within a very short time the second island fortress had fallen as a direct result of air power.

With Malta a long-established stronghold of ground search R.D.F.[5] and Pantelleria newly equipped with British and American R.D.F. units, Lampedusa remained the last gap in the defence of the Sicilian Narrows, through which the " Husky " convoys must pass. Ground search R.D.F. units were therefore allocated to the island in order to provide yet more forward R.D.F. cover for the invasion of Sicily.

A C.O.L./G.C.I. station, A.M.E.S. No. 896, and two Light Warning Sets, A.M.E.S. Nos. 602 and 6006, were designed for despatch to Lampedusa. No attempt was made to include the R.D.F. equipment in the initial Allied occupying force. The C.O.L. station received its orders to pack up on 12 June 1943 and embarked on three L.C.T.s at Algiers on 16 June 1943. An uneventful journey was made to Lampedusa where the unit docked on 23 June 1943.

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[1] Details of " railings " interference are given in Chapter 14.
[2] Air Ministry File C.S. 8251, Part II, Middle East Reports from Senior R.D.F. Officer.
[3] No. 233 A.M.E.S., O.R.B.
[4] A.H.B./IIJ/1/20, N.A.T.A.F. Report on Pantelleria and Lampedusa.
[5] Chapter 12 of this volume gave an account of ground R.D.F. in Malta.

The wisdom of setting off from Algiers was apparent when the L.C.T.s, en route, called at Sousse, where the shipping position was so tight that it is doubtful whether even the operational wagons would have been brought across without just as great a delay as those A.M.E.S. No. 8000 experienced.

The station was sited at Point Sacremento on the north side of the island, on the former position of an enemy R.D.F. station, and became operational on 25 June 1943, reporting to a Filter Room at Sector Operations Room. Although large formations of friendly bomber aircraft and long range hostile aircraft were plotted, Filter Room were out of touch with the mainland and were consequently unable to give identifications and showed negligible interest in air activity outside the Sector area.

A.M.E.S. No. 6006 had a non-stop journey to No. 303 M.S.S.U. at Hammamet, where its vehicles were given a hurried greasing, waterproofing, and where they were carefully packed in preparation for a beach landing.[1] Despite these precautions it did not proceed to Sousse until 15 June 1943, where it spent nine days waiting further instructions. Finally on 24 June 1943 the unit sailed, arriving at Lampedusa the following morning, but was unable to become operational until 28 June 1943—and then only for test purposes, as there was still no means of communication between the unit and Sector Operations. Having established a landline for plotting purposes, the Douglas petrol electric generators once again let down the unit and operations were spasmodic, using a power supply derived from an engine taken from an Italian concrete mixer. A replacement was sent to the unfortunate unit but even this failed. Fortuitously there was no hostile activity in this area ; during the brief moments when the unit was able to operate, ranges of over 100 miles were obtained on surface craft.

Lessons Learned in the Occupation of Pantelleria and Lampedusa

Although the occupations of Pantelleria and Lampedusa scarcely came within the " invasion " category, they served as a small exercise for the infinitely more difficult task of invading the Sicilian shores. Lessons learnt were not outstanding but the most glaring faults from the ground search R.D.F. point of view were the following :—[2]

(*a*) Drivers of R.D.F. technical vehicles and preferably the entire crew, should travel with their equipment in both assault and follow-up stages.

(*b*) There should be greater co-ordination of Allied and British inter-service Signals requirements and a tightening up of Signals responsibilities.

(*c*) Controllers and Filter Room staff should be given an order of battle with full details and a complete programme well in advance. In Operation " Corkscrew " the original plan had been to use one R.D.F. assault force reporting wave and one R.D.F. shore base reporting wave. The introduction, therefore, of three R.D.F. reporting waves and three W/T base waves shortly before the operations necessitated eleventh-hour alterations and relaying of lines.

[1] No. 6006 A.M.E.S., O.R.B.

[2] A.H.B./IIE/184, Operation " Corkscrew."

(*d*) The administration of the L.W.S.s left room for a considerable amount of improvement—and it seems that there was insufficient care in checking technical equipment before embarking.

(*e*) It was proved once again that identification could not be supplied solely by I.F.F.

Although involving a considerable degree of time and material, the foregoing events were after all only sidelines to the major task of Operation " Husky."

General Plans for Operation " Husky "

With only a short time available in which to organise the operation, Headquarters, 141 Force, was set up at Algiers to make plans and preparations, the complete details of which could not be formulated until the final defeat of the Axis forces in Tunisia had been accomplished.[1] 141 Force was to be composed of two Task Forces, the Eastern Task Force, No. 545 (British), and the Western Task Force, No. 343 (American). Their first objective was to land maximum forces and supplies ashore on Sicily as quickly as possible at points where air cover could be provided. In order to maintain these forces, however, it was essential to acquire port facilities. All the ports required in Sicily were beyond the range of fighter cover, the immediate aim of the assault forces as a result had to be the occupation of the airfields both in the south-east and west of the island, to provide the extension of air cover essential for the capture of the ports.

It was not until 13 May 1943, the day on which Axis resistance in Tunisia collapsed that the final plan was approved, leaving but two months in which to arrange training of personnel, supplies of shipping, equipment, and stores. Difficulties, already great by reason of the shortage of time, were amplified by the fact that mounting, assembly and supply of the assault forces were to take place in four different spheres—the Middle East, the United Kingdom, Tunisia and Malta.

The initial assault was to consist of eight simultaneous pre-dawn sea-borne landings on D-day with the object of capturing airfields and secondary ports in south-eastern Sicily, from which to develop an assault on Catania, and subsequent advances on Messina and Palermo.[2] The assaults were to be made by Task Forces comprising the British Forces from the Middle East, Tunisia and the United Kingdom and United States Forces from North-West Africa. The assaults were to be made as follows :—[3]

(*a*) At Avola, to capture Syracuse and Augusta, ship-to-shore assault by two strong British forces from the Middle East (to be known as " Acid North " and " Acid South ").

(*b*) On either side of Cape Passero with the object of capturing the airfield at Pachino and of supporting the forces landed at Avola, three British forces from Middle East (ship-to-shore), Malta (shore-to-shore), and the United Kingdom (ship-to-shore) (known as " Bark East," " Bark South " and " Bark West ").

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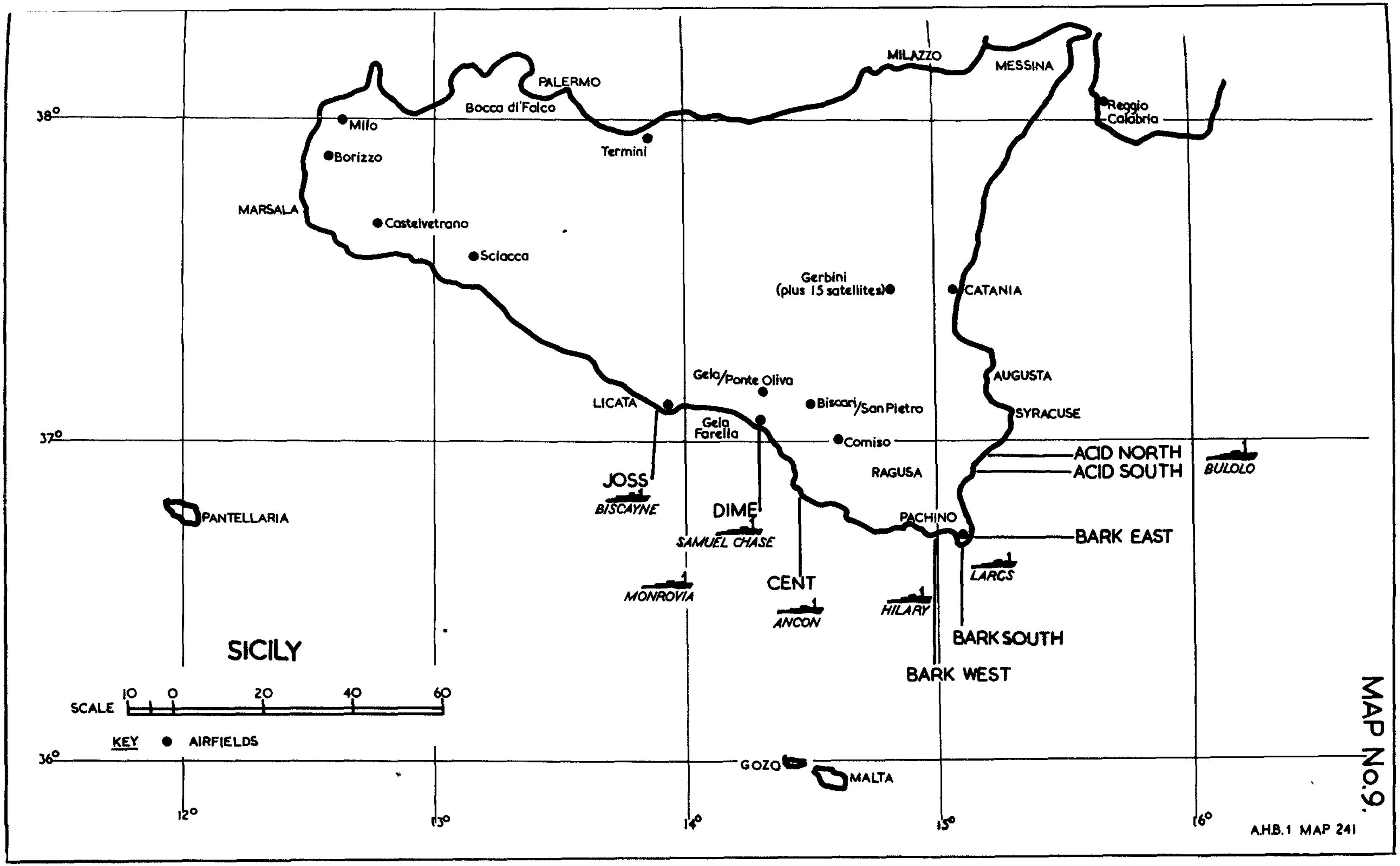
[1] Air Ministry File C.32154/46.

[2] A.H.B./IIJ5/83/125, First Draft, N.A.A.F. Operational, Administrative and Signals Plan for Operation " Husky."

[3] Air Ministry File C.S. 23602. Map No. 9 indicates locations in Sicily.



MILAZZO
MESSINA
PALERMO
Bocca di Falco
Reggio Calabria
38°
Milo
Termini
Borizzo
MARSALA
Castelvetrano
Sciacca
Gerbini (plus 15 satellites)
CATANIA
AUGUSTA
Gela/Ponte Olivo
LICATA
Biscari/San Pietro
SYRACUSE
Gela Farello
37°
Comiso
ACID NORTH
ACID SOUTH
BULOLO
RAGUSA
JOSS
BISCAYNE
PANTELLARIA
DIME
PACHINO
BARK EAST
SAMUEL CHASE
LARGS
CENT
MONROVIA
HILARY
ANCON
BARK SOUTH
SICILY
BARK WEST
SCALE
10 0 20 40 60
KEY
AIRFIELDS
36°
GOZO
MALTA
12°
13°
14°
15°
16°
MAP No.9.
A.H.B.1 MAP 241

(*c*) Near Cape Scaramia, to capture Comiso airfield, shore-to-shore assault by a strong United States force from Tunisia (known as " Cent " force).

(*d*) At Gela, to capture the airfields at Ponte Olivo and Biscari, ship-to-shore assault by a strong United States Force from Tunisia (known as " Dime " force).

(*e*) At Licata, to capture the port and nearby landing ground, a ship-to-shore attack by a strong United States force (known as " Joss " force).

These assaults were to be preceded during the night of D — 1 by paratroop attacks at selected points behind the beaches.

Ground Search R.D.F. Cover and Control

Although ample provision for R.D.F. early warning cover was to be made for the protection of the convoys and landings during the initial stages of Operation " Husky " by means of R.D.F. ships and units to be landed with the assault troops, this cover would necessarily be limited in scope. Responsibility for R.D.F. air warning cover for the Task Forces was, as a result, delegated to the following widespread provinces :—[1]

U.S.A.A.F. and R.A.F. R.D.F. stations sited in Malta and Tunisia.
R.D.F.-fitted ships.
U.S.A.A.F. and R.A.F. Light Warning Sets.
R.A.F. C.O.L./G.C.I. stations.
R.A.F. M.R.U.s.
Nos. 1, 2 and 3 Mobile Plotting Rooms Units (M.P.R.U.s).
No. 101 Mobile Air Reporting Unit (M.A.R.U.) and
No. 1 Mobile Operations Room Unit (M.O.R.U.).

Malta-Based R.D.F. Equipment

During June and early July 1943, many reconnaissance flights over Malta had been carried out by single enemy aircraft, flying at great heights and high speeds. Although plotted satisfactorily by the R.D.F. stations based on Malta, their speed and height, combined with the short distance between enemy forward airfields and their target made them very difficult to intercept.[2] In an attempt to short-circuit the inherent delays in the reporting system, experiments were carried out in handing over the fighter aircraft to a G.C.I. controller during the daylight raids. This system appeared promising, but needed a great deal of practice to develop the method properly.

In order to counter low-flying night raids on shipping concentrations, which the normal G.C.I. procedure could not tackle, two C.O.L. stations were equipped with Plan Position Indicators and the usual aids to interception and were available for the control of Mark VIII A.I. night fighter aircraft, obtaining estimated heights from the station performance charts.

Having taken precautions against night and day attacks on the island itself, it seemed probable that during the period just prior to the landing, the enemy might attempt very low-flying raids on shipping concentrations lying off Malta. It was realised that insufficient warning of this type of attack would be given by C.O.L. stations, so two Naval Type 277 R.D.F. sets were erected at suitable points to cover the most probable arc of enemy aircraft approach towards the anchorages.

[1] A.H.B./IIJ/5/83/124, Second Air Outline Plan for Operation " Husky," 25 March 1943.
[2] Air Ministry File C.S. 14598, Part II.

It was not only short-range aerial activity that had to be taken into consideration. During the months preceding Operation "Husky," fairly large-scale fighter sweeps were made over the south-east corner of Sicily by Malta-based aircraft. The R.D.F. system succeeded in presenting a fair picture of these sorties and of the enemy reaction to them, provided they did not take place outside certain range limits.[1] It was probable that there would be a large-scale enemy air reaction to Allied landings on Sicily and that it might take place outside the range limits of the existing Malta R.D.F. cover. In order to counteract this, a Type 16 Fighter Direction Station was brought into use. The Type 16 had been developed in the United Kingdom for long-range control of fighter aircraft over the Low Countries. It was envisaged that based on Malta it might fill a similar role over Sicily, and was put into operation a few days before the assaults were made, despite forebodings as to interference by reflections from the 1,000-foot hills of Sicily and phenomenal ranges owing to the large atmospheric refraction of low elevation radiation in the Mediterranean.

In all, Malta had fourteen R.D.F. stations, comprising four M.R.U.s, four C.O.L. stations, two G.C.I. stations, two Type 277s, one Type 16, and one Type 11 to be kept in reserve in case of enemy jamming. The latter equipment was only obtained after considerable trouble, as the first consignment of sets was sent by Air Ministry on the long route via the Cape and was not due to arrive at Malta until August 1943.[2]

In addition to receiving reports from her own stations, Malta was to plot information received on the two assault R.D.F. reporting waves and from Pantelleria. Plots from these four sources were to be filtered and broadcast on medium power for the benefit of Headquarters Ships of both British and American Task Forces and forward fighter controls in Sicily.

With the build-up of the invasion of Sicily, additional mobile R.D.F. units arrived in North Africa from the United Kingdom and from the Middle East Command. Those stations destined for transport to Sicily came under the North African Tactical Air Force control, but the North African coastal R.D.F. Chain under North African Coastal Air Force was not to be neglected. Sicily actually lay beyond the range of the North African coastal R.D.F. units except for the few which perched precariously on the Cap Bon peninsula, but valuable R.D.F. protection was still available from the Chain for the North African ports and harbours in which invasion shipping was concentrating, and in which amphibious assault training went on by day and night.[3]

Ground Search R.D.F. Plans during the Assault Phases

If during the assault phase of the invasion of Sicily Allied fighter and bomber aircraft were to be utilised to the limit of their capability in providing cover and support for an assaulting force, it was necessary that some means for their direction and control should be established. The most effective method of providing this control was considered to be the use of R.D.F. ships operating in conjunction with Headquarters ships,[4] the latter receiving filtered information from the R.D.F. broadcast wave. Daytime control facilities were installed in Headquarters Ships for Operation "Husky," and it was not until later landings that Fighter Direction vessels were specially provided for the purpose.

[1] Air Ministry File C.S. 14598, Part II, Encl. 6A.
[2] Air Ministry File S.20034, Part I. [3] A.H.B./J1/99, "Mare Nostrum."
[4] A.H.B./IIJ5/83/123, Air Outline Plan for Operation "Husky" (Signals). The locations and names of the Headquarters ships are shown on Map No. 9.

G.C.I. Stations on Landing Ship Tanks.—Towards the end of the planning stage, on 7 May 1943, experiments were carried out with a G.C.I. station, A.M.E.S. No. 8012, mounted aboard Landing Craft Tank No. 363 in Algiers harbour. Results were so encouraging that, despite poor reports which had emanated from the United Kingdom on similar tests,[1] it was arranged that G.C.I. stations should operate from three L.S.T.s during the night D/D + 1, one each off " Joss," " Bark " and " Acid " beaches,[2] the stations coming under the control of three Headquarters Ships. Owing to the difficulty of landing heavy and unwieldy R.D.F. vehicles during the initial period, it was hoped that these shipborne units would provide full R.D.F. cover for the convoys, as the necessity for preventing the enemy from bombing the Allied shipping by night could not be too strongly stressed.

Stage I—Beach Landings.—Each assault convoy was to include Royal Air Force Signals units, the rôle of which was to relieve Headquarters Ships of the onus of fighter control and air raid warnings, as soon as they could set up ashore.[3] These components consisted of an Advanced Landing Ground Signals Section, two Light Warning Sets, a skeleton Wireless Unit of five Observer Posts in Jeeps, the nucleus (or " A " Party) of a G.C.I. Unit[4] and details of Air Formation Signals. They were to be associated with a Field Force Headquarters Signals Section which was to be the Royal Air Force Signals Centre for the area. To these was added at the eleventh hour a most essential part—the mobile Operations Room itself, with two controllers and a staff of eight, called a Mobile Plotting Room Unit (M.P.R.U.)—the whole comprising a Forward Fighter Control. The M.P.R.U. was to receive the Malta R.D.F. broadcast and in turn was to rebroadcast air-raid warnings to Headquarters Ships and A.A. Units.

Stage II—The Capture of Airfields.—Fighter protection by shore-based aircraft could not be provided until airfields had been captured and their defences finally established against attack by enemy land forces. As soon as this was effected, Advanced Landing Ground Signal Sections were to proceed to each airfield in company with the Light Warning Sets and Mobile C.O.L./G.C.I. stations.[5] In the follow-up convoys, M.R.U.s and extra C.O.L./G.C.I. stations would be provided to reinforce long-range R.D.F. cover and to take over sites evacuated by the original R.D.F. units as they moved forward to cover captured ports and airfields.[6] Provision was also made for replacing casualties to both personnel and R.D.F. equipment that might occur in the assault stages.

Stage III—Establishment of Sector Operation Rooms and Filter Rooms.—The whole air warning system was to be co-ordinated as soon as the advance of our forces made this possible, and arrangements were to be made for the setting up of Sector Operation/Filter Rooms. The plan of operations in

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[1] Appendix No. 30 gives a brief history of G.C.I. equipment fitted on L.S.T. 305. Air Ministry File S.20034, Encl. 9A, and No. 8012 A.M.E.S., O.R.B., refer.

[2] See Map No. 9 for location of assault beaches.

[3] Appendix No. 31 is a list of R.D.F. units taking part in the invasion of Sicily.

[4] G.C.I. and G.O.L. Units were to land in the assault phases divided into " A " and " B " parties, the former containing the R.D.F. receiver, transmitter and aerial vehicles, one power vehicle and V.H.F. gear (where applicable). This was to save shipping space in the convoy, and it was expected that the station would be able to carry on with this scale of equipment for a limited period, until the " B " parties could be transhipped in a follow-up convoy. (Air Ministry File C.S.23602.)

[5] A.H.B./IIJ/5/83/123, Outline Plan (Signals) for Operation " Husky."

[6] Air Ministry File S.20034, Encl. 8A.

eastern Sicily envisaged the early fall of Catania to the British Eighth Army and in conjunction with No. 211 Group of the Western Desert Air Force, two new units, No. 101 Mobile Air Reporting Unit (M.A.R.U.) and No. 1 Mobile Operations Room Unit (M.O.R.U.) were to make their début, arriving with the D + 7 convoy.[1]

Formation of No. 101 M.A.R.U.

As a further development of the Wireless Unit, Air Ministry decided in the summer of 1942 to form an experimental Mobile Air Reporting Unit (M.A.R.U.). Its function was to supply an associated Mobile Operations Room Unit (M.O.R.U.) similar to that used by the advanced Sector of No. 211 Group during the Western Desert operations, with information on all air activity over 60 miles of military front, using both visual and R.D.F. sources but passing plots by W/T so that other Services would have access to its broadcasts.[2] Fifteen observers were to give visual cover over the allotted area, generally operating within five miles of the front line, and three Light Warning Sets, located behind the observer posts provided forward and lateral R.D.F. cover. The Filter Room, known as the Air Warning Centre (A.W.C.), was to operate some 15 to 20 miles behind the front line, the unit headquarters lying adjacent to it. The entire outfit was to be fully mobile and all personnel were to be trained on semi-commando lines.

After many months of hard work and experiment in the United Kingdom, the unit was ready to board H.M.T. *Franconia* on 28 June 1943 for despatch to Sicily. An analysis of operations had shown that the average time taken for R.D.F. ground observer's plot to be passed to the Air Warning Centre, filtered, broadcast, and finally displayed on the M.O.R.U. operations table, was 22 seconds, and had been as low as 10 seconds. This was comparable with the results of the static filter organisations using landlines. Aircraft identification was expected to be the greatest obstacle. This was due to the lack of comprehensive movement liaison and the fact that I.F.F. information from the Light Warning Sets was never 100 per cent. reliable or available. The Observer Posts were useful in the case of aircraft recognition but many tracks would never come within their limited range.

Siting was an important point in the final assessment of the performance of the M.A.R.U. It was essential that Observer Posts and Light Warning crews determined their exact position on arrival at a fresh site as only a slight discrepancy in location would produce a great inaccuracy on the plotting table. During trials in the United Kingdom the fact was brought home in no mean manner that any form of trailer hampered movement on wet ground, and four-wheel-drive prime movers were incorporated into the unit to speed up mobility. As a final improvement, the Douglas petrol electric generators, which had caused so much trouble to the Light Warning Sets in Tunisia, were replaced by very reliable Lister diesel generators mounted on six-wheel chassis.

There was every reason for optimism that the M.A.R.U. organisation, after its prolonged deployed training in the United Kingdom would co-ordinate the air reporting system once it was established ashore in Sicily. Thus the mobile Operations Room Unit was to receive well-filtered track information from the R.D.F. and Wireless Observer Unit screens by this means.

[1] A.H.B./IIJ/5/83/123. [2] No. 101 M.A.R.U., O.R.B.

Selection of R.D.F. Sites in Sicily prior to the Invasion

It was obvious that the success or failure of immediate R.D.F. cover on the approaches to, and over, the invasion areas depended to a great extent on the immediate availability and suitability of the sites to be taken up by the R.D.F. units. Therefore keen attention was paid to map-siting beforehand. This was especially necessary in Operation "Husky" as the situation demanded R.D.F. warning of enemy aircraft approaching from mountainous areas, and permanent echoes from these very hills might render the R.D.F. operations completely useless. A further limitation was the orchards, woods, vineyards, and the rolling nature of the foothills which stretched down to the beaches.[1] In addition to these two restrictions of access and topography certain technical limitations, individual to different types of R.D.F., had to be taken into account with greater care than under normal siting conditions. These were backward radiation, horizontal width of main forward lobe, and magnitude of side lobes, all of which would give spurious "forward" and "off bearing" permanent echoes from the mountainous areas. It was particularly important to take these factors into account for stations fitted with P.P.I. tubes, on which plotting device even small spurious echoes would form a block that effectively masked the larger aircraft echoes. The difficulties encountered, therefore, were in finding sites which satisfied the following conditions :—

(*a*) Were operationally suitable, *i.e.*, covered the approaches and target areas.

(*b*) Were technically suitable for the type of equipment, *i.e.*, high sites for C.O.L. stations and flat sites clear of obstacles for G.C.I. stations and M.R.U.s.

(*c*) For G.C.I. stations and M.R.U.s, had some form of close range hills to screen radiation from the more distant 4,000-foot mountains and 12,000-foot Mount Etna. Or alternatively were in such a position that the mountain tops fell below the "permanent echo" angle, to reduce permanent echo configuration.

(*d*) Were readily accessible from, and close to, the beaches.

(*e*) Were ready for immediate occupation, *i.e.*, no obstacles barring the easy movement of vehicles.

No attempt was made to site the Light Warning Sets since, because of their mobility, they would be required to take up positions defined by the M.P.R.U.s according to "on the spot" development of land operations. However, a briefing pamphlet called "The siting of British Light Warning Sets," dealing particularly with siting in mountainous areas to obtain reduced permanent echoes consistent with performance, was prepared and issued to the senior N.C.O.s i c units some time before the operation.

Servicing Organisation for R.D.F. Units planned to take part in Operation "Husky"

Signals and R.D.F. servicing organisations—although a vital necessity during later stages of any campaign—were not of high enough priority and were too bulky to be included in the assault convoys of an amphibious operation. Consequently the two Mobile Signals Servicing Units, Nos. 305 and 306, were scheduled to arrive in Sicily on D+14, No. 305 embarking at Alexandria,

[1] Air Ministry File S.20034. Encl. 8A.

ex-Middle East, and No. 306 was sent direct from formation and training in the United Kingdom.[1] For the first fortnight after the initial landings of the R.D.F. units, all technical servicing was to be the responsibility of the unit R.D.F. mechanics. Any servicing beyond their capacity was not to be available until the M.S.S.U.s landed. Other arrangements were planned for the complete replacement of the unserviceable equipment by airborne supply direct from the Middle East.

Air Transportable R.D.F. Equipment held in Reserve

Although all R.D.F. units concerned in the invasion were to carry adequate reserves of expendable parts, in order to guard against emergency requirements in the event of stations becoming unserviceable, an air transportable reserve of R.D.F. equipment was to be held in readiness at Air Headquarters, Eastern Task Force, Tripoli.[2] It consisted of six Light Warning Sets, three Mobile Operations Rooms and other Signals facilities.

This final embellishment of the general overall plan for the supply of R.D.F. equipment during the Sicilian campaign, showed that considerably more care and thought had been given to the provision of R.D.F., both for assisting in fighter control and providing satisfactory cover to fighting forces, than had hitherto been the practice. Although later events showed there was still room for further improvement from the planning aspect, it was apparent that the R.D.F. unit was no longer regarded as of secondary importance. There was a much more widespread interest and respect for their capabilities.

In order to achieve the maximum degree of surprise, the several assault convoys from east and west followed the normal convoy routes, close to the North African coastline prior to D-day, converging in the general area south of Malta.[3] This action was meant to suggest to the enemy a threat towards Crete, and at the same time a decoy force (" H ") manœuvred in the Ionian Sea as a potential threat to the coast of Greece. On the night of 9 July 1943, the heavily-laden ships turned north and silently approached the shores of Sicily, to deliver the first of a series of blows on Italian soil which were ultimately to lead to the downfall of the Axis regime.

[1] Nos. 305 and 306 M.S.S.U., O.R.B.
[2] A.H.B./IIA/1/67, Detailed R.A.F. Signal Plan on Operation " Husky."
[3] Air Ministry File C.32153/46.

CHAPTER 20

GROUND SEARCH R.D.F. IN THE LANDINGS IN SICILY (OPERATION "HUSKY")

On Saturday, 10 July 1943, British, Canadian and American troops, conveyed under air protection by the biggest fleet yet seen in Mediterranean waters, invaded Sicily. Attacks by Allied paratroops had effectively weakened enemy opposition and successful landings on a long stretch of coast were accomplished with small loss of life and equipment. Gains made on the first day were rapidly, extended, and the first strong bridgehead in the south-east of the island was speedily established.[1]

In the air, the softening-up operations against the enemy forces in Sicily had started some three weeks earlier. From 20 June 1943 the battle for air superiority began with a crescendo of attacks by Allied heavy and medium bombers, which continued on an increasing scale, and the plan to neutralise the enemy airfields in Sicily was put into action. At the outset, the enemy strongly opposed the raids against his western Sicilian airfields but the strength of his fighter defence decreased rapidly as the Allied attacks continued unabated. On 9 July 1943, D — 1, only two enemy airfields, Sciacca and Milo, were in full use on the western end of the Island, intermittent use was made of Comiso in the central area, and of the numerous Gerbini satellite airfields only two still showed slight activity.[2] In the main, the enemy air force had been broken and required little more to effect its complete annihilation. This destruction of the enemy's principal weapon against the Allied amphibious invading forces contributed in no mean degree to the ultimate success of the landing.

Fighter Protection of the Assault made by Land Forces

Fighter squadrons operating from Malta, Gozo and Pantelleria were under the control of the Air Officer Commanding, Malta. Those based on Malta provided fighter cover for "Acid," "Cent" and "Bark" beaches,[3] those in Pantelleria for "Joss," and those on Gozo, reinforced by Malta squadrons, for "Dime" beach. In view of their strictly defensive role and their limited numbers and endurance, the fighter aircraft took their forward direction from Headquarters Ships[4] throughout the operation, as it was of great importance that the fighter aircraft should not be vectored far from their patrol areas.[5] Had this been allowed to happen there would have been a serious danger of unplotted enemy aircraft appearing suddenly from over the Sicilian hills and finding the Allied shipping and beaches unprotected. Air Staff in each Headquarters Ship therefore preferred to keep the fighter aircraft under their immediate control rather than hand them over to the Naval Fighter Direction Ships.

Headquarters Ships controlling fighter aircraft were fed with R.D.F. information from cruisers, monitors and A.A. ships accompanying the assault forces. These ships were fitted with long-range naval R.D.F. and reported in the

[1] A.H.B./IIJ5/81, Report on Operation "Husky" by 23rd S.C.O.R.U., Headquarters, N.A.A.F.
[2] Air Ministry File C.S. 23602, p. 9.
[3] A map showing the assault beaches and their code names is given at Map. No. 9.
[4] For names of Headquarters Ships, *see* Map No. 9.
[5] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean, para. 36.

(C27392) M 4

combined Air Warning Code on the assault R.D.F. reporting wave of the force — separate frequencies being allotted to the British and American Navies. The R.D.F. plots which were received and filtered in British and American Headquarters Ships proved, on the British side, to be of considerable value, although rarely indicating height or identity and sometimes being jammed by radiations from the ship's own transmitters. The short-range R.D.F. was of very little value. Certain American Headquarters Ships carried long-range R.D.F. with Plan Position Indicator presentation and height finding, but it was not clear to what extent interference from these excellent installations was responsible for the poor communications in the ships.

The Operations Room aboard the Headquarters Ship did duty for all three Services, which not only caused considerable congestion within its limited confines, but also made it practically impossible for Royal Air Force personnel to carry out the normal functions of a Fighter Sector Operations Room crew.[1] Until W/T silence was broken during a later stage of the voyage, R.D.F. plots were passed by visual methods and were then transcribed to the Operations Room in signal form. There was thus a considerable time-lag in the passing of R.D.F. information, and more delay was caused by the refusal of the Navy to give priority to signals containing movements of enemy aircraft. Signals relating to hostile air action were passed by routine method in amongst a welter of administrative matters. As experienced in the invasion of Pantelleria, the air raid warning system on board ship was vague. The Headquarters Ships also suffered from lack of adequate briefing beforehand and were completely out of touch with the general air situation when at sea. Despite these difficulties, the method of Fighter Control adopted by Air Headquarters, Malta, worked excellently, and there was every indication that it would have been most satisfactory had there been serious air opposition. Fighter protective measures covering the convoys were successful, and by last light on " D " Day twelve craft only out of approximately 2,000 ships had been damaged by enemy attack.[2]

Type 16 R.D.F. Station based in Malta

In addition to the forward direction of fighter aircraft by Headquarters Ships, it had been intended that Malta should attempt controlled interceptions direct by means of a Type 16 station which, it will be recalled, had been brought out from the United Kingdom and had been established on the island just prior to the operation. In practice, permanent echoes from Sicily were strong enough to prevent continuous plotting of overland tracks, and persisted even when the R.D.F. beam was at maximum elevation. This station therefore played no part in " Husky " except occasionally to assist fighter aircraft to rendezvous with Allied bombers.

Protection of Shipping and Land Forces by Night

It had been realised during the planning stage that if defeated in the air by day, the enemy would resort to night bombing on an intensive scale. Ample provision was therefore made for the landing of G.C.I. stations as early as possible after the assault, and as a further counter-measure three G.C.I. stations were mounted in Landing Ships Tank for employment at "Acid," " Bark " and " Dime " beaches, to act as forward controls for Malta G.C.I. stations. Despite the short time available for installation and training, the results

[1] A.H.B./1D4/159, D.C.A.S. Folder, " Reports on our Operation ' Husky '," Encl. 1A.
[2] Air Ministry File C.S. 23602, p. 11.

obtained by these ships during the first two nights of operation effectively demonstrated that shipborne Royal Air Force ground search R.D.F. would have considerable value in future similar amphibious operations.[1] The effectiveness of these units mounted on L.S.T.s was reduced, however, to a certain degree by virtue of the fact that in two cases the ships were loaded with priority equipment intended for off-loading on D-day. This necessitated the L.S.T. spending the night of D + 1 in port unloading, thereby defeating the object for which the G.C.I./L.S.T. combination had been created.[2] The valuable equipment of A.M.E.S. No. 8028 aboard L.S.T. No. 407 came very near to complete destruction as a sitting target to enemy bombers while the ship unloaded a number of tanks. The utmost credit was due to the unit's crew for repairing the R.D.F. set with such commendable speed after it had been damaged in the attack and for obtaining such good results in difficult conditions.[3]

The Unit operating off " Joss " beach for the protection of the Licata area, was also not a complete success. The fault lay in the hurried last-minute substitution of a fresh L.S.T., and resulted in a situation in which the R.D.F. aerial vehicle could not be raised to deck level by the L.S.T. elevator, owing to its size. It finally had to be loaded on to the deck by a crane, thus prohibiting any possibility of a speedy landing on a beach by this particular G.C.I. unit. With this type of aerial it was also impossible to operate the G.C.I. transmitters and the V.H.F. R/T simultaneously.[4]

To be fully successful, the ship-borne G.C.I. station should have operated well off-shore to avoid the strong land permanent echoes. In this action, the ship's commander could not go out beyond the destroyer belt 3 miles away) which again seriously handicapped the G.C.I. operations. Nevertheless the unit was able to give night fighter pilots two " visuals."

The full story of the " Bark " sea-borne G.C.I. station was long and complicated and stressed the inadvisability of obtaining supplies for such a venture from so distant a base as the United Kingdom.[5] On arrival off Cap Passero on D-day, the unit was still very far from being *au fait* with the situation and was merely furnished with its R/T callsign by the Headquarters Ship, H.M.S. *Hilary*. Owing to the comparatively small amount of enemy opposition encountered in the early stages of the operation, another G.C.I. station was put ashore and operated on the same V.H.F. frequency, thus causing far too much R/T traffic on one channel.[6] The seaborne R.D.F. unit, however, gave contacts in two hours of actual uninterrupted operation, resulting in two enemy aircraft destroyed and two damaged.

Landing of Mobile R.D.F. Units during the Assault Stage

Although boisterous weather had broken suddenly upon the Central Mediterranean area on the morning of 8 July 1943, and it seemed possible that the Allied landings might be delayed, fortuitously the wind calmed down considerably by D-day, 10 July 1943, and only a heavy swell remained, running rather more strongly along the most westerly Sicilian beaches. Slight opposition

[1] Air Ministry File C.S. 23602, p. 11, and A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean. [2] *Ibid.*, p. 23.
[3] A.H.B./IIE/190, Lessons learned in Operation " Husky," Encl. 6A.
[4] Air Ministry File S.23602, p. 67.
[5] *See* Appendix No. 30 for brief history of G.C.I. equipment fitted on L.S.T. No. 305, which was the forerunner of the Fighter Direction Ships used in the invasion of N.W. Europe.
[6] Air Ministry File C.S. 20672, Part II, Encl. 127A.

was encountered from coastal batteries, but all planned beachheads were established rapidly, tactical and strategical surprise being achieved. The ports of Syracuse and Licata were very soon in the hands of the British Eighth Army, together with the landing grounds at Pachino and Licata.[1]

Landings of R.D.F. stations proceeded smoothly in almost all cases. An instance of an R.D.F. convoy which drove off its L.C.T. into 4 feet of water and made shore with its equipment intact, spoke well for the efficiency of the crew of the vehicles and the thoroughness of the waterproofing.[2] "A" parties of the C.O.L./G.C.I. stations and the fully-crewed Light Warning Sets were landed in the early stages with comparative ease, but an incident in the American sector showed the risk of bringing such equipment in so early as to subject it to enemy action and possible capture. A Light Warning Set had actually to be destroyed by its crew when its capture by the enemy seemed imminent.

Once ashore, the majority of R.D.F. stations were mustered without much difficulty and proceeded to their sites according to plan, after reconnaissance by the technical officers concerned. On site, the gear was made operational with commendable speed, particularly in the case of the Light Warning Sets brought from the Middle East. The mobility of these stations was definitely increased by the Middle East Radio Installation and Maintenance Unit fitments into the Crossley vehicle—the average time taken to become operational being 30 to 50 minutes, the actual aerial erection occupying approximately 20 minutes of this time.[3] In addition, the arrangement of the R.D.F. set forward in the Crossley vehicle allowed the maximum amount of domestic kit to be carried.

Where possible, land-lines were connected to the appropriate Mobile Plotting Room Units from C.O.L./G.C.I. stations, the Light Warning Sets and Wireless Units depending on W/T plotting. In some areas on the first night there was an over-generous distribution of C.O.L./G.C.I. stations and L.W.S.s—this being a result of the fortuitous escape of all R.D.F. units from damage during the assault.[4]

C.O.L./G.C.I. Stations Ashore in Sicily

As the best example of the successful landings of R.D.F. equipment, the "Bark" mobile G.C.I. "A" party, complete with its associated Sector Operations Room was ashore at 0930 hours on D-day. This was the climax to a period of hard training from the day the unit was formed in May 1943 from experienced Western Desert R.D.F. Operators for the express purpose of landing in Sicily. The R.D.F. equipment comprised the latest type to arrive in the Middle East, and included the only power-turned aerial of the Desert Air Force R.D.F. organisation.[5] The unit had been loaded on to flat cars to travel by rail from Alexandria to Tobruk and thence by road to Tripoli. Here preparations were made to make the outfit truly mobile. Crews were divided into their "A" and "B" parties and Controllers flew to Malta to liaise with the night-fighter crews stationed there, with whom they were subsequently to work on night-fighter control.

In mid-June 1943, the "A" party had arrived for the coming action. Early in July 1943 they moved to the assembly point, where the final water-proofing stages were given to the equipments before they ultimately

[1] Air Ministry File C.S. 23602, p. 11. [2] *Ibid.*, pp. 23 and 67.
[3] A.H.B./IIE/185, Operation "Husky," R.D.F. aspect.
[4] Air Ministry File C.S. 23602, p. 24.
[5] A.H.B./IIJ5/82, The History of No. 871 A.M.E.S., Encl. 1A.

took their place in the assault convoy. During the night the L.C.T. lost the convoy and so did not reach Pachino beach until eight o'clock on D-day. Assault operations, which had begun at four o'clock, appeared to be progressing favourably, the warships already shelling a good half-mile inland. Permission was not granted for the unit to land immediately, however, as the Control Ship did not wish to expose secret R.D.F. equipment to unnecessary danger. When permission to land was granted, the L.C.T. pulled into the beach, the ramp was lowered and the first vehicle, with the Commanding Officer at the wheel drove off—straight into deep water, where it stalled. A bulldozer, however, quickly righted the situation and the L.C.T. was able to rebeach, landing the rest of its cargo without mishap.

The beachhead was still the scene of some confusion, as odd pockets of Italian infantry were being winkled out and herded together. A quiet field some distance from the landing place was found, and the unit began de-waterproofing its equipment while enquiries were made as to the local military situation. Despite the co-operation of the Royal Air Force Beach Unit, no satisfactory information could be obtained as to the state of affairs around Pachino airfield, which was the proposed site for the G.C.I. station. Personal reconnaissance found the location still under fire with little hope of a way being made by the evening. In these circumstances, a flat field near the beach was chosen for a temporary site.

Some engineering difficulties were experienced in traversing irrigation pipes, but a little explosive soon cleared the way. A most satisfactory arrangement was made whereby the Mobile Plotting Room Unit, the Advanced Landing Ground Section and the G.C.I. station were all placed together in the same area and were connected by land-line communications. Two Light Warning Sets were sited in the nearby hills to give early warning cover. That night, the G.C.I. unit operated with some difficulty on a poor site with an anti-aircraft gun within 20 yards of the antennæ. Several raids took place and aircraft under this unit's control shot down two *Ju.88s*, despite the fact that it was the first occasion on which the controller had worked with the unit. A large basket of incendiary bombs fell dangerously close but fortunately failed to open, burning in a mass which was finally extinguished with considerable trouble. While the unit was dismantling the following morning, its originally designated site was found to be clear. A hasty move was made and the equipment was again operational by noon at Pachino airfield, with full landline communications established by the Air Formation Signals.

The "Cent" beach R.D.F. units spent D-day on their L.S.T. at sea chasing their pontoon, which had broken adrift on the passage over. They disembarked on D + 1 at 1200 hours and by 2000 hours the mobile G.C.I. station had passed its first plot from a site near the landing beach. Early the next morning the unit moved to Comiso and became operational at the airfield. There was very little for it to do, however, due primarily to the lack of enemy air opposition. It was not until D + 4 that it had the chance to show its prowess, and three enemy aircraft were destroyed by night fighter aircraft under its control.

The "Acid" R.D.F. organisation was part of the air defence of the two Sicilian ports, Syracuse and Augusta, a most vital responsibility. As there was no airfield in that area, the communications requirements for the R.D.F. early warning and control system were planned to be met by an augmented

Field Force Section, but no Advanced Landing Ground Signals Section. Unfortunately this Forward Fighter Control was found to be equipped on far too light a scale, and with a lack of training on the part of the personnel the system was unable to relieve the Headquarters Ship, H.M.S. *Largs*, of her fighter defence control duties until D + 13, by which time they had been reinforced with personnel and equipment.[1]

Despite the often exposed forward positions of the R.D.F. units, there were in all very few casualties. A.M.E.S. No. 15051, the G.C.I. unit which landed at "Dime" beach for a site on Gela airfield, unfortunately lost both its controllers.[2] When the "A" party reached the shore they found American Commandos (Rangers) clearing the area of land-mines which had been laid in profusion by the enemy. In order to protect themselves from snipers' bullets, the unit personnel dug themselves in on the sandy beach to wait until they could proceed on their way to the airfield. During the morning several Rangers were observed lying either wounded or dead on the sand dunes. The Senior Controller of A.M.E.S. No. 15051 went forward to attempt to give them medical attention. The first man he reached was dead, and as he made his way towards the second he touched off a land-mine, causing multiple injuries to himself, from which he later died, and killing the wounded man. The deputy Controller, having gone to procure a stretcher for the wounded, took a short cut across the dunes and set off a second mine which killed him and seriously wounded two airmen accompanying him.

A slight contretemps was experienced by the "Bark South" G.C.I. unit in attempting to land south of Potropalo. This unit had come originally from an Iraq site, and on its way to its final assembly point in Malta, had spent some weeks at the Combined Operations Training Centre at Kabrit in Egypt. This training was now proving invaluable. The L.S.T. touched down on D + 1 approximately 40 yards from the beach. A vehicle of No. 1 M.P.R.U. which was also aboard, was first to drive off but became bogged in a deeper channel and it was considered impracticable to make further landings. The L.S.T. was therefore backed away and went further round the coast to the eastward, where the equipment was landed without a hitch.[3] Contact was made with the Royal Air Force Beach Unit, and, after de-waterproofing, the R.D.F. convoy moved off to join A.M.E.S. No. 871 at Pachino, the G.C.I. unit becoming operational the following morning, plotting to the M.P.R.U. via A.M.E.S. No. 871.

British Light Warning Sets ashore in Sicily

The British Light Warning Sets, mounted in vehicles, performed satisfactorily on the whole. There were a few instances of stations setting off, however, in charge of relatively inexperienced N.C.O.s and not being heard of for 48 hours. In one area, L.W.S.s were planned to go into the assault without a load-carrier or even a motor-cycle. Under these conditions the personnel either had to go without their rations or had to drive in on their R.D.F. vehicle on their way to collect the necessities of life, thus closing down their R.D.F. watch.[4]

One L.W.S., operational four miles from the German positions, could not make W/T contact with its appropriate Operations Room. It therefore had to dismantle its station in order to drive back and discover the reason for this

[1] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean, para. 51.
[2] No. 15051 A.M.E.S., O.R.B. [3] No. 887 A M.E.S., O R.B.
[4] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean, para. 135.

breakdown of communications. It was found that the Operations Room was unable to listen-out for this particular station as it had been busy with three other stations working on the same frequency—in fact, W/T contact for this unit was not established until eight days after its arrival in Sicily.[1]

The Light Warning Set aerial arrays stood up well to the wear and tear of as many as twelve erections and dismantlings, the only doubtful part being the screws which attached the top main vertical section of the aerial array to the bottom main vertical section at the clamps. General R.D.F. cover performance was satisfactory, average ranges being 60 to 70 miles, with maximum ranges of the order of 100 miles.[2]

The planning and supply of R.D.F. units for the invasion of Sicily proved to have been quite sound, but the steps taken to co-ordinate the combined information that these smaller units could provide were found to be far less satisfactory.

M.P.R.U.s Landed with the Assault Forces

The Mobile Plotting Rooms were too small and primitive and the arrangement of twelve field telephones all with the same ringing tone, placed on shelves round the inside of the box wagons was enough to daunt the staunchest operator. There was no doubt that, on the whole, the staff of these Operations Rooms were inadequately briefed. They had no access to intelligence information which had proved its worth in the past as invaluable for aircraft identification, and much of the general picture had to be obtained from the Signals Section with which they were associated and with which they had no previous contact or training.[3] The V.H.F. R/T equipment was inadequate and the staff were under-established for the 24-hours working required of them. In these circumstances, the Forward Fighter Controls could not efficiently relieve Headquarters ships of fighter direction and air raid warning duties.

These conditions were improved by the advent of No. 211 Group and No. 244 Wing at Pachino on D + 3, who took over control of Pachino fighter squadrons from H.M.S. *Hilary* and the M.P.R.U. On D + 1, 11 July 1943, the enemy launched a counter-attack in the Gela area but was repulsed after some small initial success. Augusta Port and the airfields at Comiso and Ponte de Olivo were taken by the Allies on 12 July 1943, and No. 324 Wing moved into Comiso on D + 6. By D + 7 control of all aircraft in the vicinity of Sicily was transferred to shore-based sectors under No. 211 Group, and the Headquarters Ships were instructed to close down on the controlling R.D.F. waves.[4]

No. 1 M.O.R.U. and No. 101 M.A.R.U.

It had been intended that No. 1 Mobile Operations Room Unit (M.O.R.U.) and No. 101 Mobile Air Reporting Unit (M.A.R.U.)[5] should share the responsibility of all offensive and defensive air operations (except strategic bombing) with Headquarters, No. 211 Group, the newly-evolved Operation Room system to be landed as early as possible after the fall of Catania. Unfortunately this plan miscarried due to the delay in the fall of Catania. The

[1] No. 6011 A.M.E.S., O.R.B.
[2] A.H.B./IIE/185, Operation "Husky," R.D.F. aspect, Encl. 105A.
[3] A.H.B./IIJ5/8, para. 52.
[4] Air Ministry File C.S. 23602, p. 11, and A.H.B./IIJ5/8, para. 54.
[5] Details of No. 1 M.O.R.U. and No. 101 M.A.R.U. are given in Chapter 19.

M.O.R.U. and M.A.R.U. convoys had to be diverted, part to Augusta and part to Syracuse, where unloading was further delayed because berthing priority had to be given to Army reinforcements. While anchored in the harbour at Augusta, the store ships containing the M.A.R.U. equipment were set on fire by enemy action and sunk. In order to salvage the M.O.R.U. equipment, the remaining store ships were sent back to Malta until Catania had fallen to the Allies.

The loss of all the equipment for the M.A.R.U. in the docks at Augusta was largely made good by masterly improvisation coupled with a certain amount of borrowing from other units.[1] A Filter Room was built up in a converted mill on 30 July 1943, for the day protection of ports and installations in the Eighth Army area and westwards to Gela, the night-fighter protection of both the British Eighth and American Seventh Army areas, and Air-Sea Rescue work for the Allied Air Forces. This state of affairs was to exist until such time as the replacement equipment requested from the United Kingdom allowed the unit to return to a mobile basis. Fortunately there were only minor casualties among the crew, caused by heavy raids at night on the Augusta docks. At the sinking of the store ships, only one officer and one airman were aboard, and both of them were rescued from the sea unhurt.

By the last week of July 1943, the M.A.R.U. was sufficiently organised to keep a listening watch for information from two C.O.L. stations, three L.W.S.s, a group of four Wireless Observer Unit posts, Naval R.D.F. and the Malta Filter Room. Good R.D.F. plots were obtained from the C.O.L. stations and useful visual information was given by the Observer Posts. The performance of the remaining sources of R.D.F. information was not of much value, and in the case of the Naval R.D.F. and one L.W.S. nothing was received at all.[2] It was obvious at that time that rationalisation of the reporting system as a whole had become an urgent requirement; the use of too many sources of R.D.F. information led to filtering difficulties and the co-ordination of the raid reporting picture became impossible. Until this was effected, the M.A.R.U. could not be expected to provide really useful finished tracks for its associated No. 1 M.O.R.U. Nevertheless, despite minor disadvantages and isolated examples of untoward difficulties, the R.D.F. early warning and fighter-control system generally worked quite well, and 98 enemy aircraft were destroyed in the first seven days after the assault for the loss of 28 of our pilots; in addition another 53 enemy aircraft were destroyed by G.C.I.-controlled night fighter aircraft.[3]

Follow-Up Movements of R.D.F. Units in Sicily

An Allied advance was in progress on all sectors by D + 3, 13 July 1943; the assault on Sicily was successful, and the next requirement was to enlarge the bridgehead. Sufficient R.D.F. equipment was available to allow close follow-up of the British Eighth Army advance up the east coast of Sicily, and additional R.D.F. equipment was landed to the south-west of the Island for use with the American Seventh Army.[4]

Follow-up convoys included further Type 8 Units, Mobile Radio Units and the " B " parties of the units which had taken part in the assaults. The Type 8 Units were to be available for use as reporting or controlling C.O.L. or G.C.I.

[1] Air Ministry File C.S. 23602, p. 23.
[2] A.H.B./IIE/190, Lessons learned in Operation " Husky," Encl. 2A.
[3] A.H.B./IIJ5/8, para. 30.
[4] Air Ministry File C.S. 23602, p. 11.

stations for leap-frogging those units already ashore, and the Mobile Radio Units were to provide " floodlighting " cover and height-finding facilities. The splitting of C.O.L. and G.C.I. units into " A " and " B " parties had led to disorganisation. Arrangements for the shipment of the " B " party containing the major portion of the R.D.F. personnel, the domestic equipment, a large quantity of spares and the second diesel-electric power supply, seem to have broken down completely in some cases. This had a serious effect on the units generally, since it meant that not only were the skeleton crews strained to their utmost capacity, but the stations were inadequately equipped with transport for domestic purposes, such as obtaining food and water.[1] In addition, the running of one diesel power supply for such a long period without maintenance led in some cases to a serious unserviceability of a station.

From the coastal belt the hills rose very steeply inland and, in general, the operation of the C.O.L./G.C.I. apparatus was confined to the coast in order to provide essential R.D.F. cover over the ports and forward areas and at the same time give the best possible medium high-flying cover over inland approaches.[2] In some areas, permanent echoes made the latter task extremely difficult. One C.O.L. station was sited on a 1,500 foot cliff in order to obtain low-flying cover for enemy aircraft attacking Syracuse harbour.[3]

With follow-up R.D.F. convoys, the old mistake was made in separating crews from their technical vehicles, as had occurred in operations " Torch " and " Corkscrew." Not only did this cause considerable delay before stations could become operational, but it also exposed the personnel to unnecessary danger from enemy raids while awaiting the arrival of their equipment at docks, harbours, and on the beaches.[4]

Units coming from the United Kingdom still travelled as separate entities. A.M.E.S. No. 8032 sailed from Liverpool, having had only one opportunity to inspect its technical vehicles and none at all of looking over the general purpose wagons. Although both men and equipment arrived without loss, it was found that few of the alterations suggested by the technical officer while at R.A.F. Station Long Cross had been carried out, and none of the deficiencies had been made good.[5] On arrival at Algiers the unit was attached to the American Army. Despite the rather more materialistic advantages of better rations and more regular mail, the unit found this arrangement far from satisfactory. The chief drawback was that while it could not draw on American stores, the Royal Air Force apparently denied its very existence. After much trouble and delay, some of the more vital parts missing from the technical equipment were supplied by the local Maintenance Unit, but to the detriment of other stations, as A.M.E.S. No. 8032 was not officially on its strength.

The officers and personnel reached Gela on D + 4, 14 July 1943, making a wet-shod landing in three feet of water for 50 yards. The vehicles arrived later on 17 and 18 July 1943, all except the aerial tender which was found to be too large to go on the L.S.T. Several days passed and finally the Commanding Officer flew back from Gela to Tunis to hasten the arrival of the aerial. He found that no one was taking an interest in the fact that one G.C.I. unit had its aerial tender missing, and it was not until he had approached the highest Naval and Air Force authorities that the essential vehicle was shipped to

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[1] Air Ministry File C.S. 23602, p. 23.
[2] *Ibid.*, p. 24.
[3] A.H.B./IIE/193, T.R.E. Report on a visit to the Mediterranean theatre, 11 June–26 August 1943.
[4] A.H.B./IIJ5/8, para. 128.
[5] No. 8032 A.M.E.S., O.R.B.

Sicily, eight days after the remainder of the equipment had arrived. Thus the unit was non-operational for eight days at a vital period.

When the English fully-mobile G.C.I. stations came up in the later stages to replace the Middle East units, the fact that they used the aerial with a mean height of 12 feet 6 inches gave trouble with the permanent echo configuration of the given sites. A temporary solution employed was to dig in the wheels of the aerial vehicles so that the mean aerial height was decreased to nearly 10 feet, as for the Middle East units.[1]

A G.C.I. station for "Dime" beach area fared better and, having disembarked, moved off with the American No. 3 Air Defence Wing to Port Empedocle, where technical and domestic sites were soon erected and operations begun. Some time later the R.D.F. convoy moved up to Cefalu via Palermo. Owing to unavoidable delay due to the trucks' radiators boiling, an attempt was made to drive by night, but the Crossley transmitter and workshop trailer developed faulty brakes and ran away. The driver edged towards the roadside and jumped clear, the transmitter finishing up on its side with its front wheels in a large hole. The convoy bivouacked on the road and the next morning an American crane hauled the transmitter upright. It was found to have sustained little damage.[2]

Mobile Radio Units were not planned to arrive in Sicily until a later date, in view of the time taken for them to come into action and the fact that they could not be used for controlling or low cover.[3] Their equipment, however, did not reach Sicily until a week after the units had arrived in most cases, and the erection of one station was unnecessarily retarded by the components of the masts arriving with no markings to indicate their position in the framework.[4]

One unit, after a brief rest at Oran where it had disembarked from the United Kingdom in May 1943, was practically on the move continually until 31 August 1943. This was the hottest period of the year, and roads were often dangerously narrow, with bad surfaces and climbs up to 4,600 feet. Sandstorms and siroccos were encountered by the drivers, the majority of whom had only learned to drive three weeks before leaving England. The loads were excessive and the vehicles under-powered for the country to be traversed.[5] During the early part of August 1943, on the way to Termini East, the transmitter vehicle of this unit also met with an accident due to brake failure and overturned. Again, an American crane came to the rescue and righted the vehicle. The latter was practically wrecked but the senior M.T. driver drove it slowly and carefully to Termini East, where it was found that the transmitter could soon be repaired.

With the C.O.L. and G.C.I. stations providing coastal protection, and with further seaward cover with accurate height-estimation from the Mobile Radio Units, the main bulk of inland cover was provided by the Light Warning Stations, which had once again proved their worth. Night bombers attacking the east coast ports always approached round the west side of Mount Etna (which provided an all-time record in R.D.F. permanent echoes) but careful siting of Light Warning Sets to the south-west of the mountain enabled a fairly good advance warning to be provided for the G.C.I. stations controlling the night fighter aircraft.

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[1] A.H.B./IIE/185, Operation "Husky," R.D.F. aspect, Encl. 105A.
[2] No. 8031 A.M.E.S., O.R.B.
[3] A.H.B./IIJ5/8, para. 128.
[4] Air Ministry File C.S. 23602, p. 23.
[5] No. 329 A.M.E.S., O.R.B.

This campaign confirmed the conclusion reached in North Africa that the Light Warning Set, carefully sited, could produce valuable information in country where the more powerful R.D.F. equipments were virtually ineffective due to permanent echoes. Light Warning Stations being small and available in sufficient numbers could be placed to cover specific inland lines of approach. Excellent results were obtained by deploying two Light Warning Sets close together so that they were affected by permanent echoes on varying azimuths.[1] This enabled a fair medium and high-flying coverage of quite a large area to be obtained. A further example of the value of carefully planned siting was the setting up of L.W.S.s in valleys down which enemy aircraft might approach. A station set some distance up the sloping side of the valley could give the best low-flying coverage along its length. Where permanent echoes caused blind areas, these were offset by differently oriented sets. In the Allied advance towards the Catania plain a series of ridges running east to west were encountered and overcome by placing L.W.S.s some short distance down the southern slope of the ridges. This had the effect of providing medium and high-flying cover unencumbered by permanent echoes from the succeeding ridges. When necessary the L.W.S. also acted as an efficient coast watching station.

The Failure of Identification of Friendly from Enemy Aircraft

I.F.F. generally showed a very poor return. The conversion to Mark III had been made shortly before the operation but there were still large numbers of aircraft fitted with Mark II. The change to Mark III I.F.F. was not responsible, however, for the poor I.F.F. return, since no M.R.U.s (the only stations which could pick up Mark II) were planned to arrive in Sicily until D + 14. A great part of the effort of the night-fighting organisation during Operation " Husky " was devoted to intercepting unidentified friendly aircraft.[2]

Air Movement Liaison was neither well planned nor well executed. On the signals side, the communications provided appear to have been just adequate for passing what information was furnished. Malta relayed information received from the mainland to forward controls on the base waves, the inter-F.D.O. wave and the R.D.F. broadcast.[3] There were, in addition, air movement broadcasts from Headquarters, N.A.T.A.F., but notification of this latter service was not received by at least one Headquarters ship in time for watch to be opened on the appropriate frequency. It had been decided some weeks prior to the operation that the Friendly Aircraft Approach Code suitably amended would meet the security requirements, but this amendment was not finally issued until a day or two before the operation, and it was not received by a number of important controls.

The identification system, from both R.D.F. and Air Movement Liaison Section sources, left much to be desired. Under the prevailing conditions of Allied air superiority, the loss of fighter effort in intercepting unidentified aircraft which subsequently were recognised visually as friendly was not too serious a matter. Nevertheless, the partial failure of I.F.F. for R.D.F. identification must be regarded as a shortcoming which could be very serious in such an operation, were the opposing air forces on a parity.

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[1] Air Ministry File C.S. 23602, p. 25.
[2] A.H.B./IIJ5/8, para. 140.
[3] *Ibid.*, para. 137.

Provision of Maintenance and Servicing for R.D.F. Equipment

The requirements for radio equipment in the campaign were continually changing as the nature of the fighting altered. It was thus not possible to demand of Air Ministry in the United Kingdom apparatus to meet a particular situation, with any hope that the demand might be met in time to be effective. New specialised apparatus was therefore likely to be valuable only when it solved a problem which was always going to be present (*e.g.*, night fighter defence of bases), or when it was of a type which lent itself readily to adaptation on the spot to meet changing conditions.[1] The detailed practical design of radio equipment assumed a much greater degree of importance in the field than it did in static warfare. It was extremely difficult for production staffs at home to appreciate detailed practical problems of this nature, and facilities had therefore to be provided locally for the carrying out of modification work, sometimes up to quite a high degree of complexity. For ground R.D.F., the Middle East Radio Installation and Maintenance Unit (R.I.M.U.)[2] performed this function, and had been largely responsible for the success which attended the use of mobile R.D.F. stations in the North African and Sicilian campaigns. Even with the experience gained in North Africa incorporated in the designs, the services of this unit were still essential in putting last-minute modifications on equipment sent out from England for the Sicilian invasion.

North Africa at that time only had the nucleus of a Maintenance Unit capable of carrying out special modifications. The lack of this service had already begun to be felt in Sicily. Due consideration was being given at that time to the suggestion of a special unit to be detailed at home for this type of work, as part of the preparation for a front in North-West Europe ; and whether competent technical staff should not be detached from home research and development establishments to study tactical adaption problems in each of the war theatres.

In the campaign area in Sicily, two M.S.S.U.s, Nos. 305 and 306, had been landed on D + 9 and D + 14. Again, some delay arose from the fact that the units had travelled separately from their equipment. In the case of No. 305 M.S.S.U., which had sailed from the United Kingdom, its equipment had been completely repacked at Liverpool by the embarkation authorities, thus nullifying the careful preparation of packing notes made by the unit officers at the Royal Air Force Station, Chigwell. While standing by for the arrival of their equipment, the units were unable to move from the dock areas and thus stood in grave danger of becoming casualties in the enemy air attacks on ports and harbours.[3]

With their equipment unloaded and their workshops set up, the M.S.S.U.s found plenty of work to do with the abundance of R.D.F. units in operation on the island, in addition to the many Signals units also requiring servicing. Due to the number of R.D.F. stations available, those which had suffered most were able to be taken off the air and given a complete technical overhaul without any loss of R.D.F. cover.

After the assault phase, those R.D.F. units left operating at captured enemy ports and bases settled down to carry out their normal reporting and controlling duties, as many of them had done in the early days of the war in the United Kingdom. The units which followed up the Armies' advance did so with the same keenness as they had shown in the previous campaigns of the Western Desert and Tunisia.

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[1] A.H.B./IIE/193, T.R.E. Report on the Mediterranean theatre.

[2] For details of work carried out by R.I.M.U., *see* Chapter 12 of this volume.

[3] Nos. 305 and 306 M.S.S.U.s, O.R.B.s.

R.D.F. Lessons Learned in Operation " Husky "

The invasion of Sicily occurred eight months after the first Allied large-scale combined amphibious operation—Operation " Torch."[1] The two actions were dissimilar in many respects, the lack of effective resistance by the French in North Africa and the shorter supply route to Sicily being two of the major differences, yet many of the lessons learned in Operation " Torch " could have served as a guide in the planning of Operation " Husky."[2] Although this was true of the broad planning, it seemed, however, that even eight months was too short a period for all the minor defects to be eliminated. Despite the fact that these errors might be small in themselves, multiplied by a number of units involved they could become a potential danger in an undertaking of this magnitude. In order to clarify the picture, lessons learned in the invasion of Sicily, as far as R.D.F. was concerned, were summarised after the operation as follows :—

Planning.—It was obvious that the planning staff should have included officers experienced in specialist jobs such as telecommunications, R.D.F. security and Fighter Control, and that files of the lessons learned in previous operations should have been at the disposal of the planners of future campaigns. In this particular case, equipment was coming from diverse theatres and it was therefore essential that, in any such similar circumstances, the description and composition of Signals and R.D.F. units should be standardised. If this was not possible, then each theatre should have been kept fully informed of developments elsewhere.

Day fighter control.—The method of operating fighter aircraft employed in " Husky," with Malta as the main control and with ships acting as subordinate forward controls was satisfactory, and it appeared that it would have been equally suitable in conditions of much heavier air opposition. More efficient provision should have been made, however, on the Headquarters Ships to receive R.D.F. plots from initial shore installations and for them to be issued with full instructions, not only for the assault phase but also for the subsequent handing over of control to a shore-based sector. There would have also been less muddle at this critical moment if the Senior Controller of the sector had travelled aboard the Headquarters Ship, in order to gain a knowledge of the general air situation and some experience of the reliability of the various sources of R.D.F. information.

The lack of one or more long-range R.D.F. sets, preferably fitted with Plan Position Indicators, for the Controllers use on board ship was a stumbling block to effective controlling. It was not possible to install these equipments in Headquarters Ships owing to the unavoidable interference with Army and Navy channels of communications. Therefore it was strongly recommended that specialist Air Force Fighter Control Ships should be introduced into any future operation of this nature. Controller of seaborne G.C.I. stations should maintain closest liaison with Headquarters Ships and, if possible, should have some form of launch or amphibious craft to enable them to visit other ships and units on shore. The importance of the exchange of R.D.F. information between R.D.F.-fitted ships was paramount, as only by this means could all get as full a picture as possible.

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[1] For details of Operation " Torch," *see* Chapter 17 of this volume.

[2] A.H.B./IIJ5/8, Summary of lessons learned.

Fighter control ashore.—It was found that the forward Fighter Control Units were equipped on too light a scale to be able to take over control of fighter aircraft from the Headquarters Ships. One solution of this problem would have been for the "A" party of the main Fighter Control organisation to be included in the D-day convoy on a selected assault, complete with an adequate staff, wireless equipment, landlines, Operations Room and Intelligence Service, or for improved forward Fighter Controls to be used. In the latter case they should have been entities with V.H.F. equipment designed for continuous running, and their Operations vehicles should have been considerably developed and crews greatly enlarged to cope with their duties effectively.

A reserve fighter control organisation would have been a worthwhile investment in case the first one landed suffered severely from enemy action, as the success of the whole operation might well depend on the fighter cover available. Some sort of visual control was also needed ashore as soon as possible to effect interceptions on low-flying aircraft attacking anchorages and beaches. Possibly a Wireless Unit fitted with Low Power V.H.F. R/T equipment under the care of a Control Officer would have satisfied this requirement.

Night fighter control.—The main lesson learned with respect to night fighter control was the fact that both C.O.L./G.C.I. stations and L.W.S.s must be landed complete with all operating personnel and motor transport and not broken down into assault and follow-up parties. If this was found to be impossible due to shipping space, then the "A" parties should have been larger than those which took part in Operation " Husky " and should have included improved V.H.F. equipment for ground-to-air communications, more technical spares and personnel and the " B " parties should have been put in earlier than D + 14. Both G.C.I. and C.O.L. controlling should have been used, and it was essential that Controllers should be adaptable to either system.

It was demonstrated that the requirements of G.C.I. stations aboard L.S.T.s should be the main factor influencing the movements of these ships. It will be recalled that in Operation " Husky " two of these ships had been loaded with priority equipment and had spent the first night in Sicilian ports unloading equipment, instead of operating as effective ship-borne G.C.I. stations, some 5–10 miles off-shore. If the L.S.T.s had to carry full loads, their cargoes should have been of such a nature that their off-loading could wait until the G.C.I. units had completed their controlling duties. These L.S.T.s should have been allotted for G.C.I. control early in the planning stage of each combined operation on an approximate scale of one per 25 miles of front, and in order to provide protection against air attack, all technical vehicles except the aerial tender should have been carried in the tank space. This latter vehicle would have had to be so modified that it could be off-loaded through the tank space of the L.S.T., instead of by crane or derrick as was the case in Operation " Husky."

Air warning system.—The operation against Sicily had shown the importance of concentrating first on the setting up of G.C.I. stations and C.O.L. stations, which had proved to be the backbone of the R.D.F. system, and of considering the Light Warning Sets afterwards. Notwithstanding, the L.W.S.s played an extremely valuable part and it was again emphasised that each unit must be provided with a 15-cwt. load carrier. Events had shown that only the best N.C.O.s should be chosen to be in charge of the Light Warning Sets, and it was considered necessary that M.S.S.U.s accompanying the expeditionary forces should have an administrative section responsible for R.D.F. units which were already technically under their care.

Wireless Observer Units landed on D-day were considered a useful addition to the early warning system—particularly in mountainous country where the R.D.F. Units might be slow in going into action and suffer from permanent echoes. When Air Movement Liaison was poor the Observer Units were invaluable for providing reliable enemy aircraft recognition. A free-lance R.D.F. Officer with a jeep should have accompanied each main landing to assist in siting stations and to arrange their subsequent moves.

The need, already experienced in Operation " Torch," for all a mobile unit's vehicles to be prime movers was stressed again in Operation " Husky." Although lessons learned from the previous invasion of North Africa had been applied to the R.D.F. units landing with the assault forces, the follow-up convoys were still sent separately from their vehicles, leading to considerable delay in the progress of the units concerned.

Identification of aircraft.—In any operation it was vital that speedy and accurate identification of aircraft should be available. Despite the conversion to Mark III I.F.F. (which was not complete) prior to Operation " Husky," the R.D.F. identification system was not satisfactory. Of the supplementary services which aided identification, intelligence services could have been invaluable. If possible, V.H.F. D/F should have been used on shore earlier in the operation for intelligence purposes, and an interchange of intelligence information should have been arranged on a frequency specially allocated to this service.

Air Movement Liaison was disappointing in this Operation. It should have been centrally planned prior to the operation, and all Commands involved should have been issued with instructions detailing their responsibility for passing movement signals. Air movement broadcast should have been arranged, and facilities for their receipt provided in H.M. and U.S.N. ships, Royal Air Force Fighter Controls, G.C.I. stations and Army A.A. units, with a suitable code introduced for these broadcasts.

Inadequate dissemination of R.D.F. technical information overseas.—Finally, as an overall criticism of the lack of liaison between overseas and the home-based personnel on R.D.F. matters, a Telecommunications Research Establishment representative on his visit to the Mediterranean theatre between 11 June and 26 August 1943, expressed concern at finding the extent to which Headquarters personnel were ignorant of the latest radio developments in the United Kingdom.[1] The majority of R.D.F. staff officers in North Africa, Malta and the Middle East had been overseas for several years, and were naturally not able to appreciate the uses to which the newer R.D.F. aids might be put in their particular sphere. This technical isolation was the direct result of the inevitable rule that overseas personnel must serve a minimum of three years before returning to the United Kingdom. It was suggested that progress in the use of R.D.F. overseas would be greatly accelerated if this rule could have been waived in the case of technical staff officers.

In the absence of full R.D.F. technical information, it was clear that requirements could not be stated by Overseas Commands. On the other hand, it did not seem that Air Ministry had a sufficiently clear picture to realise fully

[1] A.H.B./IIE/193, T.R.E. Report on the Mediterranean theatre.

the needs and possibilities for radio overseas, having no individual person or department specially responsible for it. It was therefore strongly recommended that a radio officer be appointed to the staff of the Director of Overseas Operations, or that the overseas requirements for R.D.F. and radio aids should be co-ordinated by special branches in the department of the Director of R.D.F. These branches would then be able to keep in touch with the particular problems of Overseas Commands in the same way as those of the Home Commands were cared for. Mediterranean Air Command was not, in fact, fulfilling this function, probably owing to the large distances involved, and to the fact that production data of R.D.F. equipment were not available to those who had the responsibility for making policy decisions.

The Final Rout of the Enemy in Sicily .

In less than a week from the initial landings air and naval support had enabled the Allied troops to advance rapidly and secure airfields, centres of communications, bases, and the important harbours of Augusta and Syracuse.[1] The failure of the enemy to organise any effective counter-attacks might be attributed in some measure to uncertainty as to where exactly in the Mediterranean the blow would fall, but there was little doubt that the controlling factor was the havoc caused to his airfields, communications and radar system by the strategic bombing of the Allied Air Forces.

By 5 August, Catania and the rest of the island, excepting the north-eastern tip, were in Allied hands. Enemy resistance in the air had been completely smashed and from then onwards it was clear he was fighting a rear-guard action, while his troops and equipment were withdrawn across the Messina Strait to Italy.

By D + 14, 24 July 1943, a great profusion of R.D.F. equipment was in Sicily, enough to protect an island ten times its size, and for the first time in the history of R.D.F. the familiar cry of " shortage of equipment " was not heard. In fact, the surfeit of R.D.F. information was inclined to lead to confusion on occasions. Nevertheless, this operation had shown considerable improvement of the overall R.D.F. organisation as compared with the one or two outstanding unit performances which had " saved the day " in former operations.

At dawn on 17 August 1943 the Allied forward units entered Messina and enemy resistance ceased. In a little over five weeks the Sicilian campaign had brought the Allied forces to the doorstep of Axis-controlled Europe. The R.D.F. units, in company with the rest of the combined forces, were preparing to leave the stepping-stone of Sicily for the assault on the Italian mainland.

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[1] A.H.B./IIJ5/8.

CHAPTER 21

GROUND SEARCH RADAR IN THE MEDITERRANEAN CAMPAIGN, SEPTEMBER 1943–MAY 1944

The Allied grand strategy against the European Axis powers had been decided at the Washington Conference of May 1943 (" Trident "). There, the Allied leaders had agreed on the continuation of the policy of the Casablanca Conference, namely, of operating in the Mediterranean because it was in that theatre that comparatively small forces of the Western Allies could produce the maximum effect. It was also obviously desirable to exploit to the full the considerable successes already gained in Egypt, Libya and North Africa. The invasion of Sicily had been the first major step in implementing this policy, and it was resolved that the armies were to pass on to Italy as soon as possible.

There was one main aspect in which the impending campaign against Italy was to differ from the preceding operations in North Africa and Sicily. The major attack on Europe from the United Kingdom (Operation "Overlord") was contemplated for the early summer of 1944. Operations against Italy were not therefore to have the priority in personnel and equipment which had been accorded previously in the Mediterranean theatre.[1] In fact, some first-line troops of much experience were ultimately to be returned to the United Kingdom in time to take part in the Normandy assault.

General Eisenhower was invited to submit a plan calculated to eliminate Italy from the war and at the same time contain the greatest possible number of enemy troops. Such an operation would ensure a greater measure of success for an assault in north-west Europe, by keeping the enemy occupied throughout the winter while preparations were being completed. The success of any plan depended largely on the political situation in Italy and the rate of progress of the final conquest in Sicily; consequently it underwent constant changes.[2] No useful purpose would be served by considering in the Signals narrative the many problems and considerations which led at one point to plans for five major amphibious assaults coming under discussion in a period of eight weeks. These included such projects as the invasion of Sardinia or Corsica, a direct assault into the town of Naples (assuming a sudden collapse of Italy), and the invasions of the " toe " and " heel " of Italy.

This chapter therefore deals only with the final stages of the planning of the invasion of the Italian mainland in so far as they affected the ground search radar policy. The narrative then continues by considering important features of the employment of the mobile radar units in the Italian campaign, together with an account of the strategic broadening of the radar cover in the north-western Mediterranean, made possible by the setting up of stations on Sardinia and Corsica after the occupation of those islands by Allied forces. The role of ground radar in the invasion of the South of France is also included in this chapter. In view of the very wide field covered by this narrative of the later phases of the Mediterranean campaign, it is inadvisable to follow in detail the individual moves of the many radar units involved. Rather has particular emphasis been laid on the lessons learned in the operational use of radar raid reporting and fighter control during the amphibious combined operations.

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[1] Air Ministry File C.32152/46, Commander-in-Chief's Despatch on the Italian Campaign.
[2] A.H.B./IIJ11/21, " Baytown " Naval Operations.

Final Stages in the Planning of an Invasion of the Italian Mainland

After exploring the various strategic possibilities, it was decided that the Italian mainland should be the Mediterranean Forces' next objective, and by 5 June 1943 plans were prepared giving a tentative target date of 1 September 1943, but it was still not settled as to where the first blow should fall.[1] By 18 July 1943 it had become apparent that the war should be carried to the mainland immediately Sicily had fallen to the Allies, but by the 25 July the downfall of Mussolini had been accomplished, bringing with it the probability of an Italian Armistice and the desirability of an assault on the Naples area at a much earlier date than had hitherto been envisaged. A direct attack upon Naples or Rome was ruled out and orders were issued to prepare plans for amphibious operations in the Gulf of Salerno with a target date of 9 September 1943. This operation was given the .code-name " Avalanche."

The outline planning for Operation " Avalanche " was not begun until 4 August 1943. At the time it still had not been decided whether Operation " Avalanche " or Operation " Buttress " (a seaborne assault in the " toe " of Italy) would be mounted. Consequently planning for both operations had to be carried out simultaneously and arrangements had to be made to load the convoys to sail from North Africa for either.[2] This was no easy task, since " Buttress " was to be essentially British-controlled from the air standpoint with the Desert Air Force playing a prominent role, while " Avalanche " was to be essentially American with XII Air Support Command as the controlling formation.

The North African Air Force (N.A.A.F.) planning staff had been assembled at the *École Normale*, Algiers, since 29 June 1943, where they were in close co-operation with the staffs of the Army and Navy forces concerned, which were housed in the same building. A combined Signals Board, consisting of representatives of all these forces, was formed to discuss inter-Service matters arising out of the general plans. It became increasingly evident as the Sicilian campaign progressed that sufficient forces would be available for a crossing of the Strait of Messina (Operation " Baytown "), and on 16 August 1943 it was decided that this operation should be essayed on 3 September 1943. This was to be followed by an attack on the Gulf of Salerno providing enemy reinforcements did not preclude such a move. Operation " Buttress " was abandoned and XII Air Support Command took over the detailed planning for " Avalanche," with the N.A.A.F. planners continuing to act as a co-ordinating authority with the other two Services.

General Plans for Operation "Avalanche"

Two landings were to be made in the Gulf of Salerno, one to the south of the river Sele, to be known as the Southern Assault Force, and the other to the north of the river, to be known as the Northern Assault Force. The latter was to comprise the British X Corps. Having landed on the beaches to the north of the River Sele they would deliver the main blow.[3] Their objectives were to be the port of Salerno, Monte Carvino airfield, and the important rail and road centres of Battipaglia and Ponte Sele. The Southern Assault Force

[1] Air Ministry File C.32152/46.

[2] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean, July–September 1943.

[3] Air Ministry File C.32152/46.

was to comprise the United States VI Corps which was to operate on the right flank of the British X Corps and establish a beachhead south of the Sele River, advance inland to seize the high ground and prevent enemy movement into the plain from east and south. Having seized the port of Salerno and Monte Corvino airfield, the Northern Assault Force was to advance northwards as rapidly as possible to consolidate the high ground separating the Salerno-Naples plains, the initial seizure of which would be the task of the Commandos and Ranger battalions landing on the Sorrento peninsula.

Ground Search Radar Planning for Operation "Avalanche"

Ground search radar units were well-established as an essential factor of the Royal Air Force component for any operation involving air cover. One of the major requirements, therefore, to be met by the Signals Section during the assault phase was the provision of radar cover over the convoys, beaches, and assault troops ashore. Salerno Bay is backed by hills on all sides, consequently it was unlikely that good radar cover would be obtained towards the land because of permanent echoes, but a fairly extensive sweep would be available to stations with their aerial systems orientated seawards.[1] In view of the fact that the Signals commitments for Operation "Avalanche" were substantially the same as those for Operation "Husky," much of the organisation remained unaltered. Certain modifications had, however, to be incorporated to meet fully the conditions imposed by variations in the disposition of units and, secondly, to allow for a strengthening of those points found by experience to be weak.[2]

Fighter Control during the Assault Phase

Fighter control during the approach towards the Italian mainland was to be effected in a similar fashion to that exercised during the Sicilian landings, only on a considerably less ambitious scale. Radar information was to be obtained from the following sources :—[3]

(*a*) Warships fitted with radar.
(*b*) Seaborne G.C.I. stations.
(*c*) Track broadcasts from the Sector Operations Room/Filter Room in Sicily.

During this phase, no radar cover was to be available from shore-based stations, as Salerno lay out of the range of the nearest Allied-occupied territory. It was therefore imperative that the best possible provision should be made for carrying radar with the convoys, and that communications for the reception of radar plots by the Headquarters Ships should be extensive. The main source of radar cover during the approach was to be from seaborne G.C.I. stations and it was considered vital that at least two such units should be provided.

In view of the distance of approximately 192 miles between the north-eastern tip of Sicily and the assault regions, the Headquarters Ship and Fighter Direction Ships in this operation were to be regarded as the main fighter control units. There was to be one Headquarters Ship, U.S.S. *Ancon*, with H.M.S. *Hilary* acting as standby Headquarters Ship, and H.M.S. *Ulster Queen* controlling carrier-borne fighter aircraft of the Fleet Air Arm.[4] Shore-based

[1] A.H.B./ID/12/46, Operation "Avalanche," Plans.
[2] A.H.B./IIJ11/28, Bigot "Avalanche," Tactical Bomber Force, Encl. 6c.
[3] A.H.B./ID/12/46.
[4] *Ibid.* and A.H.B./IIJ5/8.

fighter aircraft in Sicily were to take off under the control of a Sector Operations Room/Filter Room in the Messina or Palermo areas and were to transfer to the Headquarters Ship control as soon as they came within R/T range. As a result of past observations, U.S.S. *Ancon* was to be fitted with P.P.I. radar, the receiver to be situated in a room next door to the Combined Operations and Filter Room in order that it might be used to the best possible advantage by the Controller, with a parallel P.P.I. tube placed for monitoring purposes in the Main Operations Room. Greater care was given to the training of operators and other staff selected for duty on board U.S.S. *Ancon* and H.M.S. *Hilary*, and discipline was considerably improved, as the success of the operation might well depend on the efficiency of the Air Force organisation in these ships.

The general control of night fighter aircraft was to be undertaken by the U.S.S. *Ancon*, but the aircraft were to be fed from the ship to the seaborne G.C.I. stations for the final stages of interception. The positioning of the L.S.T.s carrying the G.C.I. stations would have to be decided in the light of conditions existing during the operation. By day it was suggested that these ship-borne units might also be used for providing low cover—working as C.O.L. stations.

Provision of Radar Units ashore

It was important that full provision should be made for the operation of fighter aircraft as soon as they could be based on the mainland. It was therefore necessary to land Signals Units on D-day to provide radar cover, ground-to-air communications for the control of day and night fighter aircraft, and communications to the Sector Operations Room/Filter Room in Sicily and the Rear Headquarters of the XII Air Support Command.

British radar units, marshalled in Sicily and North Africa for the impending operation, were drawn from the Desert Air Force and North African Tactical Air Force (N.A.T.A.F.). For the purpose of Operation " Avalanche " they were to be attached to the American XII Air Support Command. The initial radar cover was to include one G.C.I. station, one C.O.L. station and probably up to six Light Warning Sets, augmented by a Wireless Observer Unit for ground observation, and a small intelligence section.[1] As soon as the G.C.I. station could be established ashore, it was to take over from the seaborne G.C.I. station ; but as a result of the difficulty of pre-selecting a good G.C.I. site in Salerno Bay it was thought that it might be advisable to continue the latter stages of control of night fighter aircraft from the seaborne G.C.I. equipment for several days. With this in view it was essential that these L.S.T.s fitted with G.C.I. stations, having landed their load of non-technical vehicles, should be anchored according to the best position for aircraft control each evening, at the request of the Air Controller—so long as his requirements were consistent with the safety of the ship and the general naval situation.

Following the promising performance of the G.C.I. stations erected in L.S.T.s which had taken part in the invasion of Sicily, it was considered that the experience they had thus gained should be put to use in the current operation. Unfortunately the two most efficient radar units had been unloaded and set up ashore in Sicily in the early stages of Operation " Husky " and lack of time precluded their removal from the radar network for inclusion in Operation

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[1] A.H.B./IIJ11/30, Encl. 2B, "Avalanche " Policy, Org. I.

" Avalanche." A completely untried unit, A.M.E.S. No. 8015, was obtained from the Middle East, where there were no ship-trained radar crews available, and experienced controllers were posted for duty with it from the formerly seaborne G.C.I. stations now land-based in Sicily.[1] Once again shortage of time prevented these officers from reaching their destination, and the unit had to go into action carrying men and equipment which had hitherto had no experience in this type of operating. The second sea-going G.C.I. station was to be A.M.E.S. No. 15076, which had featured rather unsuccessfully off the shores of Sicily.[2]

Operation " Husky " had shown the need for some means whereby the Controller on a seaborne G.C.I. station could visit the Headquarters Ship and radar units ashore. The Navy, however, were unwilling to lower one of their ship's boats because of the possibility of it being lost. It was therefore suggested that each seaborne G.C.I. station should carry an amphibious Jeep to be at the disposal of the Controller, and the Naval Planning Staff concurred with this proposal.

Fighter Control Ashore

The advanced Sector Operations Room Unit of the American XII Support Command was to be set up on shore on D-day. The signals activities of this unit included the reception of plots by W/T from the radar stations and the wireless unit, and it had to provide communications to the Sector Operations Room/Filter Room in Sicily, communications for fighter control, and communications to the Rear Headquarters of the XII Air Support Command.[3] Having established these, the unit was then to take over fighter control and other Air Force communications from the Headquarters Ship U.S.S. *Ancon*.

There was the possibility that a successful assault might be followed by a very rapid advance by the Army. In that event, forward fighter controls would have to be established for the reception of radar plots and fighter protection over the advanced ground forces. It was impossible for the advanced Sector Operation Room Unit to undertake this commitment since it had to remain in the coastal area for the defence of the ports and beaches until relieved by heavier units coming in through ports. It was therefore considered necessary to land two mobile fighter control units of the American XII Air Support Command with the first follow-up convoy ready to move forward with an immediate advance. Advanced Landing Ground Sections, carrying the usual signals equipment, were to provide airfield control facilities, a British unit for the British squadrons and American for the U.S.A. squadrons.

The radar cover ashore was to be augmented by the addition of two C.O.L./G.C.I. stations, also to land on D-day, to be sited in either capacity in accordance with the radar requirements obtaining in the assault phase. An M.R.U. was to be landed and set up in order to provide all-round high cover and height-finding, and further Light Warning Sets were to follow up to complete the radar build-up.

At one stage in the planning, an airborne operation was envisaged and six Type 6 L.W.S.s from the Middle East, A.M.E.S.s Nos. 621–624, 630 and 631, were sent to Headquarters, N.A.A.F., to take part, but this operation was

[1] A.H.B./IIJ11/32, Encl. 36A, D.A.F. detailed planning for " Buttress."
[2] *See* Appendix No. 30 for brief history of a G.C.I. station on L.S.T. No. 305.
[3] A.H.B./I.D/12/46, Plans for Operation " Avalanche."

subsequently cancelled.[1] The total supply of British radar equipment for use with the American XII Air Support Command from the assault phase until D + 24 was therefore as follows :—[2]

D-day (9 September 1943) ..	Two C.G.I. stations mounted on L.S.T.s. Two C.O.L./G.C.I. stations to be landed. Four Light Warning Sets to be landed.
D + 3 (12 September 1943) ..	One C.O.L./G.C.I. station. Two Light Warning Sets.
D + 6 (15 September 1943) ..	One C.O.L./G.C.I. station. One M.R.U. Four Light Warning Sets.
D + 24 (3 October 1943) ..	One C.O.L. station.

One Mobile Signals Servicing Unit was to be sent in for maintenance and servicing of Signals and radar units not later than D + 6, 15 September 1943.

Provision of a Mobile Operations Room Unit (M.O.R.U.)

As soon as Naples or any other suitable port in the area was open, a Mobile Operations Room Unit was to be landed to take over the static defence of the region, thus allowing the American XII Air Support Command Sector Operations Room to be withdrawn and prepared to move forward for the control of offensive fighter aircraft over the tactical forward area.[3] The M.O.R.U. was to be drawn from Sicily if required and would be replaced by a permanent fighter control organisation provided by the North Africa Coastal Air Force (N.A.C.A.F.).

Ground Search Radar Planning Difficulties occasioned by the Need for Operational Flexibility

The landing in Salerno was to be the inauguration of a campaign which might possibly be a long and bitter struggle for the Allied forces throughout the length of Italy unless a collapse of the occupying Axis troops could be speedily accomplished. It was thus difficult to foresee, with any degree of accuracy, the extent to which ground search radar equipment would be needed in the ensuing months. In order to exploit a rapid move forward which would follow an initial success by the assault troops, it might be necessary to bring No. 211 Group and Headquarters, Desert Air Force, complete with their normal signals organisation, from Sicily, leaving the minimum requirements for the crossing of the Strait of Messina (Operation " Baytown ") should the latter be in progress at that time.[4] Headquarters, N.A.T.A.F., might also have to move to the Italian mainland from Sicily, together with its full signals facilities.

Operation " Baytown " and the Italian Surrender

It will be recalled that plans were envisaged also for another move to the Italian mainland by the short sea crossing of the Strait of Messina between Sicily and Italy. (Operation " Baytown.") In the event of this taking place more or less simultaneously with Operation "Avalanche," fighter control was to be exercised by No. 211 Group of the Desert Air Force, based in Sicily. Since radar cover could be given from Sicily, no Royal Air Force Mobile Radar

[1] A.H.B./IIE/106, " History of Radar in N.W.A.A.F."
[2] A.H.B./IIJ11/28, Bigot " Avalanche," Tactical Bomber Force.
[3] A.H.B./I.D/12/36, Plans for Operation " Avalanche."
[4] A H B./I.D/12/46, Plans for Operation " Avalanche."

Units were included in the assault phase of Operation " Baytown." For the build-up, No. 101 Mobile Air Reporting Unit[1] was not available. It will be recalled that its mobile equipment had been lost in the invasion of Sicily, and the replacements from the United Kingdom had not arrived by September 1943.[2] It was therefore decided to employ No. 1 Mobile Operations Room Unit with four L.W.S.s, two G.C.I. stations, and one M.R.U., reporting directly to it.[3] It was considered that this radar network would not be required until at least a week after operation " Baytown " was launched.

The Eighth Army launched its assault across the Strait of Messina on 3 September 1943 and quickly gained a firm foothold on the Italian mainland, under air cover operating from the Sicilian airfields. Only loose control of aircraft was employed ; ground targets were largely by eye and opportunity as the front line began to move forward. Ground search radar had only an indirect contribution to make to the success of this operation—it provided early warning cover over the base area of Sicily.

Before the action against the Italian mainland began, secret meetings and discussions had been held in Lisbon between representatives of General Eisenhower's Staff and General Castellano, an Italian emissary, since 15 August 1943.[4] As a result, the King of Italy and the Badoglio government (which had replaced Mussolini's dictatorship after his fall from power in July) decided to accept the terms of surrender laid down by the Allied Powers. The military terms were signed on 3 September 1943 and the surrender broadcast on 8 September, announcing the Italian government's decision to give all aid possible to the Allied forces. During this period the Germans were fighting delaying actions as Allied forces advanced from the " toe " of Italy.

Operation "Avalanche," the landing planned for the Bay of Salerno, designed to take the enemy forces in the flank and rear, was therefore launched. An intensive bombing programme was carried out to neutralise the enemy's defences and to try and drive the *Luftwaffe* northwards by heavily attacking the southern and central Italian airfields, thus facilitating the task of the landing forces.[5]

The Landings at Salerno—Operation "Avalanche "

The Headquarters Ship, U.S.S. *Ancon,* sailed from Algiers at 0700 hours on 6 September 1943, joining into one force with the convoys (which had embarked from Oran, Bizerta and Tripoli) north of Palermo on D — 1. As the assault craft made their way towards the target area they set a course slightly north of the direct route in order to try and achieve a similar strategical surprise to that previously effected by the landing parties in Sicily.

The proclamation of the Italian armistice was picked up by the radios of the convoys making their way northwards to Salerno and consequently instilled a false sense of lightheartedness into the majority of the assault troops. The senior officers who realised the gravity of the situation were able to warn their men that the landings would probably be grimly opposed by German troops embittered by the news of the surrender of their former ally. But many of the troops were scattered in small ships and had no one aboard to counter the pervading holiday spirit.

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[1] No. 101 M.A.R.U. never became mobile again. Although its radio vehicles reached Brindisi in Italy on 26 September 1943, the unit was disbanded and absorbed into No. 211 Group as part of " Z " Sector for the defence of Sicily on 7 October 1943.

[2] Details of this loss are given in Chapter 20 of this volume and in No. 1 M.A.R.U., O.R.B., September 1943. [3] No 1 M.O.R.U., O.R.B. [4] Air Ministry File C.32152/46. [5] *Ibid.*

The convoys had sailed under the radar cover of the North African coastal Chain and then that of the Radar Units based on Sicily. During the approach of the assault troops, day and night fighter cover was provided by aircraft of North Africa Coastal Air Force (N.A.C.A.F.), controlled initially by N.A.C.A.F. Operations based in Sicily.[1] Before the convoys came together, one of them had been attacked by enemy aircraft as early as D — 2, 7 September. During the late afternoon and evening of D — 1 on their way to the anchorage, the ships were shadowed and attacked several times and again later in heavy strength on that and following nights. Wireless silence was broken to allow U.S.S. *Ancon* to take over control of night fighter aircraft, using the P.P.I. Radar with which she was fitted, and three enemy aircraft were brought down with two probables.

On board the ship there were two Operations Rooms, a Fighter Operations Room which housed the Operations and Filter Board in one room, and a Main Operations Room for the Directing Staff. The former was small and consequently suffered continual overcrowding by individuals seeking information on the air battle directly from the Controller instead of finding out for themselves from the duplicate board in the Main Operations Room.

The assault took place in Salerno Bay at 0300 hours on the 9 September 1943. The landings were made from two convoys, one anchored off Salerno in the north of the Bay and the other in the south near the mouth of the River Sele.[2] Wireless silence was broken on all channels and U.S.S. *Ancon* (in the southern convoy) resumed her full functions as the main Fighter Directing Ship and Advanced Headquarters of the XII Air Support Command. H.M.S. *Hilary*, the flagship of the northern convoy, acted as standby ship to the American vessel. Although this was her primary role, the Air Section aboard was much more usefully employed and over a longer period than during Operation " Husky.[3] Moreover, and mainly as a result of experience gained during the latter, the Section functioned with a markedly greater degree of efficiency, and personnel on the whole worked well.

During the preliminary stages the enemy concentrated his main effort against the anchorage, employing by day low-flying attacks by fighter-bomber aircraft, synchronised with precision bombing by *D.O. 217* aircraft using radio-controlled bombs, and precision bombing at night with the aid of flares. Radar information of these raids for the filter table aboard U.S.S. *Ancon* was obtained from the ship's radar, from other ships fitted with radar, and from the seaborne G.C.I. stations. Of these sources the first was by far the most fruitful. Liaison with Sicily was a noticeable failure. No track broadcast was received from No. 1 Mobile Operations Room Unit and nothing was heard of the M.O.R.U. on the inter-Fighter Direction Operations H.F. R/T, although it was considered that perhaps the range in this case was excessive for the operation of H.F. R/T. Standing aircraft patrols were maintained according to the pre-arranged programme and they functioned quite satisfactorily, but it was not safe to assume that things would always go well with the main Fighter Directing Ship cut off entirely from a Base Operations Room.

Of the two seaborne G.C.I. stations employed, one was damaged beyond repair by enemy shell-fire while unloading on the beach on D-day, and was returned to Bizerta. The second unit, A.M.E.S. No. 15076 aboard L.S.T.

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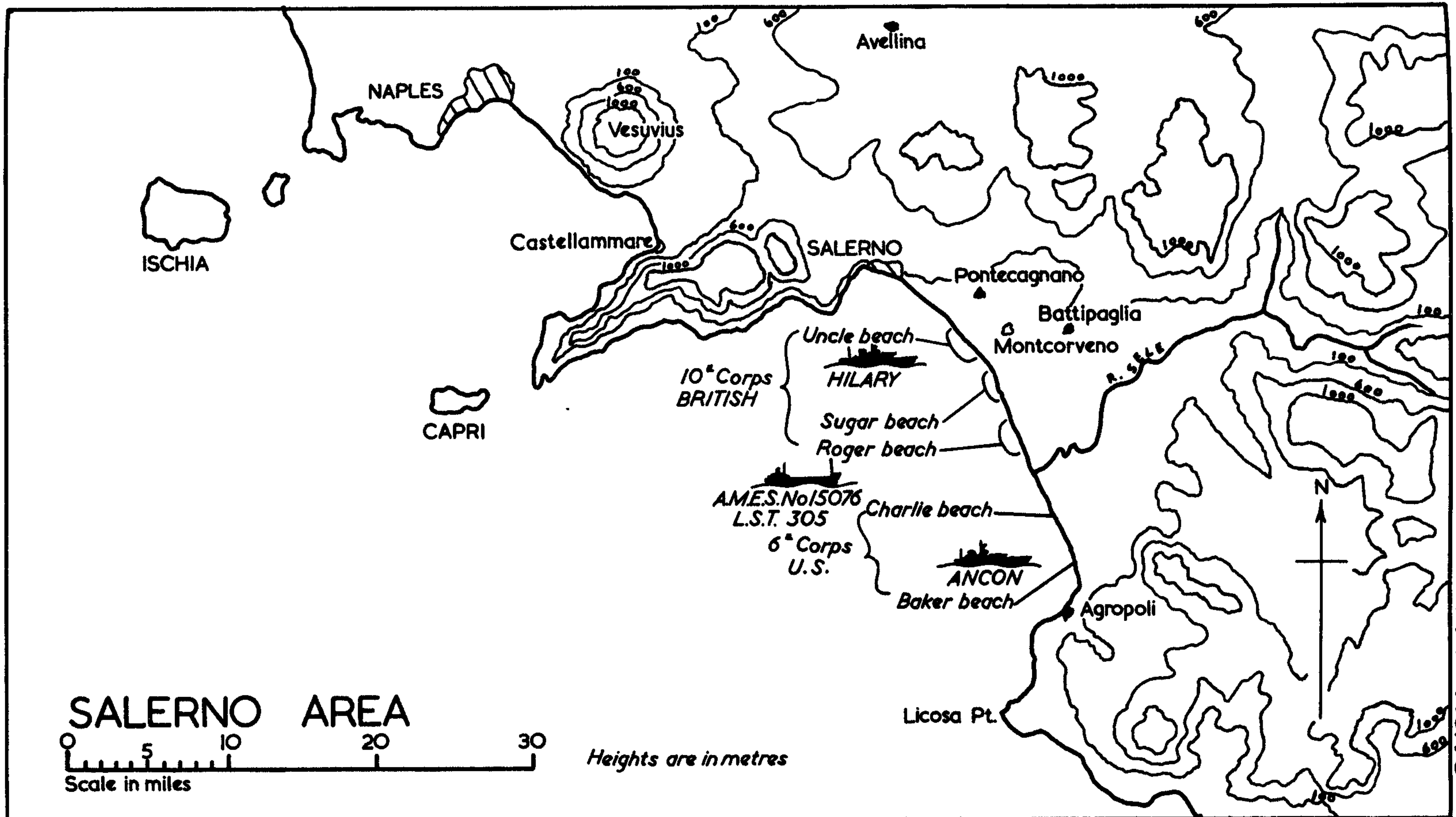
[1] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean.
[2] *See* Map No. 10 for details of landing beaches.
[3] A.H.B./IIJ11/9, Report on H.M.S. *Hilary* in Operation " Avalanche."



NAPLES
Avellina
Vesuvius
ISCHIA
Castellammare
SALERNO
Pontecagnano
Battipaglia
Montcorveno
R. SELE
Uncle beach
10th Corps
BRITISH
HILARY
Sugar beach
Roger beach
A.M.E.S. No 15076
L.S.T. 305
Charlie beach
6th Corps
U.S.
ANCON
Baker beach
Agropoli
CAPRI
Licosa Pt.
N
SALERNO AREA
0 5 10 20 30
Scale in miles
Heights are in metres
100
600
1000

MAP No. 10.

No. 305, made an effort to improve the poor radar facilities brought about by the permanent echoes from the surrounding land masses. A satisfactory agreement had been reached with the Navy that, consistent with the requirements of navigation and the safety of the ship, the seaborne G.C.I. stations would be sailed and sited according to the wishes of the Controller. The arrangement worked admirably and there were no difficulties in the siting and movement of this remaining C.G.I. station.[1] It sailed well out from the shore every night, reducing to a considerable degree the obstructing permanent echoes.

Unfortunately there was a last-minute change of the operational frequency allotted to A.M.E.S. No. 15076 from 6,520 kilocycles per second (54·35 metres) to 6,240 kilocycles per second (57·25 metres), the latter frequency having already been allotted to a landing G.C.I. Unit, A.M.E.S. No. 887.[2] Neither U.S.S. *Ancon* nor H.M.S. *Hilary* were advised of the change, and the standby main transmitter in L.S.T. No. 305 was out of action so the G.C.I. station could not be called on the agreed World Guard R/T channel. Consequently the ships had no knowledge that the unit was operating until D + 2, 11 September 1943. In the planning stage it had been proposed that the seaborne G.C.I. stations should be used during the day for C.O.L. work. This proved to be impossible because of the lack of sufficient personnel to work a 24-hour watch system. Arrangements had been made to attach additional operators to the units for this purpose but they had not reached the port of embarkation in time.

The inadequate radar cover was counter-balanced to some extent by the wealth of information obtained by the Intelligence Sections on each Fighter Directing Ship, and, despite the fact that there was a lack of radar plots by the ships, there was no shortage of air raid warnings. This was particularly noticeable in the southern anchorage where there was no central authority for the issue of alarms, and where in some cases the ships were at a state of alert for eighteen hours out of the twenty-four.[3]

Ground Search Radar Units based on the Italian Mainland at Salerno

Two C.O.L./G.C.I. stations were disembarked as planned, on D-day, 9 September, the units sailing in their entirety and travelling with their vehicles.[4] A.M.E.S. No. 887 had been briefed for a landing on the South Beach but through misrouteing of certain craft, all XII Air Support Command Signals vehicles and their crews were instructed to go ashore with the Northern Assault.[5] At 1900 hours A.M.E.S. No. 887 had just beached one vehicle when a sharp air raid occurred and the crew were confined to their L.S.T., finally making shore some distance further north at 2245 hours. It had been intended that the radar convoy should proceed immediately to a site one and a half miles inland but the Allied initial advance had not fulfilled expectations and the enemy were still within a mile of the site. The convoy was halted close to an A.A. battery where it spent a noisy and tense night. An enemy counter-attack developed on a nearby airfield and it was thought at one point that A.M.E.S. No. 887 would have to go back on its tracks.

The unit remained, however, and the following morning, by 0900 hours, sufficient progress had been made by the forward troops to enable it to proceed to its site. The equipment was set up under anything but ideal conditions,

[1] No. 15076 A.M.E.S., O.R.B.
[2] A.H.B./IIJ11/9, Report on H.M.S. *Hilary* on Operation " Avalanche."
[3] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean.
[4] It will be recalled that great hardship had been caused by the splitting of G.C.I. crews nto " A " and " B " parties during Operation " Husky."
[5] No. 887 A.M.E.S., O.R.B.

with surrounding artillery putting up a continuous barrage, and the enemy making their contribution with spasmodic air raids. Anti-personnel shells dropped within a few yards of the aerial during the course of erection, but no material damage was caused. At 1800 hours the station went on the air, plotting to the Gun Operations Room and, theoretically, to the 64th Fighter Wing, although communications were intermittent with the latter. A further result of the change of R/T frequency allotted to A.M.E.S. No. 15076 became apparent when A.M.E.S. No. 887 went on the air; it was found that both G.C.I. stations were attempting to control aircraft on the same channel, an impossible state of affairs which resulted in A.M.E.S. No. 887 virtually having to close down for the night. The following evening, 11 September 1943, A.M.E.S. No. 887 took over the frequency originally allotted to A.M.E.S. 15076 and an enemy aircraft was destroyed by a British night fighter aircraft under its control, despite the fact that the radar aerial turning gear had become unserviceable and the crew had to push the framework round by hand from outside the vehicle. During the early evening of 11 September 1943, the Gun Operations Room issued a warning that another enemy counter-attack was under way and the unit's domestic site was packed for a crash move. Nothing came of the alarm, however, and the unit settled down to do as good a job as possible under truly exacting conditions.

A.M.E.S. No. 871, the second G.C.I. station to land on D-day, 9 September 1943, spent a fairly uneventful night ashore, and, finding their site still in the hands of the enemy, made camp adjacent to A.M.E.S. No. 887, setting up their equipment for testing purposes. On the night of 11 September, the Commanding Officer of an Army Reconnaissance Unit brought word that the enemy had broken through a line held by the Royal Fusiliers and that A.M.E.S. No. 871 lay in the middle of the Army's holding line.[1] Rumours were rife, so in order to preserve the radar equipment, the unit left the encampment and reported to the Royal Air Force Assembly Area. Technical vehicles were taken down to the beach and the Beach Master called in an L.S.T. for their re-embarkation. However, the enemy was held and the immediate threat passed over. The G.C.I. transmitter and aerial trailer received superficial damage from shelling and bombs which dropped within 15–30 yards of them but the next morning the unit was set up on a temporary site at a nearby airfield and became operational with only two slight casualties among the personnel.

The airfield at Monte Corvino was secured by the Allied ground forces on D + 2, 11 September 1943, after a hard struggle, but it was not until a week later that it became outside the range of enemy shell-fire and could be used by Allied fighter aircraft.[2] Two landing strips had been prepared near the coast in case of such an eventuality and others were in the course of construction.

On the morning of D + 3, 12 September 1943 the control of fighter aircraft was handed over to the Headquarters, 64th Fighter Wing, U.S.A.A.F., ashore, all Air Force communications channels were closed down on the Headquarters Ship U.S.S. *Ancon*, and H.M.S. *Hilary* continued to act as standby fighter control. With sufficient fighter aircraft operating ashore, the aircraft carrier force was withdrawn. The same evening U.S.S. *Ancon* sailed for Algiers. The 64th Fighter Wing U.S.A.A.F., had landed complete with all low power signals equipment for the control of fighter aircraft, with the exception of a

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[1] No. 871 A.M.E.S., O.R.B.
[2] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean.

V.H.F. D/F fixer layout. Good communications to aircraft were maintained from the outset and there was no doubt that the policy of establishing a full fighter control organisation from the start without first putting in a nucleus system employing very low power equipment (as had been the case in Operation "Husky") was justified. The two G.C.I. stations landed on D-day plotted to the Operations Room of this Wing from temporary sites, but communications were somewhat intermittent as landlines continually became unserviceable through damage caused by shrapnel and bomb splinters, and W/T contact was poor.

A third G.C.I. station, A.M.E.S. No. 8035 and an M.R.U., A.M.E.S. No. 329, were disembarked on D + 4, 13 September 1943, at Salerno and as neither unit was able to proceed to its preselected site they bivouacked on the beaches, where they were subjected to severe enemy bombing and long-range shelling.[1] Four Light Warning Sets were also landed in the early stages of the operation and performed as satisfactorily as possible in the unfavourable circumstances. W/T contact was extremely difficult owing to the rising land masses, and, like the larger radar installations, the sets suffered from permanent echoes.[2] Douglas petrol electric generators were still the units' only means of power supply and caused inordinate delay and periods of inoperation, as they had done when first used in the invasion of North Africa.

The enemy made continuous use of low-flying attacks by fighter-bomber aircraft on the anchorages and beaches in the assault areas.[3] Because of relatively poor radar cover inland owing to the inability to carry out the planned deployment of radar stations, and the ready concealment effected by the mountains behind the Salerno plain, almost no early warning of these attacks was received. In nearly every case the enemy adopted the same tactics, approaching low over the hills or through the valleys, flying seawards to a suitable position and then attacking down sun. A fair number of casualties were inflicted on these sneak raids by Allied fighter aircraft but, without a comprehensive radar system to give adequate warning, most of the enemy aircraft were shot down after unloading their cargo of bombs.

To increase the radar cover in Salerno Bay in an attempt to counter these enemy tactics, A.M.E.S. No. 15051 was despatched to Capri, soon after the initial assault on the mainland, with the intention of its being used as a controlling C.O.L. station overlooking the Naples area, and plotting to an Advanced Fighter Control Section of the 64th Fighter Wing. Unfortunately it was quite impossible to find a suitable C.O.L. site on the island and the station had to be set up on a very indifferent G.C.I. site close by the harbour. Almost the entire cathode ray tube was blotted out by permanent echoes and, in addition, the V.H.F. R/T gave poor results because of the screening of the aerials by land formation.

On the mainland, the build-up of the radar network continued. Two more C.O.L./G.C.I. stations, A.M.E.S.s Nos. 8015 and 8043, were landed at Salerno by D + 7, 16 September, and on D + 11, 20 September, a C.O.L. station, A.M.E.S. No. 8020, from North Africa Coastal Air Force was brought in and sited temporarily at Battipaglia, 8 miles south of Salerno.[4] The radar network, planned for use with the Headquarters 64th Fighter Wing, was completed on D + 15 by the arrival of a second M.R.U., A.M.E.S. No. 332, and a C.O.L.

[1] No. 329, A.M.E.S., O.R.B.
[2] Nos. 6037 and 6038 A.M.E.S., O.R.B.s.
[3] A.H.B./IIJ5/8.
[4] No. 8020 A.M.E.S., O.R.B.

station, A.M.E.S. No. 886. The latter had spent a brief spell at Messina to give cover to the Eighth Army troops landing in Calabria and had been brought back to Milazzo in order to take part in the follow-up phase of Operation " Avalanche."[1] It had originally been planned that this unit should go in on D + 9, 18 September, but shipping delays ultimately prevented its transhipment until 24 September 1943.

The Allied advance was much slower than had been expected so that the beach-head became seriously congested during the first two weeks of the operation. Indeed, on D + 5, 14 September 1943, a serious threat to the landing forces had developed through an enemy thrust down the Sele River valley.[2] Only after heavy bombardment of the enemy's positions by the Allied Air Forces and warships was this critical menace to the bridgehead turned.

During this difficult time in the Salerno area, the Eighth Army, pushing up from the " foot " of Italy, were making excellent progress, under orders to link up with the bridgehead with all speed to relieve the enemy pressure on the Allied forces there. However, the military situation at Salerno had already turned in favour of the Allies before contact between the American Fifth Army in Salerno Sector and the British Eighth Army occurred on 16 September 1943.[3] This junction, together with the Allied air and naval bombardment of the enemy positions, set the seal to the success of the Salerno operations. The Allies then had an unbroken line running across the entire width of the Italian peninsula.

In the more stable circumstance resulting from the establishment of this Allied line, deployment of the radar networks along more stereotyped principles was possible. Before passing on to a consideration of the radar raid reporting and fighter control organisation set up, however, it is necessary to review the lessons learned, from the ground search radar point of view, of the operations at Salerno.

Lessons Learned in Operation "Avalanche" (as reported after the landing)

These should have been relatively fewer considering the experience gained in the Sicilian venture, but it was noticeable that many of the troubles which had occurred in the earlier operation were repeated, a fact attributable to the planning staff not receiving reports of lessons learned on Sicily until arrangements for the invasion of Italy were beyond alteration.

For an amphibious combined operation of this nature it was indisputable that the Air Force planning staff should work in close co-operation with its equivalent Army and Navy staffs. If, as in operation " Avalanche," in order to do this the Air Force planning staff had to be separated from the Executive staff, then it should have contained sufficient specialist officers to cover all aspects of the Signals plan.[4] During the latter stages of planning a radar officer from the controlling Headquarters should have been given full powers for making frequency allocations and similar work of detailed planning, and information should have been circulated with a wide distribution giving summaries of lessons learned as they occurred.

[1] No. 886 A.M.E.S., O.R.B.
[2] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean.
[3] Air Ministry File C.32152/46.
[4] A.H.B./IIJ5/8, Signals Report on amphibious operations in the Mediterranean.

Fighter Control Afloat and on Shore.—The handling of fighter control afloat during Operation "Avalanche" showed that little progress had been made in the two months since the invasion of Sicily, in fact lack of a sound communications system from the radar organisation to a base Sector Operations Room showed a reactionary tendency. By that time it had become increasingly apparent that the control of fighter aircraft should be exercised from a ship other than that used as a Headquarters Ship and much closer co-operation was needed between these ships, Fighter Direction Ships, and the seaborne G.C.I. units, in order to improve the exchange of radar information and thus ensure greater success of the entire controlling system.

The 64th Fighter Wing Control organisation set up ashore had shown that there was no longer any necessity to employ very low power equipment in the early stages of an amphibious operation, since the beach organisation was quite sufficient to deal with all vehicles carrying low power equipment. But this unit had been well within the range of the enemy's guns and, had the latter been able to bring concentrated fire to bear on such a target, the results might have been serious. Therefore, it was essential-that a reserve fighter control organisation should be landed at the earliest opportunity, since the whole operation might well depend on the fighter cover over the area concerned. Once again it was clear that a Wireless Observer Unit post, equipped with a V.H.F. R/T pack-set and a controller would have been invaluable as a supplementary form of forward visual fighter control to be established ashore for interception of low-flying enemy aircraft during the initial stage of the operation.[1]

Radar.—The seaborne G.C.I. unit had again shown itself to be an asset in this type of operation, but there was still room for improvement in its mode of use. Radar stations used as seaborne G.C.I.s should have been used for this purpose only and not landed as soon as they were no longer required at sea. Out of the three G.C.I. stations used in Operation "Husky," two were set up as land-based stations in Sicily and could not be withdrawn in time to be mounted with the convoys from North Africa. Thus a fresh unit with no previous experience had to be employed. Between similar operations, the seaborne G.C.I./L.S.T. combinations might have been employed in the protection of convoys.

With one of the two seaborne G.C.I. stations used in operation "Avalanche" put out of action on D-day, it became imperative that an L.S.T. containing such a unit should land its cargo on to the beaches at as late a date as possible, and certainly after there was no longer danger of the area coming under shell fire. The safety and functioning of the G.C.I. equipment should have been the prime consideration. In addition, an A.M.E.S. employed in a shipborne role should have had its crew augmented sufficiently to allow for normal reporting by day and G.C.I. work at night. This actually had been foreseen by the planners, but the extra personnel had not been transhipped from the Middle East in time. Ample spares for the technical equipment, too, were essential in the event of possible breakdowns in the shipping arrangements preventing planned spare parts from arriving.

[1] The report conflicts on the need for very low power fighter control in the first stages of the landing. Both are probably desirable, but availability of shipping space is also a weighty factor. If very low power is used, the fighter pilots must be prepared in advance to expect a weaker quality of radio speech and shorter range.

After certain A.M.E.S. stations had had considerable experience of combined operations, they should have been earmarked for future amphibious operations as they must have gained much valuable knowledge of this type of action, which should not have been wasted. They should have been replaced by other mobile radar units as soon as possible rather than left to assume a relatively static role in the radar network set up ashore.

It was recommended that authenticators, a type of code verification, should be used on radar reporting waves and with track broadcasts from the outset, otherwise the enemy was presented with a simple and effective means of spoofing the Allied fighter aircraft by giving false R/T transmissions on the same frequency.

In all other respects the radar organisation of operation " Avalanche " had differed very little from operation " Husky." Air Movement Liaison had still left much to be desired, Mark III I.F.F. had been practically non-effective throughout the operation, and there were still units which had embarked from North Africa with no clear or precise briefing instructions of the part they were expected to play. It was clear that for combined operations of this nature it was advisable to hold signals exercises carried out by each Fighter Directing Ship and Headquarters Ship, to establish good mutual liaison between them. The planning staff had neither the time nor the facilities to lay on such an exercise ; this function therefore should have been performed by an executive staff, and as many full-dress rehearsals as possible carried out before the appointed D-day.

Deployment of Radar Units in Italy, September 1943

Consequent upon the establishment of an Allied line across Italy south of the Volturno River, there were two main operational controls functioning in the tactical areas, namely :—

(*a*) The U.S. 64th Fighter Wing Operations Centre and associated Radar Units[1] in its network. These had landed at Salerno and the units were deployed covering the western flank of the front.

(*b*) The No. 1 Mobile Operations Room Unit and its radar network.[2] These units had crossed from Sicily to the southern " foot " of Italy and followed up the rapid advance of the Eighth Army. Initially they moved up the west coast until the more advanced Salerno sector radar units gave forward raid reporting cover. Then No. 1 M.O.R.U. and its radar network moved north-eastwards finding itself at one time ahead of the British Eighth Army. As the Allied line across Italy was established, No. 1 M.O.R.U., operating under the Desert Air Force, took over the eastern flank of the Allied front on the Adriatic sector.[3]

The central portion of the front was on the mountains, giving a complete cleavage in the radar cover between the two sectors of Salerno and the Adriatic. From the radar point of view the territory could hardly have been more difficult. The mountainous and hilly nature of the terrain, serrated by many river valleys running from the central mountain range down to the sea, called for more radar units to be deployed than would normally have been utilised

[1] Appendix No. 32 gives details of the Royal Air Force Radar Units in the Salerno sector.
[2] Appendix No. 32 summarises the Radar Units which had crossed from Sicily by the Messina–Calabria routes.
[3] No. 1 M.O.R.U., O.R.B.

on a military front of this length. The results obtained by individual units were often particularly uninspiring, though this was no fault of the personnel; ideally suitable sites were rarely available and permanent echoes from the many hills cluttered up the cathode ray tubes.

In the Salerno sector, the enemy employed delaying tactics. All bridges were blown up in the path of the Allied advance and all possible obstacles were used to prevent any rapid progress of the Allied forces. On 29 September 1943, Castellmare, one of the gateways to Naples, fell to the Allies, and by 1 October Naples itself was in the hands of the Allies. This port, one of the finest in the Mediterranean, was given radar cover initially by the tactical Radar Units with the 64th Fighter Wing.

When it became apparent that the Allied landings at Salerno would be maintained and that their push towards the north could not be prevented, the Germans realised the danger of their forces remaining on the islands of Corsica and Sardinia.[1] The latter was too inadequately garrisoned to resist any landing in force and the enemy therefore began an evacuation of his troops through Corsica on 11 September 1943. A week later two British M.T.B.s entered the harbour of Cagliari and the Italian population surrendered. What had featured under the heading of a major operation two months earlier had been accomplished without a shot fired by the Allies.

Although deciding to evacuate Corsica also, the Germans put up staunch resistance as they withdrew their men and equipment, following the landing of a small French force on 14 September 1943, and it was not until 4 October 1943 that the final capture of Corsica was accomplished. With both islands ready for occupation by the Allies, radar sites were available to extend raid reporting cover over practically the whole of the north-western Mediterranean. In addition, the airfields on the islands could be used by Allied aircraft as bases for bomber and coastal reconnaissance aircraft. At this point it became necessary to clarify the responsibilities of the various air force elements concerned in the provision of radar cover in the Mediterranean theatre.

Segregation of Tactical Radar Units from Base Defence Radar

During operations in Sicily it had become most apparent that the Tactical Air Forces required that their radar units should be employed solely for the specific purpose of raid reporting and control in forward areas in support of the ground forces. The other responsibility of the day and night defence of the base areas and ports should have fallen to the lot of a separate organisation. In October 1943 this policy was implemented in Italy. Base Defence Sectors were formed for Taranto, Naples, Foggia, Corsica and Sardinia, and the defence of these areas, including the operation and control of night fighter aircraft, was made the responsibility of the North Africa Coastal Air Force.[2] A division was made of the areas to be defended by British and American Air Forces. The North African Coast, Malta, Sicily and the " toe " of Italy and two sectors in the east of Italy, Taranto and Foggia, were to be the responsibility of the Royal Air Force. The west of Italy, Corsica and Sardinia were to be covered by the U.S.A.A.F. Fighter Wings.

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[1] Air Ministry File C.32152/46.
[2] A.H.B./IIE/106, " History of Radar in N.W.A.A.F."

British Radar Units continued to operate with the American forces. In order to provide the large number of Radar Units[1] required in these new territories, units were moved out of theatres from which the war had receded. In North-West Africa the policy of an American radar follow-up in the static regions was still pursued, but sufficient British C.O.L./C.G.I. stations and M.R.U.s were retained to provide cover against the fairly heavy enemy attacks on the ports and convoys in that area. In Sicily, the section which had been afforded radar cover by the North Africa Coastal Air Force (N.A.C.A.F.) was taken over by an American Air Defence Wing.[2] Units were also withdrawn from Pantelleria and Lampedusa to be added to the pool of mobile Radar Units available for re-deployment in Italy, Sardinia and Corsica.

Initial Provision of Radar Cover from Corsica and Sardinia

The first Radar Unit to disembark at Ajaccio, the main port of Corsica, was A.M.E.S. No. 8001, which landed on 23 September after a 50 hours' voyage from Algiers.[3] Close liaison was established with the French, and the unit became operational on a French coastal gun-site at La Prarata on 26 September 1943. Four days later, five out of a total of eleven German aircraft were shot down by a French squadron, controlled from the Radar Unit. The remaining enemy aircraft carried out a bombing attack on the French destroyer *La Fortune*, and the British L.S.T. 79. The latter lay in Ajaccio harbour while unloading the equipment of a second Radar Unit, A.M.E.S. No. 8003. The vessel received a direct hit amidships from a glider bomb, caught fire, and was soon a total loss. Two airmen were found to be missing and six airmen and an officer were wounded.[4] Two airmen from A.M.E.S. No. 8001, who had been assisting in the unloading, were killed, and two more reported missing. The entire barrack equipment and the crew's personal kit belonging to A.M.E.S. No. 8003 were lost, and on assembling the technical gear it was found that various vital parts had been destroyed. By improvisation and local purchase, however, the unit were able to become operational as a C.O.L. station on 20 October 1943 at Calvi, plotting to the Ajaccio Sector, 150 miles away.

Consequent upon the decision to use Sardinian airfields for Allied aircraft, two Light Warning Sets, A.M.E.S.s Nos. 622 and 631, were transported by air to the island in September 1943, for early warning radar cover near Decimomannu airfield.[5] When a G.C.I. and a C.O.L. station, A.M.E.S.s Nos. 898 and 880, arrived at Cagliari on 27 October 1943, they found that complete chaos and disorganisation awaited them. There was no embarkation officer, and no one who had any knowledge of the units or who knew for what purpose they had been sent to Sardinia.[6] No British personnel could be found, and the American authorities had no instructions for them. After three days of inactivity during which time both French and American Army Commanders tried to persuade them to join alternatively an A.A. Battery and an American fighter squadron, orders were received from Headquarters, North Africa Coastal Air Forces, for the units to proceed to tentative sites in the north of the island. As there was neither an Operations Room nor a Filter Room working in that area at that time, they were informed that there was no immediate urgency

[1] The Radar Units in North Africa Coastal Air Force Base Defence in the Italian theatre are given in Appendix No. 34.

[2] A.H.B./IIJ1/99, "Mare Nostrum," a review of M.A.C.A.F. Operations, March 1943–September 1944.

[3] No. 8001 A.M.E.S., O.R.B.

[4] No. 8003 A.M.E.S., O.R.B.

[5] A.H.B./IIE/106, "History of Radar in N.W.A.A.F."

[6] No. 898 A.M.E.S., O.R.B.

for their move. A.M.E.S. No 898 eventually became operational as a G.C.I., station at Alghero on 21 November 1943, and A.M.E.S. No. 880 as a C.O.L. station on Maddelena Island, a day later, plotting to the Operations Room of the 63rd Fighter Wing (U.S.A.A.F.).

This extension of the forward Allied radar organisation over the North-Western Mediterranean, coupled with the laying of a sound foundation for a radar chain of Base Defence Sectors, capable of giving continuous cover from the lowest levels to 35,000 feet in the rear areas in Italy, gave rise to not a little anxiety in the enemy camp. He consequently resorted to any methods which might effectively detract from the efficiency of the radar equipment. The first of these was the use of " Window."

Introduction of " Window " by the Enemy in the Mediterranean Theatre

The night of the 6/7 September 1943 saw the first " Window "[1] raid by the enemy in the Mediterranean theatre, and from then onwards he used it in most of his attacks against land targets so that successful control of Allied night fighter aircraft from C.O.L./G.C.I. stations became increasingly difficult.[2] In the base areas such as Sicily and North Africa, experiments were initiated and proved successful, of using information from Mobile Radio Units and Army G.L. sets as a palliative to the enemy's jamming measures. These equipments were practically unaffected by the type of " Window " dropped, owing to their different frequency. In the battle areas, where both fighter control and early warning were carried out by the 200 megacycles per second frequency band (1·5 metres) type of radar such as C.O.L./G.C.I. and Light Warning Sets, operations were very badly affected. At first interceptions were made quite impossible, as the controller could not select the fighter aircraft from the mass of *Duppel* on the cathode ray tube, but as the raids continued Controllers and Radar Operators became more adept in ignoring the spurious radar echoes.[3]

For the moment the enemy had found a means of causing maximum obstruction to the Allied forward Radar Units and it was not until several months later that an antidote was devised for overcoming the nuisance value of these raids. Meanwhile the enemy turned to a change in air tactics as a further means of defeating the object of the Allied ground search radar.

Introduction of a High-Powered Centimetric Radar in the Mediterranean Theatre

Following the initiation of his *Duppel* campaign, the enemy began in earnest an offensive against Allied supply routes by attacks against shipping off the coast of North Africa. His strike force consisted of several formations of torpedo bombers and glider bomber aircraft, flying very low in their approach.[4] In order to increase radar cover against these low-flying attacks, a request was made to Air Ministry in October 1943 for a number of Type 14 high-powered centimetre sets to be sent out to Headquarters, North African Air Force, from the United Kingdom. In the meantime the two Naval Type 277 sets in Malta, technically similar to the Royal Air Force Type 14, were established as A.M.E.S. Nos. 14027 and 14028 and were drafted to No. 242 Group for use in Italy. A promise of six more sets to arrive before the end of 1943 was made by Air Ministry.

[1] Called by the Germans " *Duppel.*"
[2] A.H.B./IIJ1/99, " *Mare Nostrum.*"
[3] Nos. 873, 887, 8035 A.M.E.S., O.R.B.s.
[4] A.H.B./IIJ1/99, " *Mare Nostrum.*"

In order to man the new equipment it was necessary for many of the obsolete types of units such as the earlier non-prototype Light Warning Sets, and the older C.O.L. stations (without Plan Position Indicators) to be reduced to a number basis only and their personnel sent to a Radar Conversion School for training on the newer apparatus.[1] Among those equipments relegated to the "scrapheap" were C.O.L. Stations Nos. 510 and 522, the original pioneer units employed on day fighter control in the forward areas in the Western Desert campaign.

Formation of the Mediterranean Allied Air Force

Early in November 1943 a plan was formulated to unify the command of the entire Mediterranean, adding Greece, Albania, Yugoslavia, Rumania, Hungary, Crete, the Aegean Islands and Turkey to the responsibilities of the Supreme Commander of the Allied Force, Mediterranean Theatre.[2] At the same time it was recommended by Air Chief Marshal Tedder that the Mediterranean Air Command and North West African Air Forces should be amalgamated and renamed the Mediterranean Allied Air Forces. The change took effect from 10 December 1943 and the appellation of the subordinate commands of the Coastal and Tactical Air Forces was amended accordingly.

There was very little change in responsibility of the two Commands; the Mediterranean Allied Coastal Air Force (M.A.C.A.F.) included a Royal Air Force section consisting of No. 210 Group, No. 242 Group, and Air Headquarters, Malta. It also contained the American XII Fighter Command with its 62nd and 63rd Fighter Wings, and controlled all Air Force ground radar in Africa from the Spanish Moroccan-Algerian border to Misurata, Tripolitania, and in Malta, Sicily, Sardinia, Corsica and the static areas of Italy.[3] The Mediterranean Allied Tactical Air Force (M.A.T.A.F.) included the Royal Air Force Desert Air Force and the American XII Air Support Command. It controlled all Air Force ground radar within 50 miles of the battle line, and provided radar for close support of the ground forces and for combined operations. Direct cooperation was maintained between M.A.T.A.F. and M.A.C.A.F. to ensure that no gaps in radar coverage were left as the main forces advanced.

Plans for Ground Search Radar during the Landings at Anzio (Operation "Shingle")

In order to speed up the progress of the Allied ground forces advancing slowly northwards in Italy, it was decided to attack the enemy in the flank and threaten his lines of communication. To effect this, another amphibious operation was planned in which elements of the American Fifth Army would make a landing in the Nettuno-Anzio area, 60 miles behind the German lines, with the object of seizing the high ground of Colli Laziati, south of Rome, thus facilitating the advance of the main Fifth Army forces and the ultimate capture of Rome.[4] This operation was to be known by the code-name "Shingle," and D-day was scheduled as 21 January 1944.

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[1] A.H.B./IIE/106, " History of Radar in N.W.A.A.F."
[2] Air Ministry File C.32152/46.
[3] A.H.B./IIE/106, " History of Radar in N.W.A.A.F."
[4] A.H.B./IIJ11/49, Operation " Shingle," N.A.T.A.F. Operational Instruction, 19 January 1944.

During this period, Mediterranean Allied Coastal Air Force was to be responsible for fighter protection, by both day and night, of the Salerno/Naples area and the shipping convoy lane within range of shore-based radar. General control of fighter and fighter-bomber aircraft over the assault areas and " Shingle " convoys was to be exercised by the American XII Air Support Command, through the 64th Fighter Wing.

Until the Forward Fighter Control was established ashore, fighter aircraft in the assault area were to be controlled during the day by H.M.S. *Ulster Queen,* or by either of the standby British Fighter Direction Ships, H.M.S. *Palamaris* and H.M.S. *Bulolo.* Night fighter aircraft were to report to one of these control ships by V.H.F. R/T on arrival in the landing area and were then to be handed over to one of two British seaborne G.C.I. stations, A.M.E.S. No. 15076 aboard L.S.T. 305 or A.M.E.S. No. 871 aboard L.S.T. 430. The first of these was to be positioned on the western outskirts of the shipping, controlling Mark VIII A.I. equipped fighter aircraft; the second to be in a position on the north-eastern outskirts of the shipping, controlling Mark IV A.I. equipped night fighter aircraft. Fighter aircraft fitted with Mark VIII A.I. were not to fly within 10 miles of enemy-occupied territory in order to safeguard their radar equipment against possible capture by the enemy.

A Forward Fighter Control of the 64th Fighter Wing was to go ashore on 21 January 1944 with a radar network composed of a British G.C.I. Unit, four American Light Warning Sets, and four ground Observation Posts. On approximately D + 5, 26 January, the radar equipment was to be augmented by two further Light Warning Sets and A.M.E.S. No. 871 from L.S.T. 430. Once the two shore-based G.C.I. stations were fully operational, the Forward Fighter Control was to take over full night fighter control and A.M.E.S. 15076/305 was to be withdrawn.

Ground Search Radar in the Anzio Landing (Operation " Shingle ")

The two seaborne G.C.I. stations were positioned as planned during the launching of Operation " Shingle " on the night of 21/22 January 1944, though heavy seas made operations extremely difficult.[1] Both units witnessed considerable air activity including the deliberate bombing of three fully-illuminated hospital ships by the enemy. A.M.E.S. No. 871 had no fighter aircraft available, so that controlled interception from it was not possible.

The four American Light Warning Sets and the British C.O.L./G.C.I. station, which were landed on D-day, 21 January 1944, suffered heavy bombardment while in convoy and A.M.E.S. No. 877 had great difficulty in getting its heavier vehicles ashore. This was a veteran Radar Unit which had taken part in the invasion of Sicily and was subsequently one of the first Radar Units to land at Salerno. Aircraft under its control had accounted for eight enemy aircraft in eight small raids in the first month of operation, while under fire at Salerno. After that the unit had experienced a comparatively quiet spell. Early in January 1940 it was loaded on to an L.S.T. to take part in its third major amphibious operation. On previous assignments, A.M.E.S. No. 887 had had its equipment transported by L.C.T. and had run straight off on to the beach. For Operation " Shingle " the unit was loaded on an L.S.T. and had to be transferred to L.C.T.s for landing. Such a task became almost

[1] No. 887 A.M.E.S., O.R.B.

impossible in the high seas then running, with trailers to manhandle into position. The handicap of using trailers in such an expedition was again emphasised when the vehicle towing the Diesel trailer broke its main driving shaft in attempting to drag its double load up the stiff incline which led away from the beach. If it had not been for the timely assistance of an American detachment, the incident might have constituted a serious bottleneck on this hazardous beach.

The unit became operational the same day, 21 January 1944, and attained a high degree of success during the first seven days of operations, accounting for nine enemy aircraft shot down, and one damaged. These interceptions were performed with difficulty as interference from enemy " Window " practically blotted out all other activity on the cathode ray tube ; in addition, I.F.F. on night fighter aircraft was almost totally ineffective.

A.M.E.S. No. 871, operating from L.S.T. 430, was due to be discharged ashore on 26 January 1944, but breakers on the beaches prevented its landing until 0800 hours on 27 January 1944. With commendable speed it became operational five miles east of Nettuno at 1730 hours that day.[1]

Soon after the establishment of the Anzio bridgehead, lack of suitable C.O.L. sites in the area led to the need for centimetric radar equipment, as the latter was less dependent on high cliff sites for low cover. This need was particularly evident in a northerly direction in order to provide the earliest possible detection of enemy aircraft operating from Rome.[2] A.M.E.S. No. 14027 (Type 14) was therefore transferred to the Anzio area and sited on a high inland position. Permanent echoes prevented plotting up to 40 miles range so the unit was resited on ground which rose slightly to the north and west. This had the desired effect of cutting down permanent echoes by reducing low coverage in certain areas, a technique which had previously been employed in the positioning of Light Warning Sets. A.M.E.S. No. 14027 proved to be a most successful medium for plotting aircraft between the ranges of 20–60 miles, and incoming low-flying tracks were picked up 15 miles sooner than previously. Within 20 miles, permanent echoes were still present but this was considered inevitable.

Heavy rain was experienced for some time, thus making even the digging of slit trenches and shelters an impossibility. It was also out of the question to obtain sandbags for the protection of technical vehicles or personnel. With the enemy diverting his attention from North Africa and concentrating his air attacks on the Anzio beachhead and the main battle-line, the units came under constant enemy bombardment and spasmodic shelling.[3] Near misses by bombs and shells, however, seemed to have little visible affect on the radar equipment. Superficial damage was caused to the R/T aerial of A.M.E.S. No. 887 when it was blown down by blast, and landlines suffered heavily, the two operational lines of the unit together being unserviceable for a total of 340 hours during February 1944.

Nevertheless four " kills " were made by fighter aircraft operating under the control of the two G.C.I. units early in the month. After that a new technique was used by the attackers. Interference in the form of a particularly close type of " railings "[4] jamming accompanied the raids and effectively blotted

[1] No. 871 A.M.E.S., O.R.B. [2] Air Ministry File S.20034, Encl. 18A.
[3] No. 887 A.M.E.S., O.R.B.
[4] *See* Chapter 14 for details of this enemy radio counter-measure to jam Allied radar stations.

out the entire Plan Position Indicator in the G.C.I. equipment and the cathode ray tube of the Mark IV A.I. in the night fighter aircraft. Towards the latter part of February 1944 the enemy changed his tactics once again and sent his raiders in singly at a lower altitude than usual. This meant that they were not observed by the G.C.I. stations until practically over the target, whereupon they dived to drop their bombs and made off, flying low and thus escaping observation by the G.C.I. stations on their return flight. It was therefore decided that, if possible, controlling should be carried out from the Type 14 Station, A.M.E.S. No. 14027, in the bridgehead, and the necessary V.H.F. R/T equipment and technical personnel were sent out to the unit in February 1944. The method of control adopted was similar to normal G.C.I. working, the main difference being that the small scale P.P.I. and the slowness of sweep of the Type 14 made it difficult to carry out the early stages of interception if the enemy aircraft and night fighter aircraft were widely separated in azimuth.[1] This drawback was overcome by starting the interception on the plotting board and carrying out the final stages from the P.P.I. tube itself when the fighter aircraft and target were in close proximity.

In addition to his other tactics, the enemy aircraft were taking more than usually successful evasive action and British Beaufighter aircraft had difficulty in competing with their speed.[2] Contrary to the Signals plan it was not found practicable in view of the sustained enemy effort to withdraw the remaining seaborne G.C.I. station, A.M.E.S. No. 15076, from the assault area and on 20 February 1944 the L.S.T. was hit amidships by a torpedo and sunk. All the radar equipment was lost and eight of the radar personnel drowned. G.C.I. cover was still provided over the area by the two shore-based G.C.I. units and by A.M.E.S. No. 14027, but as a result of the continuous enemy air activity it was considered necessary to make arrangements to replace the seaborne G.C.I. station as soon as possible.

Despite the efforts on the part of the enemy to render the fighter defence ineffectual, and in spite of the normal hazards and dangers of a bridgehead area, fifty-seven contacts were made with hostile aircraft during February 1944, and letters of congratulation were received by the Radar Units from General Hawkins, commanding the 64th Fighter Wing (U.S.A.A.F.), complimenting them on their splendid performance under enemy fire.[3]

Centrimetric Radar Equipment in the Anzio Bridgehead in face of Enemy Radio Counter-measures

The landings at Anzio had been undertaken to outflank the enemy in the western sector of the Italian front. There, the Germans were holding tenaciously to their positions between Cassino and the Mediterranean—which formed part of their " Gustave Line " extending across the narrowest and most mountainous part of the Italian peninsula. The Anzio operations had caused the Germans to bring down more divisions from the north of Italy and their line held; no rapid link-up between the Allied main ground forces and those in the Anzio bridgehead could be achieved. Stalemate thus developed, and the ground search Radar Units were called upon to give comprehensive raid reporting and fighter control facilities in the Anzio bridgehead over a much longer period than had been anticipated.

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[1] Air Ministry File S.20034, Encl. 18A.
[2] A.H.B./IIE/107, " History of Ground Radar in M.A.A.F."
[3] No. 887 A.M.E.S., O.R.B.

Over a protracted period, stereotyped ground radar methods which had been successful in previous operations in Italy were found to be insufficient, owing to the peculiar nature of the bridgehead area.[1] A piece of land the size of Malta, screened on two sides, within artillery range of the enemy and with, by normal standards, few suitable radar sites, presented interesting problems. Although these difficulties had been met before in similar situations, the static nature of the bridgehead area made the radar problems more apparent than in a fast moving invasion.

Certain weaknesses in the use of the Type 14 for controlling night fighter aircraft were noted. These were—

(*a*) lack of height readings ;

(*b*) lack of full directional facilities in the I.F.F. interrogator and, by virtue of the station frequency, lack of " Canary " ;[2]

(*c*) overcrowding in the operations trailer.

In order to overcome the lack of height-reading and to provide coverage within the range 0–20 miles, it was decided to experiment with an American Type SCR 584 which had become available. The Type SCR 584 was originally designed for radar gun-laying. It was an extremely accurate centimetre equipment with a narrow beam and a fine range discrimination. Certain modifications were carried out which increased the maximum range of the set from 18 to 56 miles, the maximum range of the automatic tracking to 27 miles, and ensured a height accuracy to within 200 feet up to 18 miles and to within 1,000 feet beyond. Automatic tracking of an individual aircraft was excellent and tracks could be followed through balloon ships, other aircraft, and permanent echoes. The site at Anzio appeared to be particularly suitable for this type of equipment. Thus the SCR 584, when modified, provided a useful addition. It could be used as height finder for the Type 14 and for providing low cover with height-finding on C.O.L. and G.C.I. stations. Most important of all, in common with the Type 14, it remained unaffected by " railings " jamming and was not seriously affected by " Duppel," both of which the enemy used in profusion during his small-scale night harassing attacks on the bridgehead. The Type 14/SCR 584 combination was a distinct success and resulted in the destruction of several enemy aircraft.

Throughout the remainder of the winter and spring the stalemate at Anzio and the " Gustave Line " continued. The Allies had under-estimated the tenacity of the German forces to some degree, but an immediate secondary cause of the static nature of the war at that time was the weather ; a particularly glutinous quagmire surrounded the opposing forces making a war of movement impossible.

While Headquarters, M.A.A.F.'s attention had been focussed on the radar problems arising on the west coast of Italy, the east coast radar chain had not been idle. Allied bombing sorties on enemy shipping lying off Yugoslavia, first begun in October 1943, had been increased as it was found that these attacks had a great effect in stimulating the morale of the partisans as well as causing considerable material damage to the enemy.[3] The Germans, stung into retaliation, extended their aerial activity and made several raids on the Island of Vis in particular, and over the base areas behind the Eastern Sector.

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[1] Air Ministry File S.20092, Encl. 18A.

[2] For explanation of " Canary," *see* Volume V, Part 1, Chapter 3, on I.F.F.

[3] No. 1 M.O.R.U., O.R.B.

Extension of Eastern Sector Radar Cover between Italy and Yugoslavia

Siting of the network of mobile Radar Units of the No. 1 M.O.R.U. screen had not been easy. Generally, the stations had been sited to give maximum cover in a north-westerly direction; the area from which enemy aircraft normally approached when flying from Italian airfields.[1] The Allied west coast radar stations were therefore partially blind to aircraft flying from Yugoslavian bases. In view of the increased activity across the Adriatic sea, both friendly and hostile, it was decided to increase the radar cover initially by a Light Warning Set on the island of Vis, off the western coast of Yugoslavia. This was to give low cover of the channels between the island and the enemy-occupied islands of Solta, Hvar and Korcula, and to watch for invasion forces moving against Vis itself.

A site was pre-selected for A.M.E.S. No. 6008, by Headquarters, M.A.C.A.F., but on the unit's arrival, the position was found to be quite inaccessible. There was only one main road on the island, which led from the port of Komiza to the town of Vis. It was barely two metres wide with extremely sharp double bends throughout its length and a sheer drop on both sides. A few subsidiary roads, little more than mule tracks, led off into the hills and came to dead ends. A.M.E.S. No. 6008 was finally placed on a not very satisfactory site on high ground at Fort Velington, where it had a limited sweep due to permanent echoes.[2] The crew had to build a road before the radar vehicle could be brought up to the site and the station became operational on 5 March 1944, plotting to a Forward Fighter Control Unit. The latter was in communication with No. 323 Wing on the Italian mainland and A.A., Royal Navy, and partisan Headquarters based on the island.

The unit gave a very good performance, although hampered by permanent echoes from the surrounding hills, until April 1944, when it was damaged by enemy action and a replacement was sent out from Bari. Later, in June 1944, to counter yet further increased enemy operations across the Adriatic, an additional three Light Warning Sets, supplemented by G.L. equipment for height-finding, were placed on the island.[3]

Reorganisation of Radar Control after the break through the "Gustav" and "Hitler" Lines

In addition to immediate support to ground forces, as at the bombing of Cassino on 15 March 1944, the Mediterranean Allied Air Force carried out a nearly non-stop offensive during the spring against the enemy's supply lines, with the express intention of so weakening his resources that he would not be able to withstand the eventual Allied ground attack. From 24 March onwards, all "through" railway lines to Rome and the front were continuously cut. Simultaneously a complex programme of air attacks against ports, shipping, motor transport, and northern Italian railyards contributed to the attrition of German supplies.[4] Such intense aerial activity on the part of the Allies kept the radar units well-occupied in their forward locations, throughout the weary winter months of waiting.

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[1] No. 1 M.O.R.U., O.R.B., and A.H.B./IIJ1/99, "*Mare Nostrum.*"

[2] No. 6008 A.M.E.S., O.R.B., and A.H.B./IIJ1/116/89, Part II of No. 242 Group File "The Siting of R.D.F. Stations."

[3] A.H.B./IIE/107, "History of Ground Radar in M.A.A.F."

[4] AHB/IIJ1/99, "*Mare Nostrum.*"

On the night of 11/12 May 1944, Operation " Diadem " was put into effect. Its broad objective was to score a knockout blow against the Germans in Italy, simultaneously gaining the prestige of capturing Rome and preventing the withdrawal of German troops in Italy for use against the impending Allied operations in Normandy. After a period of very bitter fighting, the Allies finally broke through the German lines, and the renewal of Allied ground activity caused a stepping-up of enemy aerial reconnaissance and bombing sorties. These, in turn, called for increased radar early warning and fighter control facilities.[1] Very considerable moves of radar stations had to be made to fulfil the new commitments. Mobile Radar Units of M.A.T.A.F. advanced with great speed, and supplementary equipments from M.A.C.A.F. were brought up from Malta, Sicily, the " toe " of Italy and North Africa to play their part in the Allied air defence.

With the move of the British Eighth Army into the Central Sector of Italy some slight reorganisation of the radar control system was necessary as aircraft control facilities were required both in the Central and Eastern Sectors. As a result of the shortage of personnel these facilities had to be provided from within the Desert Air Force.[2] This was made possible by expanding No. 1 Forward Fighter Control Unit sufficiently to take over M.O.R.U. commitments in the Eastern Sector, the unit then becoming M.O.R.U. " B," while the parent unit in the Central Sector was called M.O.R.U. " A." Both kept a comprehensive radar network. This arrangement covered satisfactorily any particular static phase, but when the ground forces began to move forward in the successful operation " Diadem," there was no provision for tactical control during the moves of either M.O.R.U.

Experiments had previously been conducted to assess the value of a Master Control G.C.I., *i.e.*, a G.C.I. station which contained the necessary facilities to accept and display information on aerial activity from other A.M.E.S. stations and to act as a sub-filter room. It was also considered that it might be possible to expand the idea further and enable the unit to operate as a Forward Fighter Control Unit. In view of the immediate need for a Fighter Control Unit in both Central and Eastern Sectors for leap-frogging the M.O.R.U. controls and also the possible necessity for a third unit in the Western Sector when the enemy was pushed back in that area, it had been decided in May 1944, to modify A.M.E.S.s Nos. 15052, 8033 and later 886.

The first principle used in the modification was that the normal working of the unit as a C.O.L./G.C.I. station should not be affected.[3] No alterations therefore were made in G.C.I. Operations Room except for additional landlines. The Nunn engine was removed from the power compartment in the back of the I.F.F. vehicle and the space thus gained was used for a plotting table with four positions round it. The scale of the map was four miles to an inch and gave an excellent picture of the general radar situation within 100 miles of the station. A square aperture was cut in the sound-proof partition enabling the Controller to sit in the Plan Position Indicator compartment and yet have a good view of the table. Room was made for an Operations " B " position and full V.H.F. R/T facilities were provided. Curtaining was arranged so that normal lighting could be provided in the remainder of the vehicle. The " inquisitor " vehicle (*i.e.*, the modified I.F.F. vehicle) was used alongside the

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[1] A.H.B./IIE/107, History of Ground Radar in M.A.C.A.F.
[2] Air Ministry File S.20034, Encl. 27A.
[3] No. 15052 A.M.E.S., O.R.B.

G.C.I. operations tender with the doors opposite to one another. A light-proof extension linked the two compartments and the walls were used for display maps showing the bomb-line and other relevant information with subdued lighting.

The units lost none of their mobility and were able to perform the following functions singly or together :—[1]

(*a*) C.O.L./G.C.I. full-reporting channel.

(*b*) Master Control Station providing filtered tracks on A.M.E.S. and W.U. information.

(*c*) Forward Fighter Control Unit.

(*d*) M.O.R.U. " stand in " during its moves.

The siting of the units to fulfil these various roles presented some difficulties at first, but a satisfactory solution was attained by selecting the best possible G.C.I. site in the area of the advanced airfield, consistent with the provision of the landlines required by the Forward Fighter Control Unit function. Gaps in cover over the bomb-line or Visual Posts were filled by the siting of another G.C.I. station plotting into, and controlled by the G.C.I./F.F.C.U., and by Light Warning Sets in addition to a Type 14 Station.

Experience gained in action showed that these modified units fulfilled a very valuable function in mobile warfare. They also provided a further example of the tendency in modern warfare to work in ever closer contact with a source of radar information, and to dispense with the separate Filter/Operations organisation designed for static defence. They were a means of employing G.C.I. Controllers full time during a period when night activity was slight, and the system of presenting the general aircraft situation immediately adjacent to the G.C.I. Operations Room enabled the Controller to change at once from G.C.I. to Sector control or vice versa during the day. This overcame the time lag inherent in the handing of control from Sector to G.C.I.

The Radar Forward Fighter Director Units were employed throughout the remainder of the Italian campaign and were very successful in the loose control of fighter aircraft for tactical purposes in support of the ground forces. In poor visibility they were able to render useful navigational aid to fighter and fighter-bomber aircraft returning from operations.

Extension of Radar Cover in the North-Western Mediterranean as a prelude to Operations against the South of France

Towards the end of 1943, with the Italian campaign still in its early stages, it had been decided that an operation should be launched from the Mediterranean theatre against southern France. Preparatory actions prior to an invasion of the south of France, which were also activated to some extent by the air support requirements of current operations in Italy, involved a large-scale transfer of air forces to Corsica and Sardinia.[2] This entailed the building of fifteen airfields, the planning of corresponding landline and W/T communications, and the installation of radar on a large scale, both for defensive and offensive purposes.

As early as October 1943 it had been decided that a valuable contribution to offensive operations from Corsica could be undertaken by long-range radar control from the most northerly point of the island. It was therefore arranged to bring the Type 16 A.M.E.S. from Malta, where it had become surplus to operational requirements with the occupation of Sicily, and to re-instal it in

[1] Air Ministry File S.20034, Encl. 27A.

[2] A.H.B./IIJ1/90/34, Signals Report on Operation " Dragoon," H.Q., M.A.A.F.

northern Corsica.[1] In addition, an American Micro-wave Early Warning Set (M.E.W.) was shipped from the United States and was sited in a complementary position to the Type 16 in order to provide long-range control throughout an arc embracing the whole of the southern French coastline and also that of north-west Italy from the tip of Corsica. The M.E.W. was a comparatively new model of a multi-control centimetric plan position radar equipment.[2]

The Type 16 was erected in a position to cover the Ligurian and Tyrrhenian Seas. Building priority was low, and it was not until 24 March 1944 that the station became operational and then only in a reporting capacity, as no official guidance had been received as to the part it was to play in future air offensive operations. Eventually a directive was issued from M.A.C.A.F. on 7 July 1944, but by this time the Allied superiority in the air was so overwhelming that there was no occasion for a Fighter Director Station in the offensive role in this area. The function of the station therefore changed on 22 July 1944, and it assumed the responsibilities of a Fighter Sub-sector Control covering the Calvi area. The most important defensive commitment of this area was the interception of the enemy reconnaissance planes engaged in reporting and photographing the shipping movements and airfield activity.

In its first phase of operation as a Fighter Director, the Type 16 had no opportunity to prove its worth. As a Sub-sector Control, however, the unit was definitely fulfilling a need during its relatively short life from the 22 July to 8 September 1944. Better results could have been achieved, but the decision to convert the unwanted Fighter Direction Station into a Sub-Filter Sector Control came too late. By the time the station was fully reorganised and on a 24-hour watch system, it was only three days before the invasion of the south of France was scheduled to begin.

Headquarters, 63rd Fighter Wing (U.S.A.A.F.), left the responsibility of issuing an operational directive for the Calvi Type 16 Sub-sector to the Borgo Fighter Sector, but none was ever sent out. The Calvi Sub-Sector was apprehensive as to the limits it might go in assuming complete Sector responsibility in its area. Added to which its formation had not been looked upon favourably by other units concerned, and the whole system suffered from a lack of comprehensive co-operation.

During the spring and early summer of 1944 radar in Corsica was further augmented and by August 1944 a lavish total of thirty British and American stations were in operation on this one island.[3] Meanwhile there had been a small-scale operational diversion on 17 June 1944, with the capture of the island of Elba (Operation "Brassard"). Radar coverage for the invasion was provided mainly by equipment sited in Corsica. Two Light Warning Sets and two American Surface Watching Radar equipments had been included in the landing forces and a Type 11 Station had been located on the island of Pianosa, just south of Elba. As soon as Elba was occupied, only one Light Warning Set, A.M.E.S., No. 6038, was left on the island for advance radar warning, reporting by W/T to Corsica. The other radar equipments were withdrawn ready for employment in operations against the south of France.[4]

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[1] A.H.B./IIJ1/90/11A, Part I, Encl. 60A, A Short History of the A.M.E.S., Type 16, in Corsica.

[2] An account of the American M.E.W. equipment in Normandy is given in Chapter 24.

[3] A.H.B./IIJ1/99, "*Mare Nostrum,*" and A.H.B./IIJ1/90/45, Planning for Operation "Brassard" (C.-in-C., MEDME).

[4] A.H.B./IIE/107, History of Ground Radar in M.A.C.A.F.

General Radar Plans for the Diversionary Operation against the South of France

This operation was given the code name "Anvil," later changed to "Dragoon," and consisted of three alternative plans :—[1]

(a) an assault in the Toulon area, followed by either an overland or amphibious assault in the Sete area,

(b) a direct assault in the Sete area and

(c) an unopposed landing in the Toulon/Marseilles area.

At the beginning of December 1943, outline plans for Operation "Dragoon" were formulated. These were sufficiently advanced by February 1944 for more detailed examination by lower formations, and representatives from Mediterranean Allied Tactical Air Force (M.A.T.A.F.) and XII Tactical Air Command (T.A.C.) were attached to the Mediterranean Allied Air Force Planning Staff for working along more detailed lines until March 1944. The plans were then ready to be decentralised, and co-ordination with the other two Services was effected.

The operation was to cover an assault mounted from North Africa, Corsica, Sicily and Italy against Southern France, east of Toulon. The main objective was to be the capture of a suitable port in order to provide a base, and subsequently either an advance towards Lyons and Vichy or westward to the Atlantic coast, to be determined by military developments. The ultimate aim was to unite both northern and southern Allied forces in France for a combined attack upon Germany.

By the second week in June 1944, the target date for D-day was pronounced as 15 August 1944. The benefit of having completed preliminary planning and co-ordination at an early date was immediately apparent ; the final Outline Signals Plan, which included all radar provision, was finished by 23 June, leaving ample time for the detailed signals instruction to be issued on all finer points of the operation. Previous operations had shown the great need for an understanding between the Navy and Royal Air Force with regard to the positioning of seaborne Fighter Control Units. In order to establish these essentials on a firm basis, a seaborne Fighter Control Board was formed under the chairmanship of the Air Officer Commanding, M.A.C.A.F. in June 1944.[2] Representatives from Headquarters, M.A.A.F. Air and Signals Plans, from Headquarters M.A.C.A.F., M.A.T.A.F. and R.A.F., Middle East formed the members of the Board and in a similar manner as the Tactical Signals Planning Committee, performed a most useful function during planning, in that agreement on all important points of difference was reached between the Air Forces and Navies, which led to certain important modifications aboard the Headquarters and Fighter Direction Ships.

By the time the outline plan for Operation "Dragoon" was a thing of substance, D-day for Operation "Overlord," 6 June 1944, had passed, and Allied troops were already in France in the north. Consequently the planners in the south were able to benefit considerably from any errors made by the northern invaders, and in the case of radar, had the advantage of some of the latest equipment which had already undergone the most exacting tests.

Acting on previous experience gained in the Mediterranean theatre, and also on the recommendations of the seaborne Fighter Control Board, it was eventually agreed that separate Fighter Direction Ships should be used for the

[1] A.H.B./IIJ1/90/34, Signals Report on Operation "Dragoon," H.Q., M.A.A.F.

[2] *See* Appendix No. 33 for terms of reference for Seaborne Fighter Control Board.

control of fighter aircraft, and the Headquarters Ship should only carry out the specific role for which it was designed. There were two such vessels available in the area, H.M.S. *Ulster Queen*[1] and H.M.S. *Stuart Prince*, but on examination they were found to lack both space and amenities for complete Air Force Fighter Control. It was therefore suggested that a specially designed Fighter Direction Tender,[2] with full radar and communications facilities might be made available from Supreme Headquarters, Allied Expeditionary Force (S.H.A.E.F.). F.D.T. No. 13, which had helped the Normandy forces successfully, was obtained from Home waters. The following ships were finally allotted as Headquarters Ships and Fighter Direction Ships :—

U.S.S. *Catoctin*	Headquarters Ship—or could be used as 2nd Standby Fighter Direction Tender.
U.S.S. *Augusta*	1st Standby Headquarters Ship.
F.D.T. No. 13	Fighter Direction Ship.
H.M.S. *Stuart Prince* ..	1st Standby Fighter Direction Ship.

In the Mediterranean theatre G.C.I. stations aboard L.S.T.s had now become an accepted part of the radar plans for an operation such as "Dragoon." At first, three L.S.T.s were earmarked for fitting with G.C.I. equipment, but with the allocation of F.D.T. No. 13 it was decided that only two seaborne G.C.I. units would be required. M.A.T.A.F. was to be responsible for making arrangements with the Royal Navy for their provision, and, in view of the mountainous terrain in the vicinity of the assault area and the consequent trouble to be expected from permanent echoes, it was deemed wise to mount a centimetric radar set (Type 14, Plan Position) in addition to the normal G.C.I. gear. This would increase the low-flying cover of these combinations and also decrease their vulnerability to enemy jamming. By 12 July 1944, two L.S.T.s had been fitted with 200 megacycles per second (1·5 metres) radar (Type 15) and one with an American SCR 584, the very accurate micro-wave radar, used effectively against enemy "Window" raids on the Anzio Bridgehead. The Type 14, however, could not be fitted in the time available, and was taken on board L.S.T. No. 32 with the intention of unloading it and getting it into operation as soon as possible after D-day.

Plans for Air Warning System during the Initial Phase of Operation "Dragoon"

During the approach to the Côte D'Azur, initial air warning was to be provided by M.A.C.A.F. from their radar resources in Corsica, through the medium of a track broadcast. In addition, certain Naval ships designated as Radar Guard Ships in the assault convoy were to give supplementary information, but no Air Force radar was to operate except in an emergency.

At 1530 hours on D-day, 15 August 1944, radar silence was to be broken and air warning cover provided by the two G.C.I./L.S.T.s, F.D.T. No. 13, the ship's radar in the Radar Guard Ships, ground observers on board ship, and track broadcasts from Corsica. By night, fighter aircraft fitted with A.I., Mark VIII, were to be despatched by M.A.C.A.F. to F.D.T. No. 13, which in turn was to hand them over to the appropriate G.C.I./L.S.T.s for interception purposes.

[1] It will be recalled that H.M.S. *Ulster Queen* had been used at Salerno and Anzio, but only restricted facilities had been available for carrier-borne forces. Since then Operation "Overlord," the Allied Landing in Normandy, had set a new standard for ship-borne fighter direction (*see* Chapters 23 and 24).

[2] A full account of the design and radar facilities of Fighter Direction Tenders is given in Chapter 23.

Four Light Warning Sets, ground observer posts and Forward Fighter Controls were to go ashore in the second wave of the assault, in addition to a Type 15 and SCR.584, comprising the equipment of the Advanced Operations party. Thereafter, a further G.C.I. station was to be landed as early as possible and the remaining radar equipment was to follow as the speed of off-loading and advance inland determined. It was estimated that the Advanced Operations on shore would be ready to take over fighter control from F.D.T. No. 13 on a limited scale by about D + 3. It was appreciated that cover ashore would be poor until it was possible to occupy the ground well behind the beach-head and that, therefore, taking over control ashore might be delayed. M.A.T.A.F. was to be responsible for the provision of radar cover over the approaches to the bridgehead area and later for all occupied territory until relieved by a M.A.C.A.F. follow-up for base defence. Great stress was laid on the need for full-scale exercises prior to the operation, involving all amphibious flagships and Fighter Direction Ships, to be carried out in sufficient time to allow any alternative arrangements on board these ships which might be found to be essential.

Ground Search Radar in the Invasion of Southern France

The main operation was launched on 15 August 1944, and was highly successful. Signals arrangements proved to be satisfactory but, as a result of the small scale of opposition encountered, were not fully tested. The performance of the Radar Ships covering the approach of the convoy was on the whole up to standard. At dusk and dawn, however, difficulty was experienced on board the F.D.T. No. 13 through shortage of V.H.F. R/T channels, when both day and night fighter aircraft were on the air at the same time. U.S.S. *Augusta*, acting as standby Headquarters Ship to U.S.S. *Catoctin*, was not an entirely fortunate choice.[1] She was heavily armed and carried seaplanes, so that very little space was available for erection of aerials. Furthermore, her fire support missions tended to take her too far away from the main assault force to fulfil the role of Headquarters Ship, should that have been necessary.

F.D.T. No. 13 had arrived too late for full tests, prior to the operation, of the additional equipment which it was carrying. In the same manner as in previous operations, despite countless attempts to reach a solution to this problem, permanent echoes presented a difficult obstacle and the same limitations with regard to positioning and freedom of movement were imposed by the Navy with a view to the ship's safety. The limit of the destroyer screen was 15 miles off-shore and once again it was found that the best operational picture by night was obtained at the outer limits of this screen. The seaward coverage here was practically free from permanent echoes and it was anticipated that the majority of raids would come from a seaward direction. During the day F.D.T. No. 13 moved in nearer the coast to give as low cut-off angle from the surrounding mountains as possible and consequently the minimum of permanent echoes. In this way high-altitude patrols were occasionally plotted but no low radar visibility overland was possible.

Owing to the lack of enemy air opposition, the G.C.I. stations mounted in L.S.T.s were not fully tried out during the operation. Positioning of L.S.T.s was dictated by considerations of safety and they were required to operate within the existing submarine screen. As had been anticipated, their

[1] A.H.B./IIJ1/90/34, Signals Report on Operation "Dragoon," H.Q., M.A.A.F.

performance suffered badly from permanent echoes, and it was extremely doubtful whether the G.C.I. stations could have operated effectively if enemy opposition had been encountered on a large scale. Isolated raids were experienced in the assault area by night and no night fighter contact was obtained because of the cluttering of the cathode ray tubes with permanent echoes.

A.M.E.S. No. 15076, aboard L.S.T. No. 32, the successor to L.S.T. No. 305, was to land a Type 14 A.M.E.S. on the island of Port Cros, but the presence of enemy troops prevented the L.S.T. from beaching until 17 August 1944. While the Type 14 was unloaded, A.M.E.S. No. 15076 was non-operational for some considerable time.[1]

The American Set SCR. 584 aboard one of the L.S.T.s was unable to function fully as lack of proper equipment made it necessary for a crude method of height-finding to be devised. On a very smooth sea, heights could be read to the maximum plotting range by taking the sea-level as the point of zero from which to read an angle of elevation, but with the movement of the ship the altitude dial swung between two extremes and a mean of these two figures had to be taken as the height of the response seen. In action, the S.C.R. 584 was most successful in tracking aircraft through permanent echoes, but there was little doubt that with some form of artificial horizon its all-round performance would have been considerably improved.[2]

Radar Units Ashore in the South of France

No radar equipment was unloaded on D-day as the beaches were not cleared sufficiently of the enemy. On the morning of D + 1, 16 August 1944, one Type 15, one S.C.R. 584, and three American Light Warning Sets were landed at St. Tropez. The Type 15 was sited as a C.O.L. station, and the S.C.R. 584 was set up close by in order to read heights and to plot in the areas which would be blocked by permanent echoes for the Type 15. Shore radar coverage proved poor because of the surrounding terrain, and contributed little to the seaborne facilities.

The Type 14 and S.C.R. 584 which had been prevented from landing on the island of Port Cros from L.S.T. No. 32 until D + 2, became operational on the evening of D + 3, 18 August 1944, and gave good radar cover in a west and north-westerly direction. Owing to the lack of enemy air activity, however, they were not called upon to handle night fighter aircraft.[3]

The American Microwave Early Warning Set (MEW) and the British Type 16 in Corsica, intended for long-range control of friendly aircraft and long-range warning of enemy aircraft, had no opportunity of exercising their functions as the enemy forces in Southern France were quickly forced back beyond the radar coverage of these stations.[4] Nevertheless, the low coverage of the Type 16 was extremely valuable for air/sea rescue and emergency homing. Searches by rescue launches and aircraft were controlled by radar, and rendezvous of both effected easily ; the high power V.H.F. R/T communications equipment proving especially valuable. Excellent tracks were provided of the friendly aircraft and shipping by the MEW and, had enemy aircraft or surface vessels attempted to interfere with the landings from an easterly direction, good warning would have been provided by this station.

[1] No. 15076 A.M.E.S., O.R.B.
[2] A.H.B./IIJ1/90/34, Signals Report on Operation " Dragoon," H.Q., M.A.A.F.
[3] No. 15076 A.M.E.S., O.R.B.
[4] A.H.B./IIJ1/90/11A, Encl. 60A, History of the Type 16 in Corsica.

Identification of Aircraft during the Landings

I.F.F. proved invaluable for identification, especially as the information from the Movement Liaison Section was at times received after the arrival over the assault area of the aircraft to which the movement messages referred.[1] In addition, many of the fighter-bomber missions were armed reconnaissance aircraft, and no definite estimate could be made of the time they would return. All aircraft carried I.F.F. except the American P. 38s, but as these were used only for patrols their positions were usually known.

Lessons Learned from Operation "Dragoon"

Despite the fact that radar arrangements were not fully tested owing to the small scale of opposition encountered, experience gained during the planning and executive stages taught several useful lessons. The outstanding of these was the immense advantage of starting the planning early even though there was at the time no final firm decision to mount the operation. The benefits derived from a plan, prepared, co-ordinated as far as possible with the other Services, and issued in draft form to lower formations in ample time for consultation to be undertaken at their level, outweighed any possible waste of time spent on a scheme that might not in the end be put into practice. In this respect, Operation "Dragoon" differed from all other operations carried out in this theatre. From the initial invasion of North Africa (Operation "Torch"), the planning stages had been cut to a minimum, partly for security reasons and partly from constant change of circumstances. The draft Signals plan for Operation "Dragoon" was produced over three months before the action took place, and required very little readjustment when final plans were completed. In the event they proved highly satisfactory.

In all operations launched up to that time, including Operation "Dragoon," there had been conflict over the positioning of seaborne radar for control of fighter defence over the assault anchorages. One exception possibly was Operation "Avalanche," in which a satisfactory agreement had been reached between the Royal Air Force and Naval officers aboard L.S.T. 305. Radar for this purpose was expensive in personnel, equipment, and sea lift. If this expense was to be justified, it would appear that any risk involved in allowing these craft the freedom of movement necessary for their efficient operation should have been met. In spite of representations during the planning stages, and the formation of the Seaborne Fighter Control Board, positioning of F.D.T. No. 13 and the G.C.I./L.S.T.s was again dictated by naval considerations of safety, and these ships were forced to remain within the existing anti-submarine screen. With the mountainous country of the immediate neighbourhood, permanent echoes covered the greater part of the radar screen and displays, and rendered the control of fighter aircraft practically impossible. It was suggested that a solution might be the installation of radar control facilities in submarines, and trials were later carried out. At all costs it was essential that compromise arrangements on the positioning of Royal Air Force seaborne radar should be avoided. This was undoubtedly the major lesson learned in the employment of radar with assault forces for, had the enemy opposition been on a large scale, controlled interception from seaborne radar would have been practically useless, if at all possible.

[1] A.H.B./IIJ1/90/34, Signals Report on Operation "Dragoon," H.Q., M.A.A.F.

The other recommendations were mainly faults which could have been eradicated if full-scale training exercises had been carried out under conditions similar to those which were met during the assault. This course had been recommended after every other operation in this theatre, and was again stressed in the plans for Operation " Dragoon," but only a short test over limited ranges was in fact undertaken. Some of the results of the neglect to hold comprehensive tests were failures in certain of the radar reporting communications, inadequate W/T and R/T channels aboard F.D.T. No. 13 for its many needs, and minor faults discovered after radio silence had been broken ; most of which would have been revealed during a full-scale training trial. It would also have been obvious that accurate height-finding equipment should have been provided on board F.D.T. No. 13, and a separate control for the I.F.F. interrogator aerial system rotation was required, as otherwise coding of the I.F.F. could not be ascertained until after several revolutions of the normal aerial. Efficient operation of the American SCR.584 was hampered through lack of roll stabilisation and some means had to be devised to overcome this deficiency.

In previous operations, Air Movement Liaison arrangements had never been thoroughly satisfactory. In operation " Dragoon " the problem was given special attention, consultation with all formations took place in the early stages of planning and the problem was carefully studied from all aspects, in order to supplement the available radar information as much as possible from the identification aspect. Once again, however, arrangements broke down, because, in part, of wholesale alterations in prearranged flight plans, and the unsuitability of the code chosen for passing movement messages.

The final injunction from participants in Operation " Dragoon " was that consideration should be given to sending ashore in the initial stages the radar which would ultimately be employed for the protection of the assault area. The advancing forces could then carry radar with them to prevent wasted effort in dismantling the original screen, carrying it forward and reinstating a similar equipment in its place.

Reduction of Ground Search Radar following the Allies' Rapid Advance through the South of France

The rapidity with which the ground forces advanced through Southern France and the decreased requirement for radar as a result of the lack of enemy air opposition, relegated the movements of radar convoys to a very low priority.[1] The first M.A.C.A.F. Radar Unit entered Southern France on D + 20, 4 September 1944, to form the basis of the static defence organisation for the coast and ports of Toulon and Marseilles. In mid-September 1944, M.A.T.A.F. transferred to M.A.C.A.F. all the British radar stations that were with XII Tactical Air Command in France and in addition three American equipments. M.A.C.A.F. in turn was able to reduce its commitments.

The withdrawal of the German land and air forces from Southern France removed the threat of enemy air attack to ports and convoy routes in the Western Mediterranean and consequently did away with the need for a large proportion of radar coverage. All American and British radar stations were

[1] A.H.B./IIE/107, History of Ground Radar in M.A.C.A.F.

withdrawn from operation in North Africa with the exception of seven American sets which were handed over to the French. Sectors in Sardinia, Corsica, Sicily and the " toe " of Italy were closed down and twenty-nine A.M.E. stations rendered surplus to requirements. Four units remained in North Corsica to assist in Air/Sea rescue operations and to provide cover for shipping between Corsica and Italy. In Western Italy, south of Leghorn, four stations in the Naples area were retained in operation and continuous cover was still provided on the east coast from the " heel " of Italy to Rimini. Four stations were still operating in Malta.

In the Middle East there was a large reduction in radar cover with the proposed withdrawal from operation of all the radar stations except those providing cover for Haifa, Alexandria and Port Said. Many of the stations were withdrawn or placed on a Care and Maintenance basis by September 1944, with the exception of those lining the Libyan and Egyptian coastlines. It was considered that these might be usefully employed along the Transport Command reinforcement route from the United Kingdom to the Middle East.

Ground Radar with the Balkan Air Force

In mid-September 1944, two C.O.L./G.C.I. stations and six Light Warning Sets[1] were transferred to the operational and administrative control of the Headquarters, Balkan Air Force for air operations in support of the Yugoslav partisan forces augmented by Allied specialist ground personnel. At that juncture it was not possible to set up a separate radar maintenance organisation for the Balkan Air Force, so the technical supervision and servicing had to be carried out by the personnel of the radar units themselves. Sufficient radar spares were carried initially to make the units independent of outside supply for a période of three months. In addition, six complete Light Warning equipments were supplied as a technical reserve.

There was nothing novel in the way these units were employed operationally. Their function was largely that of raid reporting. Nevertheless, owing to the hilly and undeveloped nature of the terrain the personnel had a most arduous time. The units performed satisfactorily despite their remoteness from the radar maintenance organisation on the Italian mainland.

R.A.F. Radar in Close Support of Army Operations

Meanwhile the Allies' summer advance from the Gustav line in the south had terminated at a line between Rimini in the east and Pisa in the west by September 1944. Once more the position was one of deadlock and the campaign again took on a static nature, with the Germans occupying Bologna and the Allies Florence, to complete the impasse from coast to coast. There were minor advances by the American Fifth Army on the west coast and the British Eighth Army on the east coast but these were of little import as the centre line held fast.

During the autumn and winter of 1944 enemy air activity was on a very reduced scale. So great was the Allied air supremacy that the Germans made every effort to conserve their already numerically inferior air force. *Luftwaffe*

[1] These units were :—Nos. 8000 and 8038 C.O.L., G.C.I.
Nos. 6007, 6009, 6010, 619, 6037 and 6072 L.W.S.s.

activity was largely confined to reconnaissance. Royal Air Force ground search radar was therefore only called upon to play an early warning role for the most part. Although vigilance on radar duties was still essential, this period of the campaign was one of comparative inactivity for the main radar reporting system. Nevertheless, the initiative of the Royal Air Force radar authorities in M.A.T.A.F. was again demonstrated, for this period was spent in experiments to improve radar operational technique in close support of the Army.[1]

There were two important applications of radar as an aid to army support tried out by the Desert Air Force units under M.A.T.A.F., namely :—

(*a*) The location of the firing points of enemy mortar gun batteries by the tracking of the projectiles.

(*b*) The ground control of Allied blind bombing attacks in the tactical areas directly from the S.C.R. 584 American set.

Tests had been started in May 1944 on the use of radar equipments for tracking various projectiles and locating their origin. The work had been developed by the British Eighth Army, employing two Royal Air Force Light Warning Sets and their crews.[2] Gun or mortar projectiles were found to be readily distinguishable from aircraft and on obtaining such plots, a track and a pick-up point were established as soon as possible. Light Warning Sets on the Eighth Army front were also detecting night movements of transport. As the system developed it became an integral part of the Army methods of locating enemy batteries, the Royal Air Force detachment ceased to have any responsibilities in the matter after the experimental stages were over, but the assistance which they gave to the Army is recorded here as an example of the co-operation which had existed between the Eighth Army and the Desert Air Force since the early days of the Western Desert campaign.

The S.C.R. 584 American radar equipment had already been used in a modified form in Normandy in July 1944 for close control of fighter bomber aircraft by the United States Ninth Air Force.[3] An unmodified set became available to the Desert Air Force early in November 1944, and not to be left behind in this application of radar to the close control of tactical aircraft, they decided to go ahead with trials and operations with the equipment as it stood. Although their results[4] could not attain the standard achieved in North-West Europe, the effort illustrates the pioneering spirit in the Desert Air Force.

The Final Phase of the Italian Campaign

During the winter of 1944 the German war potential had been steadily reduced by heavy bombing, not only in Italy, but to an even more marked degree in Germany itself. The Allies had meanwhile made their plans and preparations for all-out offensives on all fronts.[5] In Italy the final Allied offensive opened on

[1] Narrator's interview with Squadron Leader A. Potts, O.R.S., Headquarters, M.A.A.F.

[2] Air Ministry File C.S. 8251, Part II, Encl. 46A.

[3] A full account of the modified S.C.R. 584 in close support operations in North-West Europe is given in Chapter 25 of this volume.

[4] Details of the close control of tactical aircraft using the S.C.R. 584 (or M.R.C.P. as it came to be known) are given in Volume V of this narrative.

[5] Details of the status of radar stations in the Mediterranean Allied Air Force as of 1 March 1945 are given in Appendix No. 35.

9 April 1945. Immediate success was achieved; Bologna was captured by 22 April and two days later the Allied troops had reached the enemy line based on the River Po. By 27 April the ground forces entered Genoa. This was followed quickly by the unconditional surrender of the German troops in Italy on 29 April 1945.

For all practical purposes the war was over for the Allied forces in the Italian theatre. The Radar Units followed close behind the advance of the Eighth and Fifth Armies, but the superiority of the Allies in the air had been so overwhelming that the ground search Radar Units made their biggest contribution in navigational aid to their own aircraft. The reporting of enemy activity was negligible during this final offensive in Italy.

CHAPTER 22

GROUND SEARCH RADAR IN THE FAR EAST, MARCH 1942–END OF WAR

The growing Japanese threat in 1941 brought forth many appeals for improved equipment and machines, but it was not until 1942 that the modernisation of the Royal Air Force in India really began. The series of disasters in the Far East suffered by the Allies, which have already been described,[1] had made it obvious that India had a very large part to play in the strategy of the War, and no hope of regaining lost ground could be considered until India was fully equipped as a base for further operations. With the collapse of Hong Kong, Malaya, the Netherlands East Indies, the Andaman Islands and Burma, all between December 1941 and May 1942, Air Headquarters, Far East, ceased to exist and Air Headquarters, India, assumed responsibility for all Royal Air Force units in South-East Asia. The few radar personnel who escaped the Malayan debacle were withdrawn to India, and units and equipment in transit were, whenever possible, diverted and sent to India and Ceylon. This chapter shows how the early warning system for the defence of India and Ceylon was built up during 1942–1943 and how radar was later used in an offensive capacity from the beginning of 1944, when the Allies carried the war into enemy-occupied territory in the fight for the re-conquest of Burma and Malaya, a campaign which was ended in August 1945 with the Japanese capitulation to the Allied Supreme Commander in South-East Asia.

April 1942 saw the inception of a programme of modernisation of a force which had remained dormant during a period of great technical advances in other combat areas. New aircraft were sent out to India, airfield expansion was given highest priority, and the task of providing signals facilities of all kinds was taken in hand. At the beginning of 1942 the screen of observer posts and radar stations necessary for the efficient fighter defence of the threatened area of Eastern India was non-existent. An Observer screen covered the North-West Frontier Province and Quetta, but was so immobile that it was considered that its transfer to the east coast of India might destroy its efficiency. Plans to cover the industrial districts of Jamshodpur and Asansol were being prepared, but no posts were established.

The Beginning of an R.D.F. Organisation in India

In order that an early warning system might be established on a sound basis, a Radio Officer was posted to the Staff of Air Headquarters, India, from Air Ministry in December 1941 accompanied by a technical expert from the Directorate of Communications Development to make surveys and fresh recommendations for siting. These officers arrived in India in January 1942. Preliminary siting surveys for radar equipments were immediately begun in the Calcutta area, which was the nearest large port and industrial area to the Japanese in Burma, and was therefore most likely to be vulnerable to attacks by the enemy. After March 1942 much work was done in organising the air defence system and further radar surveys were carried out in Ceylon, Vizagapatam, Madras, Cochin, Bombay and Addu Atoll in the Indian Ocean.[2] Surveys were also made in the Gulf of Cutch, Diego Garcia, Mauritius and the Seychelles, but the two latter areas were later transferred to the care of the radar authorities

[1] *See* Chapter 13 of this volume

[2] Air Ministry File S.14186, "India—R.D.F. Organisation," Encl. 11A.

in the Middle East. The survey of Calcutta was the first to be completed, followed closely by that of Ceylon. The latter was made first priority, as in 1942 it was feared that the Japanese fleet might seize the island and use it as a base for further operations in the Far East.

First Radar Installations in India and Ceylon

Before March 1942 there was no radar equipment in India, although by May of that year an R.D.F. staff had been established at the headquarters of No. 221 Group in Calcutta and No. 222 Group in Ceylon. The first sets installed in Ceylon were A.M.E.S. No. 254 (T.R.U.), which became operational on 28 March 1942 at Ridgeway, Colombo, and A.M.E.S. No. 272 (M.R.U.) which had been formed in Egypt and which came on the air on 31 March at Elizabeth Point, Trincomalee. The installation of these sets immediately preceded the first Japanese air raids on Ceylon—that on Colombo on 5 April and on Trincomalee on 9 April. Unfortunately, the early warning system failed on the first occasion and radar warning was not given of the attack. Of the raid on Trincomalee, A.M.E.S. No. 272 reported that the attack had been made by approximately 100 Japanese aircraft, which had been plotted in from 91 miles.[1] Prior to the raid the station had been plotting enemy aircraft at sea in the early morning, none approaching nearer than 13 miles. At Trincomalee there were about half the number of Allied aircraft available to meet the enemy than there had been at Colombo, yet a far higher percentage of losses was inflicted on the enemy in proportion to the numbers of aircraft engaged, owing to the warning which had been given.

By June 1942 thirty-six radar equipments had arrived in India. These sets consisted of five M.R.U.s, six T.R.U.s, nine C.O.L.s, four G.C.I.s, two C.D./C.H.L.s and ten portable sets. The locations of these early equipments was as follows :—

In 222 Group, Ceylon.

Operational June 1942 ..	Ridgeway, Colombo (T.R.U.).
	Galle and Elizabeth Point, Trincomalee (M.R.U.s).
	Chapel Hill, Trincomalee (CH/CHL) and a Naval set, Type 279, on same spot.
	Namunkula (G.C.I.).
Under construction ..	Mutwal, Mount Lavinia and Dutch Tower, Colombo (C.O.L.s).
	Galle (Naval, Type 279).
	Kodipotumalia, Trincomalee (CD/CHL).
	Elizabeth Point (T.R.U.).

In 224 Group Area.

Operational	Matharapur (M.R.U.).
	Chengtu (China) (C.O.L.).
	Kumming, China, Diamond Harbour, Tezpur, Deganga, Dinjan and Fort Canning (portable sets).
Under construction ..	Deganga, Gapalpur, Gidni (G.C.I.s).
	Amghata (T.R.U.).
	Diamond Harbour and Egra (C.O.L.).
	Khulna and Egra (M.R.U.s).

[1] No. 272 A.M.E.S., O.R.B., April 1942.

In 225 Group Area at Bangalore All under construction .. Saidapet (Madras) and Grubbs Island (Cochin) (T.R.U.).
Worli (Bombay) and Pallavaram (C.O.L.s).

Filter Rooms were operational in April 1942 at Colombo, Trincomalee and Calcutta. The last was originally designed as a Sector Operations Room, but was taken over for filter purposes in March 1942. Further filter rooms were sited and plans were in process of implementation at Bombay, Madras and Cochin, whilst more were envisaged at Vizagapatam, the Gulf of Cutch and in Ceylon. The first Radio Installation Maintenance Unit was by this time operational at Bombay, to look after the equipments as they arrived from England.

Indian Observer System

In the meantime, an Observer Corps system was already established in the north-west region and was working over an area covering Peshawar, Kohat, Nowshera, Rawalpindi, Abbotabad and Mona, and also over a district of approximately 100 miles around Quetta. In the east, plans for Calcutta and the industrial area of Jamshedpur and Asansol were being prepared, although no actual posts had been established. To the east and south of Calcutta a normal system could not be established owing to the difficult nature of the terrain, and it was decided that warning would have to be obtained from a series of posts established along the railway lines. By March 1942 when preparations first began to take shape, the Observer Corps system was already working in the east from Chittagong to Mymensingh and progress was being made elsewhere. No work had been done on a system west of Calcutta and no Air Observer system had been planned for the south.

Defensive Radar Plan for India, 1942

Siting for radar installations was completed along the east coast of India, from Calcutta to south of Pondicherry, by July 1942, and great activity was taking place regarding siting for the rest of the country.[1] The policy generally adopted was to provide high cover over the coastal belt, and low cover and G.C.I. stations near important targets and fighter areas.

The Signals Plan for India, prepared from information given by India Command and from that available at Air Ministry, was issued in September 1942, and laid down the following requirements for raid reporting radar :—[2]

High cover from 250 miles east of Calcutta round the coastline to about 100 miles north of Cochin.

High cover from about 100 miles north to 100 miles south of Bombay.

High cover from about 50 miles north-west to 100 miles south-east of Karachi, and

Low cover in the vicinity of Calcutta, Vizagapatam, Madras, Cochin, Bombay and Karachi.

Further long term requirements were for high cover along the coastline between Bombay and Cochin, between Bombay and Karachi, where not already covered by existing arrangements and an extension of Low Cover around Vizagapatam, Madras, Cochin, Bombay and Karachi. G.C.I. cover was required locally at Dinjan, with provision for high cover at Akyab. The total estimated requirements of equipment for India Command, including Ceylon,

[1] Air Headquarters, India, O.R.B., July 1942.
[2] Air Ministry File C.M.S. 317, " India Radar Policy—General."

Addu Atoll, and offensives in Assam were for 256 sets. These were to be divided as follows :—

T.R.U. 19.	Light Warning 70.
M.R.U. 63.	Intermediate G.C.I.4.
C.O.L. 56.	Mobile G.C.I. 44.

The majority of the early radar equipments installed in India were of the transportable or mobile type. At certain key points, however, installations were later made permanent and the mobile equipments were either used for standby purposes or released for use elsewhere. Approval was obtained in September 1942 for the erection of 180-foot steel towers for C.O.L. stations on permanent sites. It proved impossible to find contractors with sufficient experience to make suitable timber towers and so the limited timber construction facilities which were available were diverted to make 125-foot receiver towers for the " Advanced " C.O. stations, these towers having of necessity to be of wood.[1]

Radar units known as " Holding A.M.E.S.," or " H.A.M.E.S.," were established at Calcutta, Dinjan, Vizagapatam, Madras, Bombay, Cochin and Colombo. These stations fulfilled the purpose of " parent " stations for other A.M.E. stations in their areas, four or five A.M.E.S. coming under each H.A.M.E.S. Signal Wings were formed in the summer of 1943, and took over the functions of the H.A.M.E.S., except in No. 225 Group. The Holding Units held spares and equipment for other stations, looked after personnel who were posted in pending allocation to newly-formed units, and did a certain amount of maintenance and servicing for the other A.M.E.S. By November 1942, fifty-three radar units had been installed and further Filter Rooms established at Bombay, Madras, Imphal and Comilla. By the end of 1942 the system of plotting and reporting the tracks of enemy aircraft was on the way to full development. Ultimately, in December 1943, came the end of the era when the Air Forces in India lagged behind those in other theatres of war in the matter of modern equipment and aircraft, and by that time the air defence of India was supported by a radar early warning system which gave the whole of India ample notice of the approach of hostile aircraft.[2]

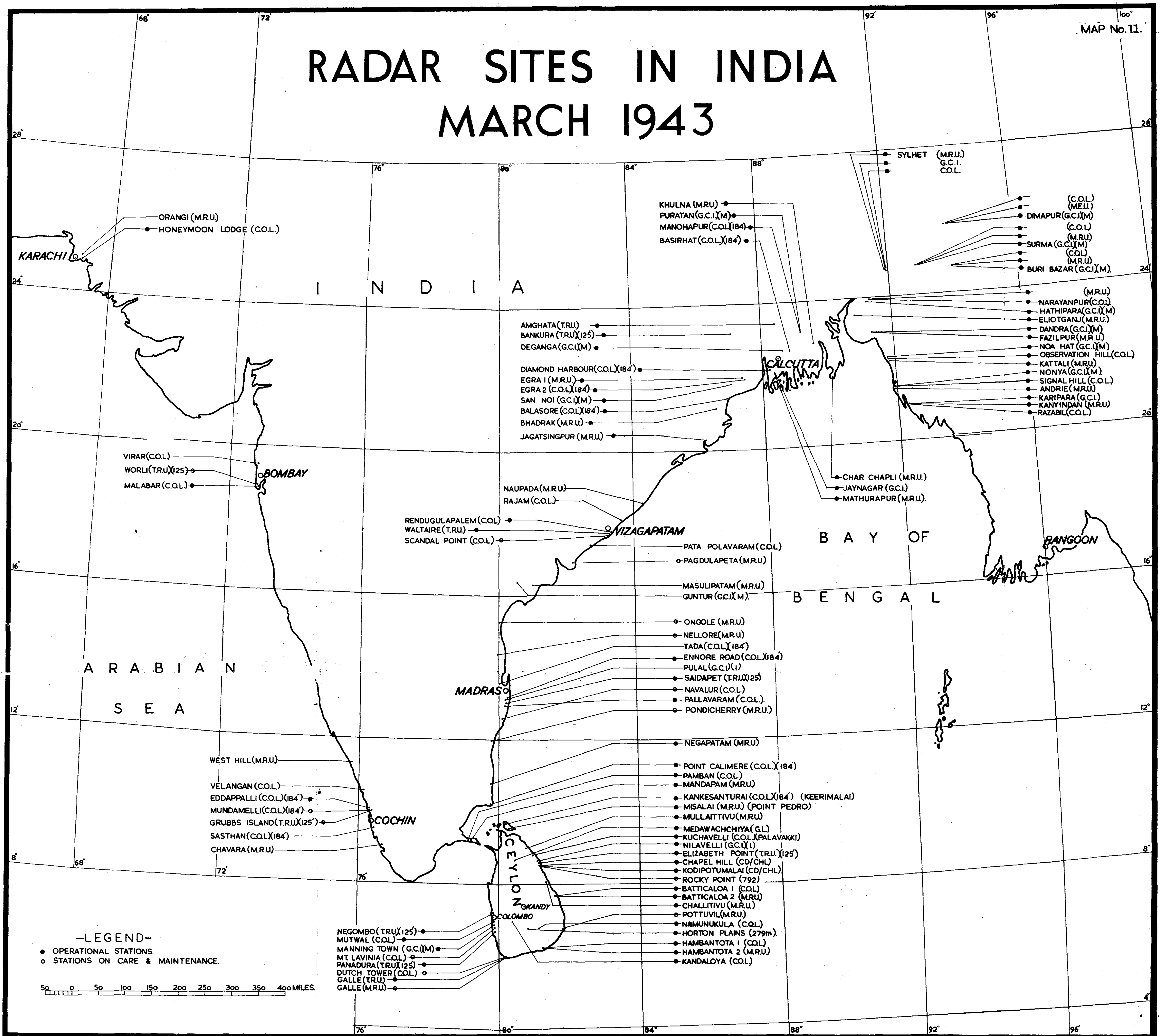
The year 1943 saw rapid progress being made with the siting and installation of ground radar equipment. In April, twelve months after radar cover was first established in India, there were fifty-two units in India and sixteen in Ceylon. Thirty-five of these provided cover for high-flying aircraft, and thirty-three gave low cover. The chief concentrations was in the Calcutta area, where thirty-six radar stations were operational. In addition, further equipment and reinforcements of personnel were steadily being sent out from the United Kingdom. Many of the earlier units had originally been destined for Burma, but had been switched to India whilst in transit, and later other equipment was diverted from the Middle East. In April 1943, sixty-four sets (thirty-eight of which were for high cover) were held in a pool at the Radio Installation and Maintenance Unit in Bombay, pending final allocation.[3] A further twenty-seven were in transit and fifty-two more were awaiting despatch from England. Sixty-nine stations were operational in India and Ceylon by the following September.[4]

[1] Air Ministry File S.4597, Part 1, " India—Policy for R.D.F. Provision," Encl. 104A.

[2] A.H.B./IIJ50/47/21, " Modernisation of Air Forces in India," and A.H.B./IIJ50/47/4, " Despatch on Air Operations," November 1943–May 1944.

[3] Map No. 11 shows the sites of A.M.E. stations in March 1943.

[4] Details of the radar stations operational in India and Ceylon, March 1942/September 1943, are given at Appendix No. 36.



A.H.B.I. MAP NO. 291

Revised Defensive Radar Plan

This plan was further revised in April 1943. The new plan was necessitated by the gradual building up of Allied strength in India and by the Allies' gradual change from a defensive to an offensive role.[1] The plan made allowances for the further expansion which would, it was hoped, take place in the following year when the first offensives towards the re-conquest of the enemy-occupied territory were planned. The revision was undertaken in view of the fact that the Japanese did not appear to be unduly threatening the west coast of India, that a lessening threat to the East Coast and Ceylon was apparent, but further cover was necessary in the north-east area. An additional important reason was the acute shortage of personnel, which made it imperative that no station should remain operational unless it was of real importance. The R.D.F. cover in India at this time had been designed to give warning of the approach, and to assist in the interception, of enemy aircraft and shipping attacking India and Ceylon, and to cover military objectives on the Burmese frontier.

On the assumption that India and Ceylon would be the main supply bases for attacks on the Far East from the west, a request for R.D.F. ground equipment necessary for use in future operations was submitted to Air Ministry for approval as follows :—[2]

(*a*) For use in a sea-borne invasion of the Burma or Siam coasts.

- (i) To provide air warning with day and night interception facilities over supply and assembly ports : Standby G.C.I. equipment, C.H.E.L. Type 14, and C.M.H. Type 13.
- (ii) For air warning with day interception facilities over the landing forces : Light warning sets, highly portable, A.M.E.S. Type 11, and C.M.H. Type 13.

(*b*) For use in a land invasion of Burma.

- (i) To provide air warning with day and night interception facilities over supply bases and the main landing grounds : Standby G.C.I. equipment, C.H.E.L. Type 14, and C.M.H. Type 13.
- (ii) To provide air warning preferably with day interception facilities over advance landing grounds, advanced Battle H.Q., lines of communications and forward troop positions : Highly portable light warning sets, A.M.E.S. Type 11, C.M.H. Type 13 and coherent pulse equipment, applied to G.C.I., M.R.U. and Type 11.

Operational Considerations of Radar, 1942–1943

1942 and 1943 were mainly used by the enemy to consolidate his conquests in Burma and the Malay peninsula, to fortify his positions, and to build up reserves and communications. The Allied forces, too, were taking stock of their position. The radar defence of India was built up from nothing in April 1942 until during 1943 the whole coast of India and Ceylon became covered with an early warning network. Once the first chain of coastal defence stations was complete, opportunity was taken to fill in gaps in cover, to render permanent the more important temporary sites, to train personnel, and to build up reinforcements of men and equipment so that when the moment

[1] Air Ministry File S.4597, Part 1. Encl. 113A. A copy of the revised plan is shown at Appendix No. 37.

[2] *Ibid.*, Encl. 114A.

came, Allied resources would be adequate. Air activity from Japanese airfields in Burma at this period was largely confined to reconnaissance raids and small attacks of " nuisance " value, though one or two fairly heavy bombing attacks were made in an attempt to damage port installations at Calcutta and elsewhere, and to cause panic amongst the civilian population. Radar cover was essential, not only to watch for and give warning of hostile raids but to report all movements of Allied aircraft and shipping. The radar stations in India never saw activity on the same scale as did the Home Chain stations in Britian, but their task was nevertheless a formidable one, as the same never-ceasing watch had to be kept on the cathode ray tubes under adverse climatic conditions. There were also many technical and operational difficulties associated with equipment used in a tropical climate where ideal sites were few and far between, and where permanent echoes were on a scale not seen in England, rendering the observer's task one of great difficulty and strain. During the monsoon periods observer posts and radar stations in outlying districts were often completely isolated for long periods and had to be supplied and maintained by air.

The first raids of consequence, apart from the early raids on Ceylon, were made at night in December 1942 on the Calcutta area when adequate radar information was given by the raid reporting system. Other heavy raids were made on north-eastern airfields early in February 1943, during the first campaign in the Arakan, but here again the enemy operated in an area where radar cover had already been established and where early warning was given.[1] In November 1943, enemy air activity increased, and a series of raids was made on Chittagong, Agartala, Fenny Palel, Imphal, Kumbhirgram, and Tiddim, with a raid by sixty aircraft on Calcutta in December. During this time Spitfire fighter aircraft, which had only recently arrived in the Command, were used operationally for the first time with very successful results.[2] The first three high-flying reconnaissance aircraft sent over by the enemy to the Bengal area after the new aircraft had come into operation were, in consequence of information provided by the raid reporting organisation, all intercepted and destroyed.

The First Arakan Campaign

An expedition was carried out by the British against the Japanese in 1942–1943 which had as its objectives the capture of the Mayu Peninsula in the Arakan, and the seizure of the port of Akyab. The action was not successful but the lessons which it taught proved of value in the larger campaigns which, in 1944, began the long struggles which culminated in the re-conquest of Burma.

The Arakan was the swampy territory on the west coast of Burma. One long range of high mountains, the Mayu Ridge, ran north to south along it ; on the coastal territory the land consisted of swamp, paddyfields and many tortuous creeks and tidal inlets. Akyab was used by the enemy as a reception point for troops and supplies and was situated on an island 90 miles south of the India-Burma border. By the end of December 1942 British forward patrols were almost in Donbaik and on the outskirts of Rathedaung. The troops, however, were operating at the end of a tenuous line of communication some 150 miles from the railhead, and some unseasonal rain rendered roads and

[1] A.H.B./IIJ50/47/9, " Despatch on Air Operations in Bengal Command," p. 12.
[2] A.H.B./IIJ50/47/9, p. 8.

tracks temporarily impassable. The delay thus caused proved fatal, and when the advance was resumed on 6 January 1943 the Japanese were reinforced and dug in.

A system of R.D.F. cover was already in operation in the area from Calcutta down the coast towards the Arakan when this expedition started, and it was able to give fair cover to the Army and Allied Air Forces. G.C.I., M.R.U., and mobile Light Warning sets were all part of the warning system, and in February 1943 the cover available in this area was as follows :—

Situation.	*A.M.E.S. No.*	*Type.*
Hathipara	682	Light Warning.
Hathipara	869	G.C.I.
Elliotganj, Comilla	247	M.R.U.
Dandra (Fenny)	877	G.C.I.
Fazilpur	376	M.R.U.
Kattali, Chittagong	378	M.R.U.
Chittagong (Noa Hat)	864	G.C.I.
Chittagong	879	G.C.I.
Chittagong	681	" Wigwam " Light Warning.
Ramu	648	,, ,, ,,
Nonya, Ramu	649	,, ,, ,,
Nonya	884	G.C.I.
Buthidaung	641	" Wigwam " Light Warning.
Karipara, Maungdaw	859	G.C.I.
Karipara	679	" Wigwam " Light Warning.

A final British assault was launched on 18 March 1943 but this was unsuccessful and heavy fighting ensued when the enemy launched a counter-offensive in the Kaladan Valley, and against Rathedaung, in March. On 12 May the British evacuated Maungdaw and Buthidaung and took up positions covering Cox's Bazar. Royal Air Force aircraft had fought well during this offensive and had succeeded in harassing the enemy considerably, but they were unable decisively to influence the outcome of the land battle.

During the monsoon of 1942 work had been in progress on a coast road down the Arakan, with airstrips running alongside, and in December No. 224 Group moved to Chittagong. A Filter and Operations Room were set up there to which the radar units reported. As the British troops moved slowly down the Arakan, close support was given by the Royal Air Force, and cover was afforded by the Light Warning sets and the heavier mobile equipment. The Allies had to meet formidable opposition from the Japanese, who made a determined bid for air mastery and who possessed good types of aircraft for tactical operations. During the campaign nearly 2,000 defensive fighter sorties were flown by the Allied Air Forces and many Japanese aircraft were shot down, in no small measure owing to the information provided by the radar system. The Japanese, however, made several heavy bombing raids on British airfields and depots, including those at Chittagong, Dohazari, Fenny and Comilla.

Early warning had been given of the attacks on the airfields in India, though the Japanese flew at low heights which did not allow the radar stations a long-range pick-up and in consequence notice was sometimes unavoidably short. The Wigwam Light Warning sets were deployed near the Armies in the field, and results were satisfactory.[1] The two in the Maungdaw area, nearest to the enemy lines, told to the G.C.I. station A.M.E.S. No. 859, where a temporary filter room sorted out information from the L.W.S. and Wireless Observer Units in the vicinity. This filtered information was then passed by W/T to the Filter Room at Chittagong. Local information was told direct to Operations Rooms by landline.

The campaign in the Arakan underlined the fact that future operations into Burma would require very adequate cover from R.D.F. stations, and every effort was made to fill in gaps by bringing other stations into operation at the earliest possible moment. Sites for further stations in the Chittagong and Cox's Bazaar region had been planned before the assault and steps were taken to complete installation. Delay, however, was experienced in the Ramu area, where an epidemic of smallpox necessitated the whole area being kept for some time in quarantine.

A report in March 1943 on the operational efficiency of stations in this area stated that, in general, the technical efficiency of radar stations was equal to and often above normal, although inexperienced operators were a handicap in some units. Height readings from the M.R.U. stations were found to be satisfactory, but those from other stations were less reliable. Estimation of numbers of aircraft had not been good, though with increased activity operators were gaining some experience in the matter. Full information was not, however, always received in Operations Rooms, even though it was passed from the radar sites. This was due to an acute shortage of personnel in the Filter Rooms, and there were not enough experienced filterers amongst those available. Most stations plotted by landline, with W/T installations in reserve. Reception on the landlines was not always good, with the result that full information did not invariably get through. Steps were taken to improve the quality of communications, and to provide each station with a second channel. Another drawback was a lack of I.F.F. and this, coupled with inadequate Air Movement Liaison reports on friendly aircraft movements, particularly in the operational area, made satisfactory identification a very difficult matter.

Reorganisation of Ground Radar Control in India Command

The ground radar organisation in the Far East was reorganised in the summer of 1943. Wireless Observer Units and A.M.E. stations had previously been controlled and maintained direct from Group Headquarters and by the Holding A.M.E. stations and Holding W.O.U.s. The growth of the radar system and the imminence of an offensive against the enemy demanded that responsibility for signals and radar units be undertaken by formations which could devote the necessary time and technical ability solely to this purpose.[2] Three Signals Wings were therefore formed within the Royal Air Force Groups, with a fourth coming into existence a few months later. These Wings took over the administration and technical control of all signals and radar units in their area. Their terms of reference also included the provision of signals and radar installations and full maintenance facilities. The Holding A.M.E.S. and Holding W.O.U.s then reverted to the roles of normal units. The Wings were very successful, and their administration helped very much to increase the efficiency of the warning system, results becoming apparent almost at once.

[1] A.H.B./IIE/203/A, R.D.F. Officer's Reports, March, 1943. (India Command.)
[2] Nos. 180–183 Signals Wings, O.R.B.

No. 180 Wing, in No. 221 Group (later in No. 231 Group) was formed at Calcutta on 22 July 1943 and initially assumed control for fifteen A.M.E.S.[1] and five Wireless Observer Units. In addition, technical and administrative control was assumed for three G.C.I. Units, Nos. 848, 849 and 851, although operational control of the latter remained vested in Fighter Wings. No. 181 Wing, also in No. 221 Group, was formed on 26 June 1943 and took over control on 1 August. Its headquarters at first was at Masimpur, near Silchar. Five A.M.E. and five W.O.U.s[2] were transferred to the Wing. No. 182 Wing became operational on 1 August 1943 at Chittagong, taking responsibility for all A.M.E.S. and W.O.U.s in No. 224 Group area. The fourth Wing, No. 183, became the ground radar wing for No. 222 Group at Colombo, and was formed at Ridgeway, Ceylon, on 26 November 1943, taking over all units in Ceylon. Of the remaining R.D.F. Units in India, stations in the Madras and Vizagapatam area remained directly under the control of No. 225 Group, as did the Bombay stations under No. 227 Group, whilst the A.M.E. station at Karachi remained the charge of No. 223 Group.

Formation of Allied Command in South-East Asia

Whilst the Allies were consolidating their forces after the Japanese conquests in the Far East, plans and preparations were being made for the eventual re-conquest of Burma and Malaya.[3] At the Conference in Quebec in August 1943 the British and United States Governments decided that joint action should be taken to provide a unified command of their respective armed forces, in order that land and sea operations against the Japanese in the Far East should be conducted in the most effective and expeditious manner. The appointment of Admiral Lord Louis Mountbatten as Supreme Allied Commander in South East Asia of the British and American Forces was announced on 25 August 1943. South East Asia Command was formed on 16 November 1943 with its Headquarters at New Delhi, and its objects the integration of all land, sea and air forces in the theatre.

Formation of Air Command, South-East Asia

Under Supreme Headquarters came the Air Command of South-East Asia (A.C.S.E.A.) and Air Chief Marshal Sir Richard Peirse became Allied Air Commander on 19 December 1943, with Major-General Stratemeyer of the United States Army Air Force as his second-in-command. The control of all Air Forces in India was now transferred from India Air Command to South East Asia Command, and policy direction came thenceforward from the Supreme Commander, instead of from the Commander-in-Chief, India.

Formation of Eastern Air Command

Eastern Air Command was set up at Calcutta in December 1943, under Major-General Stratemeyer, to look after all operations on the Burma front, and was necessitated by the operational integration of the 10th U.S.A.A.F. with the Royal Air Force. The formation comprised the Third Tactical Air Force (formed 24 December 1943 and predominantly British), the Strategic Air Force (predominantly American) and units of Troop Carrier Command.

[1] A.M.E.S. Nos. 211, 224, 248, 258, 281, 283, 319, 373, 543, 544, 567, 568, 590, 5058 and 8514.
[2] A.M.E.S. Nos. 383, 357, 869, 870, 885.
[3] Air Headquarters, India, and A.C.S.E.A., O.R.B.

Photographic Reconnaissance Units were also part of this Command. The Royal Air Force and the United States Army Air Forces retained administrative control of their respective units, but general operational policy for all formations was directed by Eastern Air Command. This amalgamation of the British and American forces led to a high degree of co-operation and exchange of technical information between the two Allies.

In April 1944 the Supreme Allied Commander moved his Headquarters from Delhi to Kandy in Ceylon. As the Allied Air Commander received his operational policy direction from the Supreme Commander in Kandy, it was essential for Air Staff to be in close touch with the Headquarters.[1] On the other hand, Air Command remained dependent upon the resources of India for the major part of the administration and sustenance of the Command—except for technical equipment and R.A.F. personnel, so it was equally important for the staffs of the Administrative Services to be in close touch with the Government of India. The result was the formation in Delhi in October 1944 of H.Q. Base Air Forces of South-East Asia (B.A.F.S.E.A.).

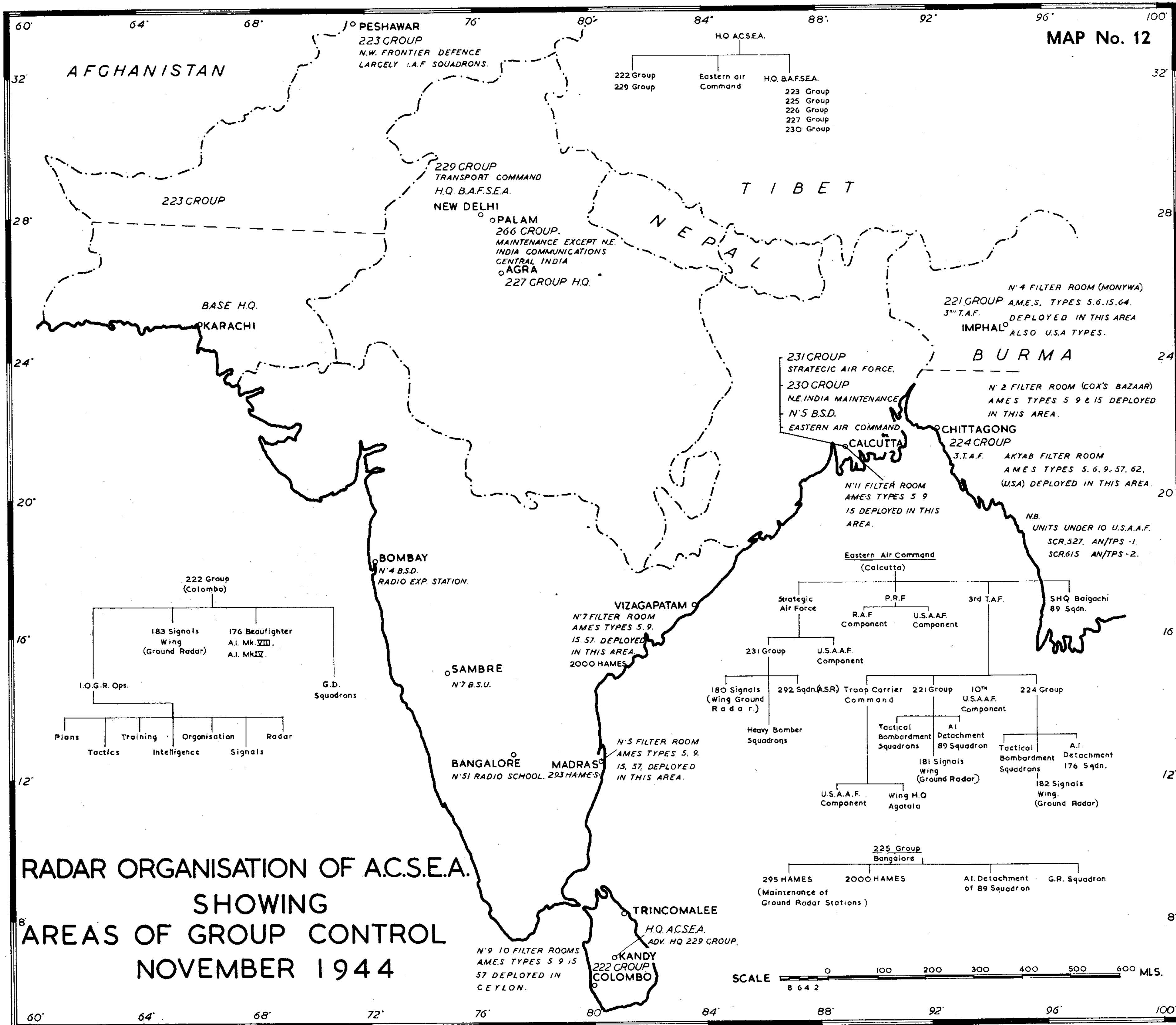
Radar Organisation in South-East Asia Command

The organisation of the Royal Air Force radar units in A.C.S.E.A. was as follows. All reporting A.M.E.S. were controlled either by one of the four Signal Wings, Nos. 180, 181, 182 and 183, or on the west coast directly by the related Group. The Wings were also responsible for the technical control, though not operational control, of G.C.I. units. Operationally, the latter were the charge of Fighter Wings under the same Group Headquarters. No. 183 Wing came under No. 222 Group at Colombo, which in turn reported directly to H.Q., A.C.S.E.A. No. 180 Wing was a formation of No. 231 Group at Calcutta, itself part of the Strategic Air Force, under the control of Eastern Air Command. Nos. 181 and 182 Wings were respectively under the jurisdiction of No. 221 Group at Imphal and No. 224 Group at Chittagong, and were a constituent part of the Third Tactical Air Force, which in turn came under Eastern Air Command. A chart showing the detailed organisation of all radar units in A.C.S.E.A. is appended to this volume together with a map giving the location of Groups and Filter Rooms in 1944.[2]

Cover for Palk Strait Area

The Palk Strait lies between Ceylôn and India, and as provision of radar cover along the Indian coast progressed, it was felt that additional cover was needed for this area, which was a very vital one, requiring protection from Japanese aircraft, and in particular for the Allied shipping which used its waters. A potential threat to the east coast of India arose in February 1944 when a considerable portion of the Japanese fleet moved to Singapore. Bases in Southern India and Ceylon were prepared and stocked for the possible advent of large forces from Bengal, and reinforcements sent in. Steps were taken to implement the radar cover in this region, and work began early in 1944 on the provision of two high tower C.O.L. stations which were sited one on either side of the strait.[3] A decision was, however, taken in August 1944 that owing to the lack of enemy activity on the west coast of India and the fact that the threa

[1] A.H.B./IIJ50/47/33, A.C.S.E.A. Administrative set-up, 1943, by A. V. M. Goddard.
[2] *See* Map No. 12, " Radar Organisation of A.C.S.E.A., showing Areas of Group Control.'
[3] A.H.B./IIJ50/47/4, " Despatch on Air Operations."



A.H.B.I. MAP N°308

from Singapore had not materialised, the Palk Strait stations should, when finished, be placed on a Care and Maintenance basis, cover to be available at one month's notice from the Naval authorities.

The radar cover in this area was fully operational by 1 December 1944, ready for the activity which followed the last phases of the advance to Burma and Malaya. Cover was provided by A.M.E.S. No. 5060 on the Ceylon side, and the other high tower C.O.L. was A.M.E.S. No. 5062 at Point Calimere, India. Other cover was afforded by A.M.E.S. No. 296 at Periyan, A.M.E.S. No. 394 at Mullaitivu and A.M.E.S. No. 14018 and A.M.E.S. No. 370 on the Indian side.

Problems of Identification at Radar Stations

In India, as in other areas, the problem of successfully identifying aircraft plotted by radar means was an important one. Although hostile aircraft were not active to the same extent as in Europe, nevertheless there were many odd reconnaissance aircraft to be plotted and occasional heavy bombing raids. In addition, from 1943 onwards, the Allied offensive was building up and heavy activity was experienced, particularly in the Bengal area and in areas near enemy territory. The Movements Liaison Reporting Section was not able to keep pace with all aircraft movements, particularly in operational areas where aircraft could not fly to schedule and this, coupled with inadequacies in the telephone reporting system, made identification very slow. This was a great drawback, particularly in those districts where the enemy was active, as successful interceptions naturally depended very largely upon speedy and accurate identification. One remedy lay in the provision of an adequate I.F.F. system, and its consistent use in all aircraft so fitted.

Introduction of Mark III I.F.F.

Mark III I.F.F. had been introduced in Great Britain in the spring of 1943, and by the end of that year its installation at ground radar stations was virtually complete. It was due to come into operational use in India in August 1943, but the installation of the necessary ground equipment took some considerable time to complete.[1] Installation at beam stations began early in 1944, priority being given to stations in the Bengal/Assam area, nearest to the enemy front, and where air activity was greatest. Due to good work by the fitting parties, who worked well once the necessary equipment was at hand, all operational beam stations in Bengal/Assam region were complete by April 1944 and at Ceylon a little later.

Great difficulty was experienced in fitting in floodlight stations, owing to the non-arrival of essential components from home. Repeated requests for the necessary gear were made by the Command and the whole programme was at one time held up because of shortage of supplies, as the equipment could not be produced locally. In March 1944 it was found that new Mobile Radio Units arriving in India were fully equipped with Mark III I.F.F., and so these installations were " borrowed " and fitted into existing operational stations, so great was the urgency. The first six floodlight stations were equipped by June 1944 through " cannibalisation," but it was not until December 1944 that all operational C.O.L., C.O.B., G.C.I. and floodlight stations using Receivers R.M.4 were fitted with standard interrogators and responsors.

[1] R.D.F. Board, Paper 421, 22 April 1943.

The maintenance of equipment proved another difficulty, owing to a lack of suitable test gear which was very slow in reaching the Command. Even when stations had finally been fitted with the necessary apparatus, they could not be kept in complete order without suitable test gear—a real difficulty in a theatre where stations were scattered and communications bad, so that the few instruments available could not be passed round quickly between neighbouring units.[1]

Shortages of Personnel

One very great difficulty which faced the British forces in the Far East was the constant shortage of radar and signals personnel. Not until the last months of the war did unit strengths come up to full establishment. Expansion of the radar programme was continually hampered by the lack of radar officers, radar operators and in particular of experienced radar mechanics. The problem was not, of course, confined to this theatre alone. By 1943–1944, when the radar branch in S.E.A.C. was attaining full expansion, the personnel shortage was being experienced in all theatres of war. Nevertheless, until priority was given in the spring of 1944, S.E.A.C. was particularly short of men in comparison with other operational areas, due to the Allied policy of defeating Germany and Italy, before concentrating fully on the Japanese.

Casualties accounted to some extent for the shortage, but in the main the real reason was the greatly increasing use of radar, and the consequent demand for more units and more men to man them. Radar had a widespread importance by 1943, it was being used more and more in an offensive as well as a defensive capacity, and many mechanics, in particular, had been withdrawn from ground radar units to maintain the ever-growing number of airborne equipments.

In the Far East all these factors had to be taken into account, and others as well. Distance was, of course, a great hindrance—reinforcements from England took many weeks to reach their destination, and even postings between units in the Command took days and often weeks, in cases where forward units were deployed at great distances from their bases. Two further important factors affecting the personnel situation in A.C.S.E.A. were the abnormally high sickness rate at certain seasons of the year, due to the extreme climatic conditions, and the regular leave which had to be given to avoid an even higher disability rate. Delays due to inadequate transport were such that an airman from a remote A.M.E. station might be away from his unit three to four weeks, in order that two weeks might be spent at one of the official leave centres in the hills. The shortage of mechanics was particularly grave, as test gear and spares were scarce, units were often at great distances from bases where Headquarters maintenance personnel were stationed, and improvisations on the spot were usually impossible. The equipment in addition sustained strain and damage from frequent re-deployments over bad roads and tracks, in unsuitable containers.

Discrepancies in establishment were to some extent compensated for by the employment of Indian officers and airmen for ground radar duties. For instance, in June 1944 the establishment for ground radar operators in the whole Command was 1,743, for which only 1,056 British airmen were available. Indians also were employed as operators, bringing the figure up to 85 per cent., but the strength was still 15 per cent. under minimum establishment.

[1] A.H.B./IIE/203/B, R.D.F. Officer's Report, December 1944.

After July 1944 Singalese airmen were trained for employment in Ceylon, Indian operators and mechanics being withdrawn from the area. For security, the policy had not at first been pursued of training Indian personnel in the operation of radar equipment, but by 1943 the need for extra personnel was so urgent that it was evident the early warning system would suffer unless further men were forthcoming to man and maintain it.[1] Consequently certain Indian officers and other ranks of the Royal Indian Air Force were selected to undergo training at No. 51 Radio School, Bangalore. This policy was very successful, and Indian personnel were employed at practically every level in the early warning system as operators and mechanics, and as radar officers at Wing and Group Headquarters, and they rendered very satisfactory service. Their initial lack of self-confidence, largely the result of difficulty in speaking in a strange language, was soon overcome. The success of the radar defence organisation depended in no small measure on the contribution made to it by members of the Royal Indian Air Force.

Deficiencies in establishment, of both men and equipment, had often to be made good by closing down all cover, except in vital areas. The personnel and equipment so released were used to man stations of greater operational importance. No station was kept permanently on the air except where this was essential and, as the centre of activity shifted, so the various A.M.E.S. units reverted to a Care and Maintenance basis. Radar cover was therefore in a constant state of flux, as forward cover could only be provided by closing down stations in the rear.

No. 51 Radio School

To meet the ever-growing gap between the numbers of operators and mechanics arriving from the United Kingdom, and demands made by the operational units, a training school was opened in India in the spring of 1943. This was No. 51 Radio School, and at first was sited temporarily at No. 289 Holding A.M.E.S. at Worli. Permanent accommodation was found at Bangalore, to which the school moved. It functioned satisfactorily at Bangalore from July 1943 until it closed, when the cessation of hostilities in 1945 rendered its continued use unnecessary.

Training was provided there for Indian airmen, who were trained as ground operators and mechanics, and for Indian Air Force officers who were given both *ab initio* and refresher courses in ground and airborne radar. The courses of training followed very much the lines of similar courses at schools in the United Kingdom, and a comprehensive syllabus was laid down. The numbers in training varied from time to time, but the figures for February 1944 are about average. On that date 64 Indian radar operators and five radar mechanics, with 13 Indian Air Force officers, were on initial course, besides small numbers on refresher courses. In May 1944 the policy was adopted of sending Indian airmen at the conclusion of their ground operator's course for pre-operational training at No. 7 Base Signals Unit in Sambre. The Chief Radar Officer of the Command noted at the time that, generally, the standard of efficiency was very satisfactory.

In addition to training Indian personnel, No. 51 Radio School gave refresher and advanced training of a kind designed to adapt the newly-arrived and newly trained tradesman to the particular radio problems of the Far East. His basic

[1] Narrator's interview with the Chief Radar Officer, India Command, and A.C.S.E.A.

training in the United Kingdom had been nothing more than a quick cram, leaving him with only a tenuous hold upon basic principles. In the course of a very long journey round the Cape and long waits in Personnel Dispersal Centres, the new tradesman therefore soon forgot a good deal of his basic training. An effort to get post-graduate and refresher training going on board troopships met with opposition, so that the Command had to shoulder a considerable commitment of *ab initio* training (for which it had no establishment) in addition to more advanced " Command training." This deficiency No. 51 Radio School set out to rectify by improvisation until such time as the new No. 7 Base Signals Unit could take over this task.

No. 7 Base Signals Unit, Sambre

No. 7 Base Signals Unit was formed in India, at Sambre, in the spring of 1944 for the purpose of forming and training all types of Mobile Signals Units.[1] Theoretical and practical training was given in all types of radar equipment used in the Command and particularly on new equipment such as centimetre sets, and the American Light Warning equipments, which personnel already in the Command had never seen in operation. A series of courses was run, attended by radar officers, operators and mechanics from all over the Command who were given preliminary training in the use of new equipment prior to its installation at their own station, so that whenever a new equipment was installed a nucleus of trained personnel could ensure its operation immediately installation was complete. In addition, at Sambre complete crews were mobilised and trained for the operation of every type of mobile signals and radar equipment. Training was given under field conditions, realistic exercises were a common feature, and the units when formed were sent direct to operate in the forward areas in Burma.

Following a directive issued by the Headquarters of the Supreme Commander, issued in October 1944, on the Signals Aspect of Amphibious Training, complete training was also given to crews who would form the radar element of amphibious operations against the enemy.[2] Much work was done during 1945 in the training of crews for the assault which had been planned to be launched against Singapore at the end of that year ; an assault which never took place on the intended scale, owing to the capitulation of the Japanese forces in August 1945 before Burma had been completely recaptured by the Allies.

Servicing and Maintenance Facilities for India Command and A.C.S.E.A.

The provision of a servicing and maintenance organisation in India was one of the first tasks confronting those officers responsible for building up the early warning system for the defence of India and Ceylon, and No. 1 Radio Installation and Maintenance Unit was formed in Bombay in April 1942. To this R.I.M.U. came all shipments of radar equipment from England, where they were checked, tested, assembled and finally allocated to A.M.E. stations in the Command. No. 1 R.I.M.U. became No. 2 R.I.M.U. in July 1943, when a similar organisation, No. 3 R.I.M.U., was set up at Calcutta to deal with equipment for the Bengal area. These two units were both disbanded in October 1943, and reformed as No. 2 and No. 3 Base Signals Units respectively. Later they became Nos. 4 and 5 Base Signals Depots.[3] As R.I.M.U.s they had dealt exclusively

[1] No. 7 B.S.U., O.R.B.
[2] A.H.B./IIE/203B, India Command Chief Radar Officer's Reports.
[3] No. 5 Base Signals Depot, O.R.B.

with radar equipment, but the expansion of the early warning system, and the preparations made for offensive operations against the Japanese in Burma, necessitated their reorganisation to include responsibility for the servicing and maintenance also of all forms and types of signals and communications equipment. Eventually a very complex organisation was built up, and valuable work was done in these units. On the radar side, equipment was prepared and supplied for new A.M.E. stations, including the provision of M.R.U., T.R.U. and A.C.H. stations, C.O.L.s, " Intermediate " and mobile G.C.I.s. In addition, a supply was kept of maintenance spares and modifications for existing radar units. Numerous adaptations and modifications of existing equipments for use in the peculiar conditions existing in the Far East were devised, developed and tested at the R.I.M.U. and many of these equipments were used successfully in the offensive against Burma in 1944 and 1945.

With the formation of the Signals Wings in 1943, maintenance of existing stations in the wings was as far as possible done by Headquarters parties, but as far as forward units were concerned, the problems of distance and inaccessibility were such that no adequate mobile servicing facilities were available, and stations had to be self-supporting for installation, transportation and day-to-day servicing. Three Mobile Signals Servicing Units were planned to be operational in 1945, for the projected offensive against Malaya, and preparations were made for their assembly at No. 7 Base Signals Unit. Only one M.S.S.U., No. 312, was, however, completed. This was assembled and mounted at Sambre and finally sent to Monywa in March 1945, but was only in service for a short time. The other projected units did not materialise, owing to the sudden collapse of Japanese resistance in Burma.

Radar State in A.C.S.E.A. in January 1944

Full details of the radar cover in India and Ceylon at the beginning of 1944, when the Allies began their re-conquest of Burma, are given elsewhere,[1] but can be briefly summarised as follows :—

	Operational Stations	*On Care and Maintenance*	*Under Construction*
Bengal Area	39	—	3
Ceylon	16	4	4
No. 223 Group ..	1	—	—
No. 225 Group ..	10	7	2
No. 227 Group ..	1	1	—
Indian Ocean ..	1	—	1
	68	12	10

The station in No. 223 Group was at Honeymoon Lodge, Karachi, and was operational for shipping only. The Indian Ocean units were on Addu Atoll Island, south-west of India, and consisted of A.M.E.S. No. 2001 (T.R.U.) and A.M.E.S. No. 5018, a C.O.L. with 184-foot tower. These stations were erected and installed by the Royal Air Force, but manned by Naval personnel, as they were used to guard a Naval base on the Island. In addition, a large number of mobile stations were ready to go forward into Burma when the Army advance required their presence, or to give additional cover in any area should the operational situation necessitate it.

[1] *See* Appendix No. 38, " Radar State in A.C.S.E.A., January 1944."

Filter Rooms

Twelve Filter Rooms were responsible for taking information from the A.M.E. stations in India and Ceylon. During the move into Burma they were supplemented as necessary by temporary filter rooms (mobile Filter/Ops Rooms), sited as dictated by the situation in the field, and passing information in turn to a main filter room. As the advance into Burma progressed, further filter rooms were erected and rearward ones closed down.[1] The Filter Rooms in India and Ceylon were as follows at the beginning of 1944 :—

No. 1.	Cochin.	No. 7.	Vizagapatam.
No. 2.	Cox's Bazaar.	No. 8.	Jaffna.
No. 3.	Chittagong.	No. 9.	Colombo.
No. 4.	Imphal.	No. 10.	Trincomalee.
No. 5.	Madras.	No. 11.	Calcutta.
No. 6.	Bombay.	No. 12.	Silchar.

Each Filter Room came directly under the control of Group Headquarters ; in the operational areas more than one Filter Room reported to each Group. As in Great Britain, close communication was maintained between Filter and Operations Rooms in all areas.

Radar Equipments Adapted for Use in the Far East

The difficult nature of the terrain in Burma and surrounding country, and its complete dissimilarity to that in other theatres of war, meant that standard radar equipments, which had been devised and used successfully in other areas, were often unsuitable for use in A.C.S.E.A. Not only was mobility essential in the forward areas, so that radar cover should be provided as the Allies advanced into enemy-held territory, but alterations had to be made in the standard vehicles on which the equipment was borne. The lack of adequate roads, the swampiness of the land, the rough tracks which had to be followed—all these precluded the general use of standard vehicles, at least for the most advanced posts and until the Allied positions had been consolidated. Consequently new methods of transportation had to be devised, and in turn this frequently meant modifications and alterations to the technical gear to enable it to be more conveniently stowed for transport or to fit into a smaller compass.

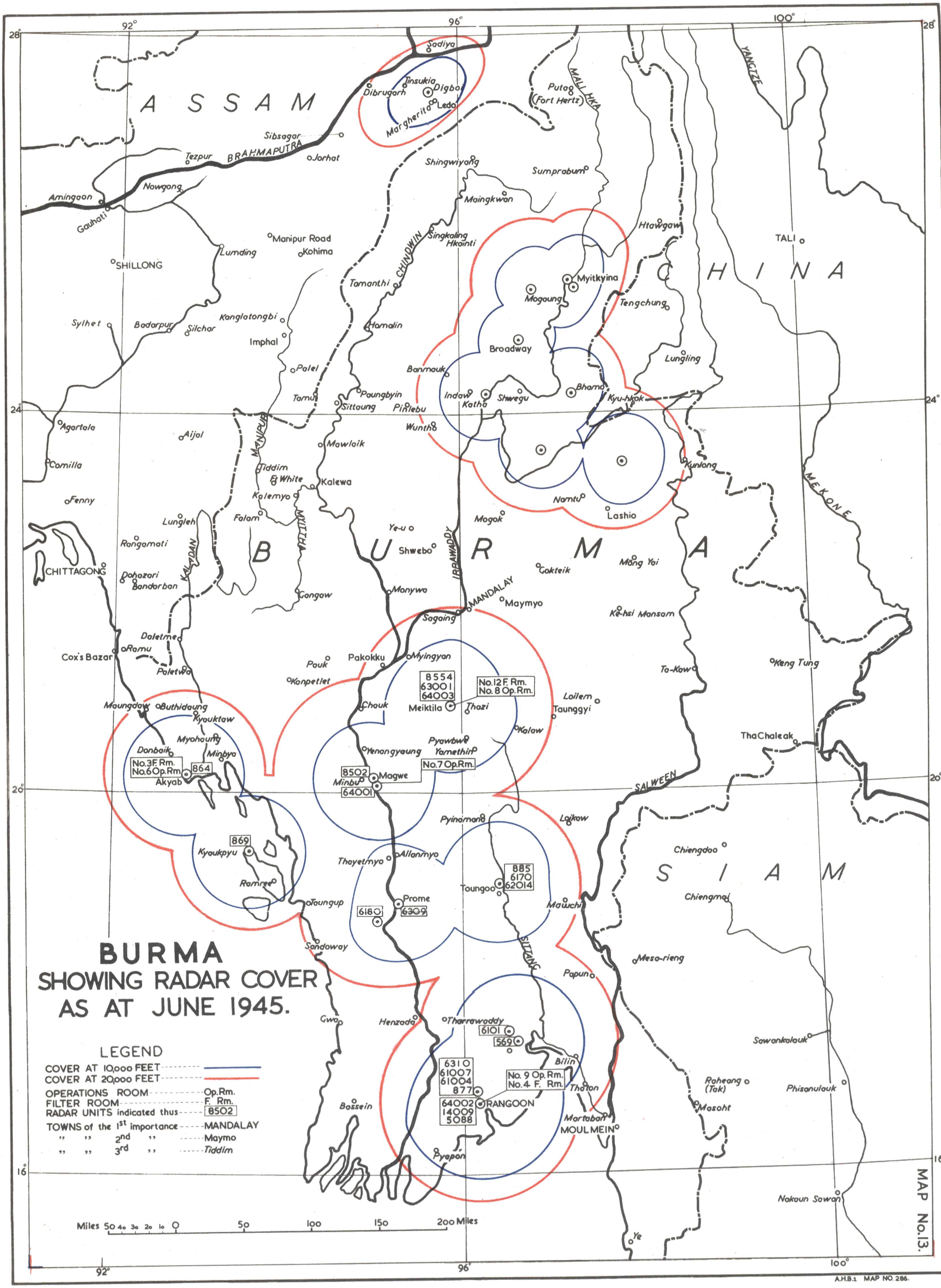
Within their own Command, radar and signals personnel at A.C.S.E.A. developed at No. 1 R.I.M.U. Bombay transportable radar sets which were suitable for special purposes. These developments included :—[2]

(*a*) A.M.E.S. on barges.
(*b*) The transport of hand-turned G.C.I. stations by air " Turkey."
(*c*) Light mobile sets, mounted on jeeps—" Mountain Goat."
(*d*) Mobile equipment mounted on a Ford C.299—" Buffalo."
(*e*) Amphibious sets, installed on a $2\frac{1}{2}$-ton amphibious vehicle Dukw—" Goose."
(*f*) LW/G.C.I. single vehicle G.C.I.—" Hawk."

A.M.E.S. on Barges

During the late summer of 1942 it was decided that waterborne A.M.E.S. might be valuable for work on the West coast of Burma and an investigation was begun into the possibility of obtaining suitable craft for the purpose.[3] One

[1] Map No. 13 gives the locations of the Filter Rooms in Burma at the cessation of hostilities.
[2] Brief in Ground Radar in A.C.S.E.A., Section 6.
[3] A.H.B./IIE/203/A, A.C.S.E.A. Monthly Ground Radar Report, Appendix " A."



A.H.B.1 MAP NO. 286.

85-foot steel cargo barge was obtained by the beginning of February 1943, and the purchase of three others was authorised. The barges were ready for the installation of radar gear by June of that year. Four barges were fitted up, A.M.E.S. No. 8514 as a G.C.I. and A.M.E.S. Nos. 5048, 5058 and 5456 as C.O.L. stations, and these were ready early in 1944.

No. 5048 A.M.E.S. was moored 200 yards off St. Martin's Island, west of Maungdaw, and became operational in February 1944, reporting to the Filter Room at Cox's Bazaar. The first report on its activities stated that it had recorded a number of hostile tracks at pick-up ranges using low aerials, and that the station was able to see tracks which could not be picked up by shore equipments. Effective cover was given round the battle area of Buithidaung and Maungdaw, whilst on medium and high flying aircraft the station provided valuable southward extension of the Arakan coastal chain. Later this A.M.E.S. was moved to Chittagong, on 23 March 1944. Technically, the barges proved satisfactory, provided they were used in sheltered waters close to a supply base. One disadvantage, however, was lack of a means of propulsion. The other three barges were used operationally from time to time as standby equipment for land stations, and proved very useful. In January 1945, Nos. 5048, 5456 and 8514 were deployed in the Ramree Akyab area. All operated satisfactorily, although No. 8514 was damaged during deployment by a hurricane and was out of action for some days.

" Turkey "

This code-name was used for the transportation of hand-turned G.C.I. sets Type 8 in Dakota aircraft, from a base aerodrome where there were facilities for loading to an advanced landing strip, newly occupied and inaccessible to base by any other means of transport. The site for the G.C.I. could be up to 5 miles from the landing strip, wherever a suitable piece of ground was available, and the equipment was taken from the aircraft to the site in a jeep. The erection of the necessary aerials and equipment was then undertaken by the crew and generally in 48 hours the unit was fully operational and on the air. The G.C.I. equipment was modified in order that each component could be carried in the aircraft. The ordinary intermediate hand-turned G.C.I. was used, but the aerial trailer was scrapped and the turntable mounted on a sectional framework carrying levelling jacks at the corners. The transmitter and receiver were slightly modified in order to facilitate handling and they were housed in standard tents, as used for Type 6 equipment. The G.C.I.s were fitted with I.F.F. interrogator/responsors and a twin Yagi aerial array. Performance was good, and the experiments could be considered a success. The first equipment, A.M.E.S. 8563, was deployed at Myitkyina on 24 July 1944.

" Mountain Goat "

This was a portable light warning set, used for deployment in the most forward areas, at places often inaccessible to ordinary motor transport. The sets were mounted in jeeps, and nine were equipped by April 1944. Owing to the limited weight which could be carried by a jeep, the Plan Position Indicator Unit, one receiver and the lower two Yagi aerials had to be omitted. The W/T equipment and spare generator were carried by a second jeep, whilst a third was required for general purposes. Hand-turned aerials were used, and when mobile these were mounted on the canvas roof of one jeep, the W/T aerial being carried alongside the body of the other jeep.

"Buffalo"

This was a Type 6 Light Warning equipment, mounted on a Ford vehicle. C29Q which was sufficiently large to carry all the radar technical equipment and the W/T equipment, but with an additional jeep for general purposes. The first unit, A.M.E.S. 6168, was operational at Tamu, south-east of Imphal, in No. 181 Signals Wing area, on 21 December 1943. Performance was satisfactory, gapfilling and height estimation were adequate, and ranges of over 80 miles were recorded. Hand rotation of the aerials was adopted, as it was found that motor turning gave too rapid a rate of sweep for effective operation against the numerous permanent echoes which cluttered up the trace. A.M.E.S. 6168 was withdrawn on 18 March and re-sited at Morem. It was destroyed by enemy action on 18 March; fortunately the personnel had been safely evacuated.

"Goose"

Trials were successfully carried out in the spring of 1944, with a complete Light Warning radar set and its associated W/T equipment, mounted on a $2\frac{1}{2}$ ton 6 by 6 amphibious vehicle, "Dukw." Power turning and a PPI unit were provided. The installation was designed for use in country where there were inland waterways but few, if any, roads, and was very useful in Burma.[1]

"Hawk"

Yet another version of the Type 6 Light Warning equipment was known as "Hawk"; this was a G.C.I. station using light warning equipment, with a 12-in. P.P.I. tube and V.H.F. and I.F.F. facilities, all housed in one rotatable cabin, with the aerial array on its side, the whole mounted on one prime mover vehicle. Operational trials were carried out in September 1944. The technical performance was found to be little less than that of a normal G.C.I. although the power was not so great. In consequence definition was not very good at far ranges. Cover was satisfactory up to 25,000 feet, both regarding range and azimuth. Working conditions, however, were bad and much sickness was experienced by some members of the crew, due to the narrow confines of the cabin, and its rotation. This was, however, alleviated by frequent change of watches, and an improvement in the cooling system. Successful trials led to an increase in the number of equipments ordered to ten, but only four were finally completed. One equipment was used in the advance to Rangoon in the spring of 1945, and another was deployed by sea and used on Ramree Island in January 1945.

"Falcon"

An aerial transportable version of the Hawk—the "Falcon"—was later devised. Eleven models were ordered but only four were finally completed. Two equipments were sent to the Bengal-Burma area in December 1944. The radar equipment for their use was taken from surplus A.A., No. 4, Mark III radar equipment. These were found valuable in the advance of the 14th Army in Central Burma during April 1945.

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[1] A.H.B./IIE/203/B, Chief Radar Officer's Report, March 1944, and A.C.S.E.A. File RS/367/TRS, "Conferences and Visits," p. 22.

Arrival of New Types of Radar Equipment in South-East Asia Command

The radar equipment provided for the early warning chain in India and Ceylon had been of the most up-to-date kind available at the time it was issued. As time progressed, however, and the more specialised requirements of radar in the Far East became known, the need arose for more up-to-date equipment to be used in some of the more vulnerable points in India, and to go forward into Burma. The original sets had been sent to India early in 1942, but since then steady technical development had been going on in Britain and newer and more effective equipments were already in use at home, and were gradually being tried out overseas. Details of the production of more specialised equipments, particularly those using centimetric wavelengths, have already been dealt with elsewhere in this volume.[1] As the newer equipments came into use, and as soon as production could be maintained on an adequate scale, a gradual supply of more modern technical sets was sent to the Far East, to supplement the older M.R.U., T.R.U. and G.C.I. sets which had given such good service.

A.M.E.S., Type 14, Mark II

The first reinforcements began to arrive in February 1944, when four Naval equipments, Type 277, known as Type 14, Mark II, were received in India. The same equipment was referred to in the United Kingdom as A.M.E.S., Type 57. These were 10-centimetre equipments, of medium power, with cheese aerials, mounted on a trailer and designed for the detection of very low flying aircraft and for providing cover for surface craft. Although transportable, these equipments were only really suitable for base defence, as their trailers made them insufficiently mobile for campaign work of a tactical nature.

A.M.E.S. 14017 became operational at Chapel Hill on 4 May 1944 and A.M.E.S. 14018 at Keerimala, Ceylon, ten days later. A.M.E.S. 14009 was also operational in May, at Chittagong to protect the Arakan front, and another station came on the air in June at Trincomalee. Altogether twelve of these equipments were allocated to the Far East and eleven had been received by May 1944, becoming gradually operational in the ensuing months. Good service was given by these stations, although a critical situation arose in November 1944 owing to a shortage of valves. It was feared that unless supplies were immediately flown out from the United Kingdom some stations would have to close. The valves, CV5 and CV35, were also in short supply at home, but fortunately a small consignment was flown out to India, just in time to keep the station operational until further supplies were forthcoming.

A.M.E.S., Types 21 and 22

During 1944 a new form of centimetric equipment, A.M.E.S., Type 21, had been introduced at G.C.I. stations in Great Britain, with very satisfying results.[2] The equipments were mobile, had a high discrimination, and were practically immune to enemy jamming which, in England, had been a great drawback to stations working on the lower frequencies. Fourteen equipments, Types 21 and 22 (the latter consisting of Type 11 plus Type 13 height-finding facilities, for use either as a G.C.I. or C.O.L.), were allotted.[3] The first two

[1] *See* Chapter 15, "Development of Low Level R.D.F. Cover after 1944 C.H.L. and Centimetre Wavelength Operations."

[2] *See* Chapter 28, "General Activities of the Home Chain from January 1944 until the cessation of hostilities with Germany," Appendix 56.

[3] A.H.B./IIE/203/B, Chief Radar Officer's Report, November 1944.

sets arrived in Bombay in January 1945 and were given A.M.E.S. numbers 21002 and 21023. Types 21 and 22 were made the main equipment at the more important G.C.I. sites, the older type sets being retained on the spot for standby purposes. The performance of these stations was satisfactory, but unfortunately they came too late to be of any real value, as by the time they had been installed the Japanese air effort had been almost neutralised by the Allied aircraft offensive.

American High Frequency Equipment

By the end of 1944 further supplies of radar equipment were reaching the Command, including the new type American centimetric wavelength light warning sets. These equipments were well made and gave excellent service, and were an improvement on the Type 6 light warning sets which had previously been used in the Command. The types received were AN/TPS–1, AN/TPS–2 and AN/TPS–3 light warning equipments of 1,100, 400 and 600 megacycles per second frequencies respectively, and were given the British Type numbers of 61, 62 and 63. Delays in putting these sets into operation were experienced, owing to damage and losses in transit.[1] The first Type 61 was, however, installed at Chittagong in November 1944. It gave light warning cover on low-flying aircraft and its performance on such aircraft over the sea was found roughly equivalent to the set, A.M.E.S. 14009, installed nearby on a higher site. A range of 50 miles proved to be average. Ten sets were in the theatre by January, three from American sources, the remainder from British stores. The first set—A.M.E.S. 61002—was later lost in January 1945 during the operations at Akyab, when the landing craft carrying it sank during a storm. This loss was particularly unfortunate as seven of the remaining sets were still being repaired after damage in transit, and were awaiting replacements of essential parts.

The first of the AN/TPS–2 sets—A.M.E.S. 62003—was deployed on 12 January 1945 at Akyab, to cover the Myebon landings. It was flown from Chittagong to its operational site in three loads by a calibration flight and was put into immediate operation, by a crew with no previous experience of such equipment. No trouble was experienced and the operational results were excellent. These equipments later proved most valuable in the Burmese campaign, and illustrated the value of light-weight robust sets in conditions such as were experienced in this sphere of warfare. The lightness of the set proved its advantages in the difficult country in central Burma, where transport difficulties were sometimes overwhelming. One set was moved successfully by glider.

The first Type 63 sets arrived in A.C.S.E.A. in February 1945 at 5 B.S.D., Bombay, and were later used in Burma. The three equipments had much in common and all were useful in the difficult country in which the Allies had to operate in 1945. The Type 63 had the greatest range, the Type 61 the narrowest beam, and was therefore best for use in areas where permanent echoes blocked the cathode ray tube. The Type 62 was extremely portable and very suitable for use by forward units ; it was probably the most useful radar set used in the Command for its specific purpose of giving information in a swiftly-moving land campaign.

[1] Delays occasioned by damage in transit are discussed more fully in the last pages of this chapter.

Reduction of Radar Cover in India from 1944

During 1944 it became apparent that the threat of attack by hostile aircraft was becoming less in certain parts of India and Ceylon, because the heavy attacks made by Allied forces on Japanese formations and airfields had reduced the number of aircraft at the enemy's disposal, and had caused him to withdraw his main bomber bases so far back that much of India became beyond his effective flying range. In addition, all his available aircraft were needed to counter the attacks of the Allies on all three fronts in Burma. Consequently, Supreme Command considered that reduction in radar cover had become possible, and authority was given to A.C.S.E.A. to carry out certain reductions from the latter part of 1944. An additional reason for reducing cover was that men and equipment were very badly needed for employment in the forward areas, and for building up cover behind the lines as the Allies consolidated their territorial gains in Burma.

The Naval stations at Addu Atoll were closed and partially dismantled in June 1944. In August of the same year instructions were given for all cover to be withdrawn from the west coast of India, with the exception of Karachi, which was required for surface vessel cover. This unit was, however, finally disbanded in September. Cover was revised in Ceylon at the same time, and A.M.E.S. Nos. 296, 5060, 14018, 8046, 5062, 370 and 553 were put on a care and maintenance basis.[1]

An investigation into the radar cover around Calcutta made in October 1944 showed that it was exceptionally strong, and overlaps by stations were not only double, but in some cases treble. In December 1944 therefore it was agreed by Air Staff that reductions might safely be made, and this was achieved in some cases by closing down stations. In other cases units were placed on a care and maintenance basis, whilst some adopted a two-watch system. Further economies were effected in the Madras and Vizagapatam areas in December and each area was finally covered by four stations only, a T.R.U. giving high cover and height-reading, a C.O.L. for long range and both high and low cover, although without height-finding facilities, a G.C.I. for fighter control and a Type 14, Mark II, for the detection of very low-flying aircraft and surface craft, and for general cover should the enemy resort to jamming. By March 1945 further economies were effected along the east coast of India and in Ceylon. In this month cover in Ceylon was retained only around Trincomalee whilst all cover closed down on the east coast as far north as Calcutta. A.M.E.S. Types 9 and 15 were disbanded, the rest were put on to care and maintenance. Personnel redundant by this closing down of cover were transferred to man light warning sets in Burma.[2]

The Campaign in Burma, 1944–1945

In January 1942 the Japanese poured in across the south-eastern frontiers of Siam. Overwhelming resistance, or by-passing it, they reached the head of the Burmese river valleys under the northern arc of mountains. The force and speed of their oncoming split the hastily assembled British-Chinese army into several parts. The British retreated across the Chindwin and over the jungle ranges into India. The Chinese withdrew up the wild gorges of the Salween

[1] A.H.B./IIJ/50/79, Radar Cover—S.E.A.C., Encls. 33A, 45A and 57A.
[2] A.H.B./IIE/203/B, Ground Radar Report for A.C.S.E.A., March 1945.

into the fastnesses of Yunnan. In a few weeks almost all the land area of Burma passed into enemy hands, and along the frontier of India emerged the three fronts around which the battles of the next three years were to be fought.[1]

During the two years following their conquest the enemy established themselves firmly in Burma and set up their forward positions on the eastern bank of the Upper Chindwin river. Here they were within striking distance of their last barrier, the mountain ranges forming the frontier between Burma and India. At their rear the Japanese had river and road communications, through which their supplies flowed, and they had possession of Burma's one big railway, which ran from Rangoon via Mandalay to Myitkyina. Their road system was based on two highways linking Rangoon and Mandalay, one following the railway, the other the river Irrawaddy. The first road reached Lashio where it joined the Burma road to China, the other petered out beyond Mandalay. There was no direct road to India, which lay 200 miles away through almost trackless jungle.

In India the British had only one railway, which ran roughly parallel to the Burma–Assam border, but much farther back. It could only be effectively tapped at three points—Chittagong, for the Arakan region ; Dimapur, for Manipur, over 100 miles from the enemy lines ; and at Ledo in the north. Behind the Indian border there were no good roads running back into India to the main supply bases in Bengal. Mountain ridges and fast flowing streams formed great obstacles between the forward Allied lines and their depots.

Apart from their occupation of central Burma, the Japanese had also infiltrated from Rangoon up the west coast to the Arakan, where they established themselves north of Akyab. The Allies' nearest port was at Chittagong, in East Bengal. Around this region, and in the Cox's Bazaar area mid-way between Chittagong and Akyab, radar positions had been firmly established during 1942–1943.

The third sector of the Burma front was in the north round Ledo, and there the Americans had concentrated ; along the Upper Brahmaputra a chain of airfields had been built, guarding their supply routes to China. In the face of many obstacles they had begun to hack the famous Ledo road out of the mountains, and by the end of 1943, under Major-General Stilwell, the American-trained Chinese troops had reached the Shingbwiyang area in North Burma and stood ready for a further advance southwards.

Japanese Offensives in 1944

In January 1944 the Japanese realised that the time had come for them to attempt to extend their western perimeter. Their positions in Burma were consolidated, communications were laid, reinforcements and supplies were available. In Europe the tide was on the turn ; although the Allied invasion of the Continent was still six months ahead, it was obvious it would take place some time during the summer of 1944, and that the Allies would be very busily engaged in Europe for many months. The Japanese therefore thought the time ripe to attempt an offensive. They probably realised that the full strength of the Allied forces could not be turned upon them whilst the European campaign lasted, and therefore decided to make their assault whilst the fighting in Europe was at its height. So, to the Japanese, early 1944 was " Now or Never."

[1] A.H.B./IIJ50/47/5, " Despatch on Air Operations, June 1944–July 1945," by the Allied Air Commander-in-Chief.

The enemy objectives were not to attempt a whole-hearted invasion of India, but to wipe out the Allied forces arranged near the Indian border, and to obtain for themselves the stores of arms and war materials which had been collected and to obtain access to means of feeding their armies, without having recourse to the long supply routes which at that time stretched behind them the length of Burma. The first Japanese offensive was the assault via the Arakan, which they launched in February 1944, and the second the advance on the central front, as a result of which the enemy actually did gain a foothold in India on 22 March, only to be flung out again, after very bitter fighting, in the following August. The third campaign of 1944 was carried out on the northern front, by Chinese, American and British troops, under General Stilwell. An account of the part played by British radar units in the first two campaigns follows.

The Second Arakan Campaign

Plans were made in 1943 for an Allied attack on the Arakan coast and lower Burma, to take place during the winter of 1943–1944, and the code-name for the seaborne part of this attack was Operation " Bullfrog." It was hoped that during November 1943 British forces from Assam and Chinese forces from Ledo would have advanced into the Mandalay area, and in consequence during December a seaborne assault was planned with the object of capturing enemy airfields in the Arakan area, and cutting communications between Rangoon and the north.

Radar was to play its part by the use of stations already established in the Chittagong/Cox's Bazaar region, and by special equipment planned to form part of the seaborne assault force. By November 1943 radar cover already extended along the coast in the Cox's Bazaar region to Ramu, but the terrain beyond this was unsuitable for more extended siting. Plans were made, and crews collected and trained for the sea part of the attack. The preparations included the use of a waterborne G.C.I. or C.O.L., to be towed to the coast near Oyster Island, and to be in W/T communication with both the headquarters ship and shore radar stations and filter rooms. In addition, three light warning sets were mobilised to be landed on Akyab Island with the first wave of landing forces, with a G.C.I. to follow. The three remaining barges were to be kept in hand prior to the assault for move to any area where they might be required. Radar sets were also mounted in an L.S.T. fitted for Fighter Direction and intended for use as a Filter/Operations Room, and other light warning sets were also held in reserve, to be moved by water to give protection in some of the creeks and waterways to the east and southeast of the Arakan area.

The original plan for a waterborne assault had, however, to be cancelled when a decision of the Teheran Conference in December 1943 allocated all S.E.A.C.s landing craft for use in European waters. The Supreme Commander decided that the assault by land should continue, and General Slim was ordered to use some of his forces to march into the Arakan, clear the Mayu peninsula to the mouth of the Naaf river, so as to ensure the safety of supplies brought in by sea, and then secure the Maungdaw–Buthidaung road. This was a 16-mile metalled highway running across the Japanese front, close behind their main positions. The Mayu peninsula was split in half, from north to south, by the Mayu range, a very high ridge of mountains, and the advantage of the Maungdaw–Buthidaung road was that it tunnelled the Mayu Range from west to east, linking the rice port of Maungdaw with Buthidaung, the chief centre of the Mayu Valley. In this area the Japanese had made a fortress with strongholds on either side of the range. The Army offensive was launched on New Year's Eve, 1943. All went well at first and Maungdaw was entered by British forces within a week. Heavy resistance was offered when the next objective was attacked, the Razabil fortress to the south, where the Japanese were well entrenched in hillside bunkers, proof against bombing and shelling attacks. On the other side of the range the British were steadily advancing to Buthidaung.

The Japanese Attack in the Arakan

Now, however, the enemy revealed his plans for an attack in the same region. As a preliminary he planned to cut off the lines of communication of the British on both fronts in the Mayu peninsula, and then advance along the coast to Chittagong, which port he hoped to capture. The whole attack was a diversionary one, planned to concentrate British forces in this area, whilst the Japanese main attack was made against the Allies in central Burma. The Japanese counter-offensive was launched on 3 February 1944 and the Allies were taken by surprise by the weight of the enemy attack and the number of his troops. British forces were withdrawn from the coastal area through the Ngakyedauk pass and took up a stand at Sinzweya.

The Japanese by-passed Buthidaung and closed in on the British from the north in the Taung Bazar area. The Allied troops were gathered together into what became known as the " Admin. box," a region one mile square, ringed with defences. Here they stood, beset on all sides but the western by the Japanese—only the pass kept them open to the sea at Maungdaw. Heavy and bitter fighting ensued and the British were hard-pressed, but again were saved from the air. Supplies were delivered from transport aircraft by parachute, and fighter aircraft broke up Japanese formations and maintained local air superiority. In this campaign, as distinct from the previous campaign in the Arakan, the Allied air forces had the advantage of Spitfire aircraft, with their greater speed and faster rate of climb, and they soon proved their superiority over the Japanese air forces. The besieged troops in the " box " held out, despite repeated attacks by enemy patrols, until supplies eventually reached them by sea from Maungdaw and until reinforcements came in from Chittagong along the coastal road. Over 3,000 tons of supplies were dropped during this siege, and more than nine hundred sorties flown by Allied aircraft. Reinforcements reached the Allies, and the last stage of the battle began on 23 February 1944. The combat had been bitter, the atrocities committed by the Japanese of unbelievable savagery, the bloodshed great, but the morale of the Allies never failed, and they eventually won through. The Japanese plans to overrun the Arakan had failed.

During all this period the radar stations already established around Chittagong and Cox's Bazaar had been of great use, plotting all aircraft movements and enabling the Allied aircraft to make many successful interceptions. Radar cover had been tightened up since the campaign of 1943 and very valuable service was now rendered by the early warning system. The first barge-mounted equipment—A.M.E.S. No. 5048—was given its operational baptism during this campaign, being moored off St. Martin's Island, west of Maungdaw, from February 1944. When the monsoon set in it was moved back to Chittagong. Further cover was given to Maungdaw in March by a light warning set, A.M.E.S. No. 6100, and a G.C.I., A.M.E.S. No. 853. Hostile and friendly tracks continued to be well plotted during the ensuing months until the onset of the monsoon in June brought air activity practically to a close. When the radar stations were established at St. Martin's Island and later in the Maungdaw area, the unusual situation existed of radar stations being actually well in advance of the front line and within range of the enemy's guns and night patrols.[1] Continuous watch was maintained in spite of these trying conditions.

Once the battle in the Arakan was over, the Allies followed up by advancing once more along both sides of the Mayu ridge, re-occupying Razabil on 10 March 1944. During the summer the Arakan was relatively quiet owing to the onset of the monsoon, and to the difficult nature of the country, criss-crossed by many streams and inlets, which in wet weather proved almost impassable. Opportunity was taken by the Allies to develop the district and make plans for using it as a supply base for the assault on Rangoon which it was hoped would take place in the following year. British troops concentrated in the area of the Maungdaw-Buthidaung tunnels and in the Kaladan valley. On the radar side, priority was now being given to units in No. 181 Wing, who were facing the enemy attack on the central front in the Imphal campaign, and consequently opportunity was afforded to radar units in No. 182 Wing to get up to date on all maintenance and to overhaul stations in readiness for the next year's operations. A programme of training and practice interceptions was put into operation with good results.

Advance into Central Burma

The Allies were also involved in a campaign which was being fought at the same time on the central sector of the front. The main responsibility for providing radar units to cover the advance of the Allies into Central Burma fell upon No. 181 Wing. When this Wing came into being in August 1943 its responsibilities included stations sited in the Imphal and Surma valleys, at Dimapur, guarding one of the vital points on the Allies' only railway in Assam anywhere near the enemy lines, and at Agartala.[2] It was difficult terrain in which to work ; communications were very bad, the land consisted of extremely mountainous country terminating in the high ridges forming the Burmese-Indian frontier, where few if any tracks existed. Good roads, water transport or railheads were non-existent. Some of the smaller units were completely inaccessible by motor transport and had to be supplied by pack mule.

Radar cover was still being built up in December 1943 when Headquarters, No. 221 Group, moved to Imphal, and were followed by No. 181 Wing Headquarters. The move towards Central Burma had begun, and the combatants were taking up preliminary positions ready for the fighting which was to follow. The A.M.E. stations were re-deployed ready to meet the forward move. No. 859 A.M.E.S. (G.C.I.) was sited at Digboi and another A.M.E.S., No. 8502, at Titabar, both designed to give cover to the United States Army Air Force airfields in the valley of the Brahmaputra. A.M.E.S. No. 6168 (L.W.) went to Tamu in the Kabaw Valley, south-east of Imphal and almost on the Burmese frontier, in December. It was followed by No. 659 A.M.E.S. in February. For some time these units provided the most forward radar cover. In January A.M.E.S. No. 383 (M.R.U.), 5070 (C.O.L.) and 5071 (C.O.L.) became operational and No. 857 A.M.E.S. (mobile G.C.I.) went to

[1] A.H.B./IIJ50/47/4, "Despatch on Air Operations, November 1943–May 1944," Sir Richard Peirse.

[2] A.H.B./IIJ50/47/48, "History of No. 181 Signals Wing" and H.Q., S.E.A.C., and No. 181 Wing, O.R.B.s.

Moirang, north of Tamu, south-west of Imphal, Nos. 5054 and 869 A.M.E.S. (mobile G.C.I.) came on the air at the same time. The armies of the Allies steadily advanced and early in March 1944 the most forward unit, A.M.E.S. No. 6281 (L.W.), was deployed on a small football pitch in the middle of high hills at Tiddim, in Burma itself.

So far, everything had gone well and the Allies were slowly but steadily marching forward. On 4 March, however, an enemy reconnaissance aircraft was shot down as the result of information received from the radar equipment at Moirang. The enemy realised that the Allies were mounting an offensive into Burma, and therefore decided that offence was the best method of defence. Hostilities began soon afterwards and the enemy began to advance towards India. He struck from Thaungdut in three directions. His purpose was threefold: to secure the line of the Imphal-Kohima supply road, to cut the supply line of the American forces who were advancing in the north towards Myitkyina and so force them back to Ledo, and to overrun the airfields in Assam and disrupt the airborne traffic which was plying over the otherwise impassable mountain ranges to China. So the enemy attempted to gain for himself the forward bases held by the Allies in India, and at the same time to cut off China from further participation in the war.

On 7 March the Allies organised their forces into a series of defence " boxes " in the Imphal valley. The terrain was completely cut off from all Indian bases and supplies and the stores and ammunition in hand at the beginning of the siege which followed were in no way adequate to meet the demands made on them. The Allies were, however, supplied by air from bases in India, and the full story of the siege of Imphal, and the system of air-supply which proved so successful, will be found in other volumes of the history of the Royal Air Force.

The radar stations, observer units, filter and operations rooms and all other ground installations requisite for the operation of fighter squadrons were in existence in and around the plain of Imphal long before the battle was joined. The radar units in the Surma and Imphal valleys reported to the Filter Room at Imphal, and did their utmost to give the defenders a clear picture of all air activity in the area. Airborne traffic was very heavy and there was much for the radar stations to report, as apart from the supply-carrying aircraft, Allied bomber and fighter aircraft were attacking Japanese lines of communication and bases, as well as the enemy's aircraft. Even at the best of times the mountainous nature of the country surrounding the Imphal valley made effective radar cover difficult, and although the stations were sited as far as possible to avoid all permanent echoes, and to supplement each other's deficiencies, there were weak spots in the warning system. Here and there were unavoidable blanks in coverage, and it was practically impossible to track enemy aircraft if they flew in at a sufficiently low altitude. The Japanese sought, too, to confuse Allied defences by splitting their aircraft formations as they neared the valley and operating singly or in sections, and this undoubtedly did cause considerable difficulty both in reporting from the radar stations, and in producing effective tracks at the Filter Room, and the problem of correct identification was an acute one.

On 16 March the first enemy troops forded the Chindwin river at Homalin, whilst a second detachment did the same at Thaungdut, 30 miles to the south. Four days afterwards the Japanese were at the borders of India, and 22 March for the first time they set foot on Indian soil. Spitfire aircraft did not immediately repeat the successes they had obtained in the Arakan, for three reasons.[1] The first was that although the G.C.I. stations in the area gave excellent performance and brought off several interceptions against enemy aircraft, the rugged nature of the terrain produced technical difficulties in the way of permanent echoes which left blanks in the radar coverage. Secondly, inexperienced Indian Mobile Wireless Observer Corps Units had recently been substituted for Royal Air Force Wireless Units, and at first a lower standard of reporting resulted. Finally, as the Japanese advanced, more and more of the early warning system was overrun and the Army Corps Commander decided that troops could not be employed for the local protection of airfields and the warning net. Consequently certain cover had to be withdrawn from the forward areas. The contraction of the warning system around Imphal was offset later by the introduction of long-range American fighter aircraft, which could penetrate further into enemy territory and harry the Japanese on his own airfields.

As the Japanese were crossing the Chindwin, another enemy column was converging by way of Tiddim, and on 12 March A.M.E.S. No. 6281 was recalled. Two hours' notice was all that the crew were given, and in this time they had to pack up and move. Not all the equipment could be taken with the crew and some of it was destroyed before the unit withdrew. The Japanese followed up with a push along the Kabaw valley and on 17 March A.M.E.S. No. 569, a C.O.L. unit, had to be withdrawn, leaving in its place a Light Warning Set, A.M.E.S. 6168, with a small crew. This unit in turn had to withdraw to the protection of the Division box at Moreh, near Tamu. It remained there until it was destroyed by shellfire on 27 March. Personnel were withdrawn without casualties, although they were subjected to heavy shelling only 400 yards from the perimeter of the base from which enemy patrols were active each night. The loss of radar cover near Tamu was a blow to the Allies, as much reliance had been placed on it for detecting the approach of enemy aircraft over the Chindwin. Without such cover it was no longer possible to be certain of the movements of enemy aircraft east of the high mountain wall separating the Imphal plain from the Kabaw valley.

By the third week in March Japanese forces had reached Ukhrul, north-west of Imphal, and were sniping along the road near A.M.E.S. No. 383, a G.C.I. unit. Defence of the station was impracticable, so it was withdrawn. Partial cover was retained by re-deploying A.M.E.S. No. 569 west of the Manipur Road and the airstrip at Imphal. When enemy patrols became active this station again became unsafe and was taken inside the defence perimeter at Imphal on 7 April.

In April A.M.E.S. No. 857, a mobile G.C.I., was withdrawn from Moirang to Buri Bazar, just south-west of Imphal. It remained safely there until the end of the month, when enemy patrols became active around the site, after they had captured a small position nearby. The unit was then withdrawn to Tulihal, a few miles north. A Light Warning Set, A.M.E.S. 6101, was in the meantime giving radar cover to the railway line near Lanka, west of Dimapur. On 21 April two Light Warning equipments, A.M.E.S. Nos. 6263 and 6170, were deployed at Yaripok and Tulihal, as permanent echoes on the traces of the main stations rendered impossible the plotting of enemy aircraft in the vicinity. The sets were withdrawn when the monsoon set in during May and June.

[1] A.H.B./IIJ50/47/4, Report on Air Operations.

Other forces of the enemy had during this time converged on Kohima, where intense fighting took place. The Imphal-Kohima road was crossed by the Japanese on 2 April, though the British garrison held out for 14 days. Allied reinforcements reached the town on the 16 April, and the enemy was flung out of the town. The last Japanese were dug out from the network of bunkers wherein they had entrenched themselves on Kohima Ridge on 14 May. The Allies took another six weeks to clear the Japanese from the area round Kohima, and a similar task was facing the Armies on the Imphal plain. The Japanese were, however, now on the defensive and were gathering their scattered forces together after their defeat. Their losses, like those of the Allies, had been very heavy, but they had not had the advantage of being reinforced and supplied from the sky, and their own lines of communication had failed them, largely owing to the activities of the Allied air forces. The heavy air activity during this period was plotted by the radar stations around Imphal and Buri Bazar. Hostile aircraft were active practically every day, generally three to six at a time, although on occasions larger formations of up to thirty and more were seen. The activity continued throughout April and May, but gradually slackened from early June, when the monsoon season was well advanced.

For the Allies the crisis in central Burma was passed ; for the enemy it was beginning. The next move was to blast the enemy's defences at Ukhruhl, their mountain base west of the Chindwin. Allied troops as a preliminary converged on one another from Imphal and Kohima and the Imphal-Kohima road was free again on 22 June. The battle for Ukhruhl which followed was a successful one for the Allies, and the Japanese were routed, again after very heavy fighting and heavy losses on both sides. By mid-July the Allied advance was on, the enemy being driven well back into Burma.

Further fighting had been concentrated around Bishenpur, near Imphal, the fighting lasting for several weeks. The enemy were at last forced back along the Tiddim Road, and the last invader was out of India on 25 August. Sittaung and Thaungdut were re-occupied by the Allies on 4 September, and Indian forces re-occupied Tiddim on 19 October. During the siege of Imphal the Headquarters of No. 181 Wing were flown out of the valley, finally taking up tented quarters at Silchar, near No. 6070 A.M.E.S. A forward detachment had been left at Imphal, but all equipment which had been stored there was removed to safe custody, for fear of it falling in the hands of the enemy, and it was flown to the three stations in the Surma Valley, Nos. 5070, 382 and 870 A.M.E.S. On 9 May No. 5070 A.M.E.S. was laid flat by a cyclone, although the technical buildings were undamaged. Further trouble was again experienced when No. 382 A.M.E.S. was flooded. After the battle at Ukhrul No. 383 A.M.E.S. (M.R.U.) was re-deployed on the Ukhrul road, and No. 569 (C.O.L.) was sent to Tamu. Wing Headquarters moved back to Imphal in October 1944.

The Allies in the meantime continued their advance into Burma, going south into Kalemyo and Kalewa, with the radar units following behind. Difficulty was experienced in transporting equipment over the extremely bad roads, and the necessity was keenly felt for very lightweight portable radar sets. Sites were found in October for radar coverage at Yazagyo and Sittaung on the Chindwin, east of Tamu. A Light Warning Set, A.M.E.S. 6170, was deployed at Yazagio on 10 November, forty-eight hours after No. 221 Group had asked for coverage in the area, and it was manned by a scratch crew from stations in the Imphal valley. No. 569 A.M.E.S. (C.O.L.) was sent to the same district on 15 November being replaced at Tamu by a G.C.I., A.M.E.S. No. 8502.

" Mountain Goat " equipment, A.M.E.S. No. 6171, came on the air at Sittaung on 19 November. This was the Light Warning set mounted on jeeps and was found very useful in the bad road conditions which prevailed. Further cover was asked for at Mawlaik on the river bank north of Kalewa and was provided on 29 November by A.M.E.S. No. 6178, which, complete with crew and one month's supplies, was deployed by gliders to Mowlaik on the Chindwin. Excellent performance was given by this station until its withdrawal in the following February. Further deployments of radar stations continued, light warning sets and G.C.I. equipments " leap-frogging " one another to Kalemyo and Mutaik, and following up the Army by giving cover wherever it was asked for or found necessary. By 9 January 1945 forward cover had been given to Maukaddaw and to the railhead at Ye-U.

A.M.E.S. No. 8554 (" Turkey ") which had been at Silchar, was flown out to Ye-U and thence 15 miles by road to Tabinguang. So it continued—as the Army advanced, so did the radar units follow in quick succession, taking up positions and becoming operational at the earliest possible moment. One unit, A.M.E.S. No. 64001, the first Australian Light Warning set to be used in the Command, struggled in 15-cwt. trucks to make the long journey from Imphal to become operational outside Gangaw on 10 January. This unit was deployed before the Allies had captured the town, before the road was made fit for 10-ton trucks, and before the main army drive in the area began.

Filter and Operations Room Organisation

The signals elements of Group and Wing Headquarters in the Bengal area had been put on a fully mobile basis early in 1944, and these establishments were fully mobile and self-contained for signals purposes. As the Armies advanced the Groups and Wings followed behind, setting up mobile Filter and Operations Rooms to which the radar stations reported. The necessary signals communications were provided by various Mobile Signals Units which were an integral part of the early warning system, and which moved forward with, or in front of the radar stations. Additional warning was given by the Wireless Observer Posts, which from the autumn of 1943 were largely manned by Indian personnel who gradually replaced British airmen, leaving the latter free for work elsewhere.

In March 1945 the Filter Room Organisation in Central Burma was altered to relieve congestion from the number of radar units plotting to the main Filter Room, No. 4. Nos. 7 and 9 Operations Rooms had been mobile for some time, moving forward with the advancing Armies. Now No. 8 Operations Room followed suit, and all three units became joint Filter/Operations Rooms. Certain radar stations were allocated to each Filter/Operations Room and continued to plot to the same unit during the advance southward. Where possible, these stations plotted by landline. Generally three radar units—a G.C.I./C.O.L. and two light warning sets, reported to each Filter/Ops. Room. Each of the latter also had at its disposal a " Turkey " or " Falcon " air-transportable G.C.I., which was intended to leapfrog forward, acting as a G.C.I./C.O.L. until the mobile Operations Room and G.C.I. Station could catch up. The combined Filter/Ops. Rooms plotted their filtered information by W/T to the rearward main Filter Room. The mobile Filter/Ops. rooms had authority to control the G.C.I.s in the interception of hostile aircraft in their area.

The Second Wingate Expedition

In March 1944 Major-General Wingate led a second expedition into Burma, with the objects of long range penetration behind the Japanese lines and the disruption of enemy communications in the Mogaung area, so leaving the way clear for General Stilwell's troops, who were advancing into Northern Burma from Ledo. Royal Air Force radar played its part before the expedition began by giving cover to the concentrations of troops, aircraft and gliders which had been built up in the Imphal and Surma valleys. Three Japanese reconnaissance aircraft had attempted to take photographs just before the expedition started, but two were successfully intercepted. In addition, on 7 April a Royal Air Force Light Warning unit A.M.E.S. No. 6181—was flown into one of the landing-strips established by the expedition forces in the heart of enemy-held territory, to replace an American set which had been destroyed in an air-raid.[1] This equipment remained operational until the airstrip was abandoned on 14 May ; the radar unit was loaded on the last aircraft to be flown out. Radar reconnaissances had been carried out near the other jungle landing-grounds but it was decided that radar cover was impracticable owing to the height of the surrounding hills.

The Northern Front in Burma

Whilst the British forces were engaged in operations on the central front in Burma, a completely different campaign had been taking place in the north. Led by the Deputy Supreme Commander, Major-General Stilwell, troops consisting largely of American-trained Chinese soldiers, Americans and some British were engaged in this theatre. After the retreat from Burma in 1942 General Stilwell had laid plans for three big projects, to re-build into an army the Chinese troops who had been evacuated into India, to keep China in the War by supplying her from a chain of airfields in North East India, and to build the Ledo Road.

The American Air Force bases were in the valley of the Brahmaputra, and cover for this area was provided by two British radar units, lent to the United States forces.[2] These were A.M.E.S. No. 859, a G.C.I. unit sited at Digboi, and A.M.E.S. No. 8502 at Titabar. Radar cover for the American forces consisted at first of five or six Light Warning sets, plus the two G.C.I.s which were lent by the British forces, and later manned and maintained by the Americans. The latter set up their own reporting system, a combination of radar and wireless observer posts, for northern Burma. Later the Type 6 equipment lent to the U.S. forces by the British was replaced by the former with the latest type American centimetre equipment. The U.S. forces maintained their own Filter/Operations Room at Lashio and a system of cross-telling existed between the Royal Air Force and the U.S. Army Filter and Operations Rooms, so that up-to-the-minute information of all aerial activity was obtained in each sector. The radar organisation in the American sector of the Burma front was not a large or complex one, as by the time the Americans had moved forward into Burma, the Japanese Air Force had been largely pinned down by Allied aircraft and there was little hostile activity on which to plot in the northern area.

[1] A.H.B./IIJ50/47/48, " History of No. 181 Signals Wing."
[2] Narrator's interview with the Chief Radar Officer, India, and A.C.S.E.A.

By the summer of 1943 American forces had advanced to the Mogaung Valley and a detachment of troops was sent to the great Japanese airfield at Myitkyina. Heavy fighting took place in this area, and the siege of Myitkyina lasted 78 days, the town finally falling to the Allies on 3 August 1944. To assist the U.S. forces in this siege, the first " Turkey," the intermediate G.C.I. carried entirely by air, which had been developed at the R.I.M.U. Bombay, was flown to Myitkyina. This was A.M.E.S. No. 8563 and it became operational on 24 July 1944, giving a very satisfactory performance. Myitkyina was of strategic importance in the Burma campaign as at this point the Irrawaddy becomes navigable, hence it was possible to ship stores by river to the Allies marching southwards to Mandalay, and also the Allies now had a railroad running to Mandalay. The move southward continued until Mandalay fell on 20 March 1945. Forces from the south made a surprise crossing of the Irrawaddy in February, attacking the Japanese airfield at Meiktila. This fell to the Allies on 5 March 1945, and then forces from the north linked up with the central troops to continue south to Rangoon—finally reached in May.

The Third Campaign in the Arakan. Operation " Romulus/Talon "

Plans were formulated in November 1944 for an amphibious operation to be mounted early in the New Year known as " Romulus " and " Talon," having as objectives the capture of enemy-held territory in the Arakan by land forces, backed up later by a seaborne assault—operation " Talon "—against Akyab Island, and thence against the Myebon Peninsula.[1] The Royal Air Force element was to be provided by No. 224 Group, the assault to be mounted from Chittagong and fighter protection being given from those airfields already established in the northern part of the Arakan area.

Radar cover was to be given by those radar stations already established in the Chittagong-Cox's Bazaar regions, and by special equipments carried in the seaborne assault. The radar equipment required was as follows :—

For the Preliminary Phase ..	One Barge, fitted as a G.C.I., with communications to No. 224 Group at Chittagong to H.Q. ship and to aircraft by V.H.F. One Barge fitted as a C.O.L., anchored near St. Martin's Island.
For the Final Approach of the Assault Forces.	One G.C.I. Barge to be used as a Fighter Director post, near Oyster Island. One Type 61 Light Warning centimetre set also at Oyster Island.
After Landing on Akyab Island	One G.C.I. " Hawk " or " Falcon " equipment. One Type 61 equipment. One Type 6 Light Warning set, and a standby. One Barge, C.O.L., to be moved from St. Martin's Island to Kaladan.
For the Consolidation Phase ..	One M.R.U., One Type 15 G.C.I. to take the place of the G.C.I. Barge. The " Hawk " and Light Warning sets then to become standby.

[1] Headquarters, S.E.A.C., O.R.B. Signals Appendices.

The land campaign was timed to begin on 11 December 1944, and the seaborne assault in January. The Army proceeded according to plan, advancing down the Mayu range from the Maungdaw-Buthidaung area, where supplies had been built up during the winter. By Christmas Day 1944 troops were at the tip of the Mayu Peninsula, looking across to Akyab Island. The anticipated fighting in this area never materialised, as the Japanese had thought it prudent to evacuate this point, so that when British troops arrived on 3 January 1945 it was found deserted. The Allies thus had their first airfield on Akyab.

The seaborne assault was launched in the meantime, and this phase of the war in Burma was fought out largely by gunboats and landing craft amidst the maze of jungle creeks and swamps which formed the coastline, with Commandos taking the offensive against the Japanese who were concealed in every waterway and hiding place. The assault on Akyab did not take place according to plan, as the Japanese had left, but they gave battle elsewhere. A fierce battle was fought at Kangaw, which covered the coastal road, during January and February and hand to hand fighting ensued between Commandos and the enemy. It took four weeks to clear this area, as the Japanese had again reverted to their tactics of underground hillside bunkering for protection.

Radar cover was available as far as Maungdaw when the last campaign in the Arakan began.[1] In December 1944 two American Light Warning sets, A.M.E.S., Types 61, were deployed experimentally at Chittagong, becoming operational on Christmas Day. A.M.E.S. No. 5048, a barge, was also operational near St. Martin's Island on 29 December. Another barge, A.M.E.S. No. 8514, became operational at Chittagong at the same time, and A.M.E.S. No. 61002 was also deployed in the area. Late in December these latter equipments were being re-fuelled and re-victualled so as to be ready to move down the coast as soon as the operational situation demanded it. In January a radar officer from H.Q. 182 Wing was sent to Akyab as liaison officer with the forward troops and on his recommendation a forward unit was formed at Akyab later in the month. This unit held a pool of essential spare parts and a specialised maintenance party for repair and overhaul of units.

Cover for the Mayu Estuary was provided by A.M.E.S. No. 6100 which made its way down the Arakan Road to become operational on 11 January 1945 at Foul Point. Ranges of over 100 miles were obtained and all round cover of the estuary was given. The Type 61, A.M.E.S. No. 61002, was unfortunately lost when heavy weather sank the landing craft in which it was being carried, on 3 January. A.M.E.S. No. 8514, the barge, was deployed on 12 January in Akyab Harbour, and operated as a C.O.L. station plotting to the Filter Room which had been set up at Akyab, and giving cover to the Allied landings at Myebon. This later functioned as a G.C.I. until a Type 15 G.C.I. was deployed on the spot. Another waterborne equipment, A.M.E.S. No. 5456, was also used in the campaign near Akyab as a C.O.L. unit.

On 17 February an amphibious operation was carried out at Ruywa, which took the enemy by surprise. Whilst this was in progress a large sea operation was carried on by the East Indies Fleet, the invasion of Ramree Island. Indian troops were landed there on 21 January 1945 and combined attacks from the air, the sea and land finally drove the Japs out. By 22 February Ramree Island was cleared. During these operations Royal Marines had on 26 January

[1] No. 182 Wing, O.R.B., December, 1944–April 1945.

occupied the Cheduba Island south of Ramree, and the occupation of the coastal town of Taungup on 13 March finally cleared the Arakan of all organised enemy forces.

Further radar cover was provided by A.M.E.S. No. 61005, American Light Warning equipment, which became operational at Teknaf from 5 January until 30 January giving cover to the south-west, south and south-east over the Mayu plain and sea approaches. Ranges of up to 88 miles were obtainable with this equipment. A.M.E.S. No. 62003 was flown from Chittagong to Akyab and came on the air on 12 January at Fakir Point, Akyab, to provide cover for the Myebon landings, giving excellent results and full cover over the Baronga Islands and the sea approaches. A.M.E.S. No. 61004 was flown from Akyab and then transferred by sea to Myebon, where it gave additional cover from 18 January. A.M.E.S. No. 6266 (a " Hawk " mobile G.C.I.) and A.M.E.S. No. 62002 were deployed by sea and were on the third landing craft to beach at Ramree Island, becoming operational on 22 January.

During February and March the positions gained in January were consolidated and sundry dispositions of the units were made in the area. Major installations were moved forward to provide full cover, releasing the light warning units for deployment further forward. Some stations north of Chittagong were placed on care and maintenance, the staffs being used to man the forward areas. The airfields in Akyab and Ramree were taken in hand as soon as the enemy left and it became a race with time to get them in action before the onset of the monsoon in May could effectively stop the assault on Rangoon—the Allies' next objective.

Radar in the Advance on Mandalay

As troops on the central front made their way southwards, radar cover in the rear was closed down, to release men and equipment for the forward units. Cover was reduced in the Surma and Imphal valleys in January, except for A.M.E.S. No. 859. All unwanted equipment was sent back to bases in India, leaving only light mobile units to follow the Army in its move southward. No. 181 Wing moved its Headquarters southward to Monywa in February, twenty-five aircraft taking much of the personnel and equipment in two days, the remainder taking three weeks to complete the journey. About this time A.M.E.S. No. 6270, a Light Warning/G.C.I. was deployed by air to Ywadan. This was a " Falcon " and the first of its kind in use. At first its performance was excellent, and comparable to that of a normal G.C.I. station, but its performance later deteriorated with its subsequent deployments and continued use.

With Wing Headquarters established at Monywa, radar cover was given by means of Light Warning Sets on the east bank of the Irrawaddy near Nyaungu, near Monywa, at Sadaung, at Dwehla and finally two A.M.E.S. were flown to Meiktila as soon as the airstrip had been rendered serviceable by the Allies. The close follow-up of the Army by the radar units continued. In one case a siting officer entered Pakoku the day before it was attacked by No. 7 Division. The radar equipments sent to Meiktila were Nos. 6178 L.W.S. and 8554 G.C.I. unit. Some delay was experienced with their deployment, due to misunderstanding by the aircraft crews which flew them in, but once the equipments were operational excellent co-operation was obtained. Heavy shell-fire was experienced by the crews of these two stations, and much of the equipment had to be buried underground. No casualties, fortunately, were sustained, though several of the crews had very narrow escapes.

Radar in the Land Advance on Rangoon

After the fall of Meiktila and Mandalay the road was clear for the advance on Rangoon, which was finally accomplished in May 1945. From Meiktila two waves of troops converged on the city, one east via Yamethin, Pyinmana, Toungoo and Pegu, the other west via Thayetmyo, Prome and Tharrawaddy. A third assault, from Akyab round by the sea, is dealt with later in this chapter.

In an attempt to increase the mobility of radar units advancing with the Army, one G.C.I. unit and one Light Warning set were allocated to each of the three operational Wings—Nos. 906, 907 and 909 reporting to a mobile Filter/Operations Room, and it was intended that the " Hawk " and " Elephant "[1] sets should push ahead with the Army in front of the two Wings moving down the main road and railway. This scheme of deployment was not a success, and some units were left idle while waiting information as to where they should become operational. In a campaign like this sufficient sets should have been available to allow of cover to be provided whilst other sets were off the air. Units were, however, deployed at Lewe, Toungoo, Pegu and around Magwe.

The advance to Rangoon was so rapid in its last stages that it was almost impossible for the equipment to keep up and still give adequate cover, and at times the Japanese aircraft attacked front line airfields, troops and forward lines from exceedingly low heights, before ground radar could be deployed. The " Hawk " and " Elephant " equipments might have been of greater use had they not been so hurriedly constructed and had it been possible to provide the crews with greater training in their use. In the conditions of war then obtaining in Burma, however, this was not possible.

It was obvious, in such a campaign as the last race for Rangoon when rapid advances were being made by the Armies, that enemy aircraft would give priority to the front lines and communications, and would make every attempt to disrupt them. This the Japanese did in January and February 1945, flying in very low to make their attacks. The main reason why he did not do greater damage was that the Royal Air Force and the American Air Forces had made such heavy and continuous assaults upon his air forces for many months past that he had little reserve left. Nevertheless he still had a few aircraft with which to harry our troops. None of the mobile radar equipment in use up to early 1944 was capable of seeing really low flying aircraft overland, and even though the radar units followed as quickly behind the Army as was practicable with the equipment available, the follow-up still was not always quick enough. Attempts had been made to overcome this difficulty with the " Hawk " and " Elephant " equipments. There is no doubt that the success of these types of mobile equipment indicated the lines along which the development of radar for operations in the field should progress. Another makeshift Light Warning set which had been tried out in this campaign was the " Giraffe," which was mounted on a truncated 105-foot mast. The results given by this equipment were excellent, but unfortunately it was insufficiently mobile, needed a crew of mast-climbers, and could not be made stormproof.

Operation " Dracula "

The code-name " Dracula " was given for the final assault on Rangoon. Planned as a full-scale air and sea assault to ensure the capture of Rangoon before the monsoon, it never came into full operation as no opposition was

[1] The " Elephant " was an American centimetre set mounted inside a Crossley vehicle.

encountered when Rangoon was finally taken in May 1945. Radar cover for the operations was to be provided by seven units.[1] These were being prepared for the enterprise since early April, and were gathered at Akyab during this process. The units chosen were A.M.E.S. No. 14009 (Type 57) to provide low cover for the operation; A.M.E.S. No. 61004 and A.M.E.S. No. 61007, Light Warning; A.M.E.S. No. 5058 and A.M.E.S. No. 8514, barge-borne equipment; and two major units, A.M.E.S. No. 376 (M.R.U.) and A.M.E.S. No. 877 (G.C.I.). The barges and Light Warning sets were loaded and under tow by units of the Eastern Fleet on 27 and 28 April respectively, and arrived at the final assembly point, Elephant Point, on 1 May. The other three units were planned to sail a week later. A.M.E.S. No. 8514 was unfortunately found to be leaking, the Operations Cabin being filled with 4 feet of water. Pumping efforts were unavailing and the barge became unfit for operations.

No opposition was encountered from the enemy when the convoy reached the waters outside Rangoon and the radar units were set up and working as soon as possible, No. 61007 at Monkey Point on 5 May and A.M.E.S. No. 5058 on the same day, at a point off-shore. A.M.E.S. No. 61004 came on the air on 9 May at Thringangyun. A.M.E.S. No. 877 was landed the following week and was sited at Mingaladon, and A.M.E.S. No. 14009 was placed to supplement the cover at Monkey Point. Only the personnel and limited equipment of A.M.E.S. No. 376 arrived, as the main equipment had been left behind when the units embarked at Ramree.

The Last Phase in Burma

The campaign in Burma was all but over. The frontiers of India were saved, the road to China was open, and Burma was practically free. The Japanese had been battered and beaten and their army was but a scattered wreck of its former glory. The way to Singapore lay ahead. Rangoon was opened to shipping on 6 May, and two days later supply ships came in to dock. As far as radar was concerned, there was little to do, as the Allied air forces had almost completely swept the Japanese from the sky. Radar cover already established on the central front in Burma—where fighting still continued—was consolidated. Instead of a solid chain of stations along the front, small groups of stations were deployed to cover five defended localities—Rangoon, Toungoo, Meiktila, Magwe and Prome. By 1 June five stations were operational at Rangoon—two A.M.E.S., Type 61, one C.O.L. (barge), one G.C.I. and one Type 14, Mark II. At the same time cover was reduced by the closing down of all stations on the Arakan coast north of Akyab; the remaining stations in this area closed the following month.

By July a G.C.I. and Light Warning network was provided from Mandalay to Rangoon, and west to Bassein. Further reductions in cover took place in August, and the three barges fitted with C.O.L. gear were disbanded. At the same time in August, plans were initiated for the last attack on the enemy, a combined assault on the Malay Peninsula, and estimated requirements for radar cover at Singapore, Port Swettenham, Hong Kong and Penang were drawn up. Crews and equipments were mobilised and in readiness to take place in the final assault. Many of the equipments and tactics to be used were modelled on those used successfully by the Allies in Operation "Overlord" and subsequently in deployment on the Continent of Europe.

[1] No. 182 Wing, O.R.B., April–May 1945.

In the meantime, isolated Japanese groups still remained in central Burma. Scattered units were left from the Arakan campaign and the assault on Meiktila, and a large force was still intact east of Taungoo, between the Sittang and Salween rivers. By this time the monsoon rains had started and the mopping-up operations entrusted to the Twelfth Army proved a difficult task.

The End of Hostilities

The final battles in Burma were fought in July and August 1945 when the last remnants of the Japanese army were defeated. The crowning blows to the Japanese came on 6 and 9 August, when American aircraft dropped the world's first atom bombs on Hiroshima and Nagasaki. On 16 August the Japanese Emperor ordered all troops to cease fire and so the war at last was over. Japanese troops in Burma surrendered to Lord Louis Mountbatten, Supreme Commander, on 28 August, and signed the provisional surrender agreement in Rangoon.

Detailed radar planning for operation "Zipper," the last assault on Malaya, ceased, and the vast sea and land invasion proved unnecessary. However, a large proportion of the assault forces sailed according to plan as units were already largely mobilised, but instead of fighting an offensive action, the troops, including the crews of radar units, went back to Malaya as an occupation force. The re-occupation of Malaya began on 3 September, and the following day Singapore was once more in the hands of the Allies.

Principal Radar Problems in the Far East

Before ending this account of radar in the Far Eastern theatre, it is advisable to consider the major difficulties which were encountered in operations there. Many of these difficulties were obvious—the nature of the terrain and its climate being the root causes. Privation of the personnel and the ravages of sickness and disease were most important factors, but a full account of these is beyond the scope of this narrative.

The radar equipment itself, as supplied from 1944 onwards, stood up remarkably well to tropical conditions. The main equipments were sufficiently robust to play their role in the type of warfare encountered. The chief deficiency (until local action was taken) was in readily portable lightweight radars, which could be easily handled, transported by pack mule, jeep or other means applicable to the rough Burmese terrain. Towards the end of the war, such equipments were being supplied from the United Kingdom, but for several years operations in the Far East had been hampered by shortage of these small radar equipments.

Lack of Spares

Another great drawback encountered in the Far East was the lack of spares and replacements of vital equipments. The great majority of parts were sent out from home with consequent delays and often losses in transport, manufacture and improvisation on the spot was often impossible. Far too often adequate spares were not sent out with the original equipment, and frequently sets failed completely owing to the lack of a relatively minor small part. Lack of spares and test gear was often a difficulty at home or in nearby overseas theatres, but replacements could usually be rushed from depots or manufacturers within a few hours or days. In the case of the Far East it might be months before spares could be received. Partly this was due to the pressing need for equipment in other spheres of war, allied to a general shortage, and partly due to distance and the consequent delays in transport.

In February 1944 the Chief Radar Officer, A.C.S.E.A., reported to Air Ministry that the greater part of the radar equipment in the Command had been operational in excess of eighteen months, and virtually no major replacements had been made, owing to their non-availability.[1] At that time this gave rise to a fairly critical situation, as the equipment was rapidly deteriorating and no spares were held in India. Often, in order to keep adequate cover in vital areas, it was necessary to borrow spare parts from standby equipment, or even from operational sets in quieter areas, and it is obvious that a policy of " borrowing from Peter to pay Paul " is, to say the least, highly unsatisfactory if carried out for any length of time.

Breakages and Damage

These were another constant source of worry to radar stations in the Command. Losses and damage in transport were frequent, and a heavy drain on the already limited sources of equipment. Some of the trouble was due to careless handling in transport, but often it was due to inadequate packaging. It was not until the war in the East was well advanced that authorities at home were able to put into practice a really adequate system of tropicalisation and efficient packing of materials designed for tropical climates, and in the meantime the radar sets in the Far East suffered. Valves and similar items were often a great disappointment, as when a long-awaited consignment arrived, too often it was found that only part of the consignment could be of use. In February 1944 the Chief Radar Officer reported that the position was acute. During December No. 2 B.S.U. at Bombay had reported that a consignment of one hundred and forty-six V.T. 98 valves, badly needed in the Command, had been tested and 95 per cent. were found to be useless on arrival.

The arrival in the Command at the end of 1944 of American Light Warning equipment was at first another disappointment, owing to the delay which was experienced before it went into operation. This equipment had been long awaited and eventually was of great value in the forward areas in Burma. However, great damage was caused in transit and losses were frequent, so that heavy delays were caused before the equipment could become operational. Instead of being sent straight to the forward areas, as had been hoped, equipment had first of all to be examined and overhauled at a Base Signals Depot. This necessitated breaking waterproof sealing in a humid climate with consequent further damage. Of seven sets of AN/TPS–2 delivered by sea in January 1945, none was received complete. Several of the cases in the consignment proved untraceable and further delays were encountered whilst deficiencies were re-demanded. Actual damage was done to the equipment too, because of insecure fastening down of heavy equipment in the transit cases. Three of the seven sets were delivered without an inner conductor for the co-axial feeders in the aerial rotation assembly and were consequently unserviceable, as this item could not be manufactured in the field, or improvised. Strong action was, however, taken to ensure that subsequent consignments were more securely packed and checked and the equipment later proved of real value in Burma.

[1] A.H.B./IIE/203/B, Chief Radar Officer's Report, February 1944.

Transport

Passing reference has already been made to transport difficulties. Although this was largely an administrative problem, it is discussed here because, in the opinion of the technical officers operating in the Far East, it constituted one of their greatest difficulties. Countless delays were experienced in the movement of both personnel and equipment owing to the inadequacy of all means of communication, and vital supplies and replacements of radar parts were often an interminable time in transit.[1] Most supplies had, in the first instance, to come from the United Kingdom and, later, the United States of America, and much time was spent at sea. Even when supplies had arrived at bases in India, further long delays resulted until the equipment reached its final destination. Radar equipment was so specialised that the want of even one small part of equipment might mean a whole set becoming non-operational as improvisations of delicate or intricate parts could often not be made on the spot.

Most heavy equipment had to be sent by rail from the ports to the various parts of the theatre, and the following are some of the difficulties which were encountered :—

(*a*) The capacity of the railways for handling freight was small, and the demand of the Services for the transport of war material had, of course, increased enormously, without a corresponding increase in facilities. Priorities had to be booked for the transport of urgent requirements, but with all Services competing for them it was obvious that even really urgent consignments might be held up pending transport of another equally urgent load.

(*b*) Dismantling of equipment was often necessary, owing to the low footbridges, narrow tunnels and gauges on routes between Bombay (the usual port of disembarkation) and other areas. Thus it happened that the chassis for large vehicles, such as those used for M.R.U./G.C.I., were separated from the main body before the rail journey began.

(*c*) As a necessary security measure, and in an endeavour to ensure the arrival of the equipment intact, escorts had invariably to be provided for each rail shipment across the country. This was a strain on manpower when there was a shortage of suitable personnel for such work.

A typical timing of rail transport, on highest priority, was thirty-five days from Bombay to Calcutta—an average of 34½ miles a day. Communications by road were often just as difficult, owing to the poor maintenance of highways and the effects of an extreme climate—heavy rainfall, for instance, causing great damage. Good roads only existed between the main cities and even these were frequently under water in the monsoon season. East of Calcutta transport was even more difficult, owing to the many waterways and low-lying waterlogged areas. During the monsoon season, May to October, road transport could not be relied upon with any certainty, as many of the roads were washed away, flooded, or in such bad repair that safe transport was impossible.

As an example, A.M.E.S. No. 383, an M.R.U., was in May 1943 to be deployed on the highest priority from Calcutta to Imphal, an air line distance of 400 miles. This convoy took seven days to get by rail to Manipur Road, the railhead. From there it took another four days by road to Imphal, a total of eleven days in all. In another case it was necessary to move A.M.E.S. No. 210 from

[1] A.H.B./IIE/203/B, " Organisation in India " (Chief Radar Officer's Report).

Chittagong to Cox's Bazaar, 60 miles, on high priority by road and rail. This journey, despite every effort made by the personnel concerned, took four days. These were priority jobs ; it will be appreciated that routine movements of technical spares (which had to follow the usual channels) took very much longer.

Often the only practicable means of transport, both for personnel and equipment, was by inland waterway. An illustration is provided by the construction and maintenance of A.M.E.S. No. 373 at Char Capli, in East Bengal. This station, built on an island, could be reached from the mainland only by barges and small launches, or occasionally a light aeroplane could be landed on a beach near the station at low tide. The practical route from Calcutta for rations and spares was by rail to Khulna (a six-hour journey) followed by a two-day steamer trip. This brought supplies to within ten miles of the island. The last ten miles had to be covered by an open boat which, owing to strong currents and winds, took a variable time in transit.

The foregoing delays were principally those encountered in India, where for two years the Allies consolidated their position before beginning their re-conquest of Burma. As the campaign gathered momentum, however, and the war progressed into Burma, the difficulties increased a hundredfold, as the distances between forward units and bases rapidly increased as the armies pressed forward.

Tropicalisation

Until the closing stages of the war in the Far East, little of the radar equipment with which the Command had been supplied was able to survive the ravages of full tropical conditions—excessive heat combined with high humidity—for a reasonable duration. Fungus grew apace within the equipment components and insulation absorbed moisture and soon broke down, whilst station equipment was for the most part unsuited to flooded sites and torrential rains. This was primarily a design fault which the most resourceful improvisation on the spot was unable to do more than mitigate partially. The technical problem had not been previously tackled properly and our own unpreparedness to meet the many transportation, siting, installation, operating and maintenance problems peculiar to full tropical conditions during the monsoon period added further to the plight of our Signals personnel. The more specialised basic training which " tropicalisation " (as it became named) involved, was not substantially embodied in the United Kingdom training curriculum until mid-1944, and Signals personnel had before then left the United Kingdom for the Far East to learn in the hard way.

Early Warning Communications

The early warning radar organisation in the Far East, in common with its associated visual observer posts (Wireless Observer Units) was dependent, as elsewhere, upon communication with filter and operational control rooms. Whereas this forms the subject of a separate narrative[1] it should be mentioned here that, in the field, torrential rains, floods and soil subsidence, falling tree branches and the depredations of natives all combined to make landlines often impracticable. Communications then had to be by W/T which, because of the mountainous nature of much of the terrain, and excessive attenuation of the ground-wave in bush and jungle, had often to rely upon scatter and hence was unreliable. Early warning suffered much from this cause.

[1] *See* Volume II, which deals with Point-to-Point Signals Organisation.

Despite the relatively late start made with the establishment of a radar organisation in the Far East in comparison with other theatres of war, an efficient raid reporting organisation was set up covering the base areas in India, while mobile radar networks for early warning and control were deployed in the tactical areas. The sequence of development had been similar to that in the United Kingdom, namely, to establish an efficient air defence using radar for early warning before paying much attention to the employment of radar offensively.

In North-East India and Burma the mobile radar with the tactical forces operated in most adverse circumstances. Within the limitations of the equipment, imposed largely by its weight, bulk and untropicalised design, the raid reporting and control was as effective as could be hoped. Nevertheless, the demand for really lightweight radar and air transportable equipment remained almost unsatisfied even to the end, a pointer to the most desirable trend for future development of radar equipments.

During the last year of the war in this theatre the Allied Air Forces held a complete ascendency over the weakening Japanese. Indeed, in the last advance into Burma the ground forces moved so rapidly that radar could not keep up with the forward units and so was not of real value in the closing stages.

CHAPTER 23

PLANNING AND PREPARATIONS FOR EARLY WARNING RADAR IN THE LANDINGS IN NORTH-WEST EUROPE (OPERATION "NEPTUNE")

Planning had occurred for a military operation against the Germans in the north of France before the United States declared war on the Axis powers.[1] American representatives had had discussions with British Chiefs of Staff in their capacity as military "observers." After the Americans declared war, one of the most important developments was the visit on 9 April 1942 of General Marshall and Mr. Harry Hopkins (President's personal adviser) to London. They met the Chiefs of Staff Committee and presented a memorandum of Offensive Operations in Western Europe, subsequently known as "The Marshall Plan." This document has a strong resemblance to the final plan for "Overlord," the code name of the operations in North-West Europe.

By May 1942 an Inter-Service Planning Staff for the invasion of Europe was formed in London. A Royal Air Force Signals representative gave initial consideration to the radar requirements for an efficient raid reporting system at this early stage. Planning and preparation for such a gigantic combined operation proceeded on low priority for nearly a year. After the Washington War Conference in May 1943 when the policy for the liberation of Europe was determined, planning was accelerated. During June 1943 the responsibility for planning the part to be taken by the Air Forces was delegated to the Air Officer Commanding-in-Chief, Fighter Command. His Chief Signals Officer, Group Captain R. G. Hart, was made responsible for the Signals planning and organisation, and had technical radar staff officers under him to assist in evolving details of the role to be played by early warning radar. Five months later, in November 1943, Headquarters, Allied Expeditionary Air Force (A.E.A.F.) was formed and the Signals Planning Staff under the Air Officer Commanding-in-Chief, Fighter Command, was joined by United States Army Air Force Officers who were integrated into the Planning Staff to ensure that both American and British ground radar problems for the campaign in North-West Europe were satisfactorily co-ordinated. A two-fold purpose was to be served by the Royal Air Force mobile radar equipment, namely, early warning raid reporting and the ground control of both day and night fighter aircraft for interception purposes. In this chapter, detailed consideration is given mainly to the raid reporting function of the ground radar organisation.[2] Previous campaigns in the Middle East had proved the value of adequate radar cover over and beyond the Allied front lines at every stage.

General Radar Organisation for the Assault Phase

The section of the French coastline selected for the landings was about eighty miles from England. Although the Home Chain stations gave radar cover to this area, the advance warning of enemy aircraft approaching the

[1] This was Operation "Round Up." An account of these plans and details of subsequent planning for operations against North-West Europe are given in the Royal Air Force Narrative "The Liberation of North-West Europe," Volume II.

[2] The ground control of fighter aircraft in North-West Europe is described in Volume V.

region would be too short to be really useful. A policy of extending the radar cover at the earliest possible moment was adopted. Three L.S.T.s (Landing Ships, Tank) were to be fitted out with G.C.I. equipment to report raids to the Headquarters Ships, the information to be used as a basis for air raid warnings and for anti-aircraft gun control.[1] Thus the radar cover was to be increased as the Allied liberation forces crossed the Channel. The Fighter Direction Tenders, as these were termed, were then to operate off the beaches to maintain the radar cover while mobile G.C.I. stations were landed from D-day onwards, to be augmented by C.O.L. stations and Light Warning Sets.[2] Thus gradually the radar cover was to increase across the Channel until the Allied bridgehead would have its own radar reporting screen independent of the Home Chain and the Fighter Direction Tenders.

The radar units to be landed in the early stages of the assault were to have the two-fold responsibility for defensive and offensive action. It had been clear from reports on operation "Husky" (the invasion of Sicily) that the raid-reporting and control of defensive fighters in the base area should not be the responsibility of composite Royal Air Force Groups which had to concentrate completely the whole of their efforts in supporting the Army. Accordingly, it was planned that under Headquarters, A.E.A.F., a Base Defence Group, No. 85 Group, was to protect the bases while the Second Tactical Air Force gave support to the armies through its Groups Nos. 83, 84 and 2.[3] All G.C.I. stations concerned with the defence of the beaches and base area were to be ultimately under the control of No. 85 Group. From the point of view of ground search radar on the far shore the chain of responsibility was thus in the form :—

H.Q., A.E.A.F.

- U.S. IX Army Air Force in the American (Western) Area, having similar radar facilities to Second T.A.F. and No. 85 Group.
- No. 85 Group, R.A.F., responsible for raid reporting and control in the Base Area.
- Second Tactical Air Force, R.A.F.
  - No. 83 Group, R.A.F.
  - No. 84 Group, R.A.F.
  - No. 2 Group, R.A.F.

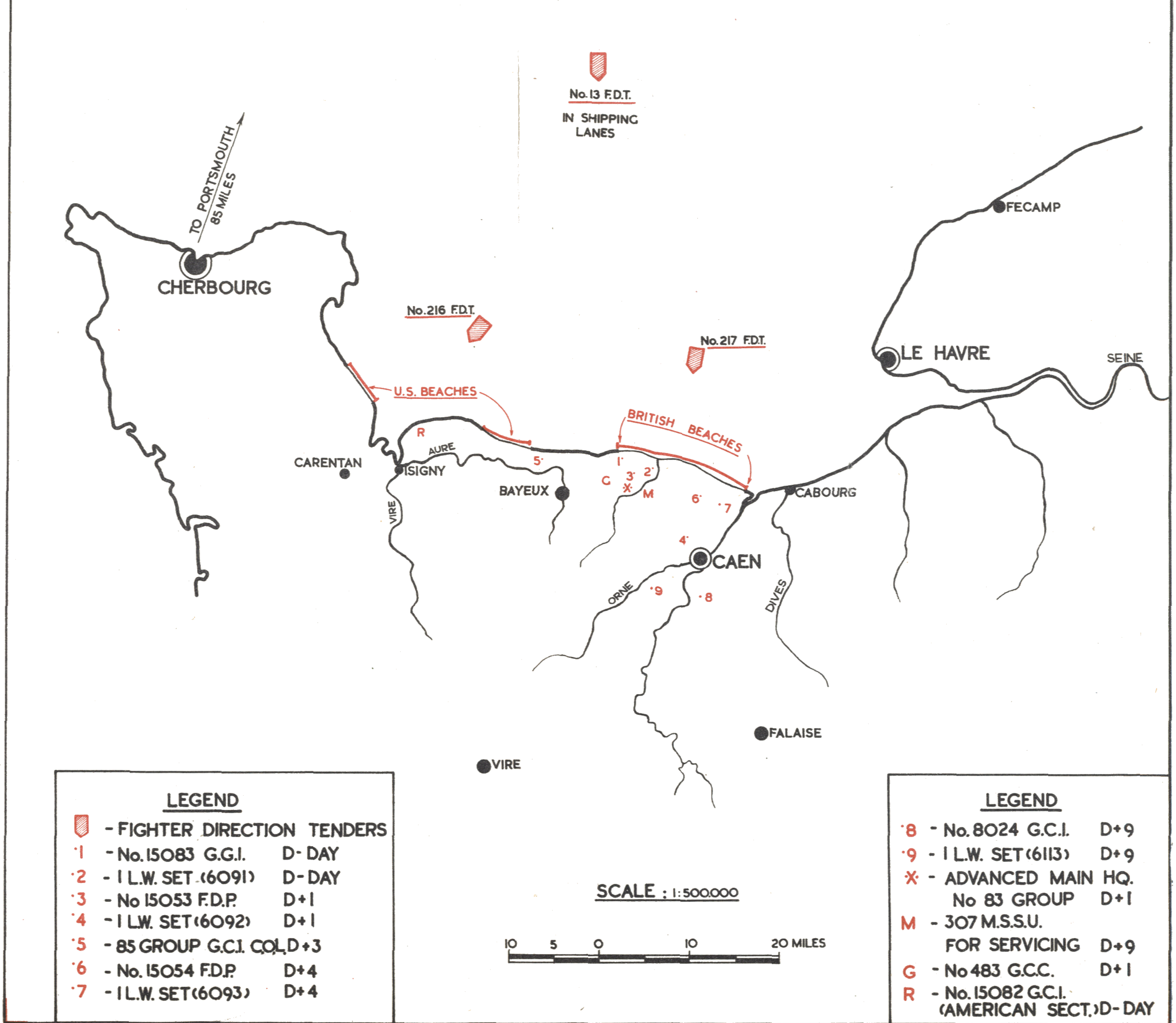
  Two composite Fighter/Fighter-Bomber Groups and a medium Bomber Group, all in support of the Armies in the British (Eastern) Area. Radar early warning and Control Units all in Nos. 83 and 84 Groups.

Given in broad outline the scheme appeared extremely simple. In practice, the co-ordination of the control of the various authorities involved, together with the provision of adequate reporting channels of telecommunication,

[1] A.E.A.F. Signals Plan for Operation "Neptune," Part II.
[2] The planned locations of F.D.T.s and G.C.I. stations on D-day are shown on Map No. 14.
[3] H.Q., A.E.A.F. File S.14005/B, para. 5.

MAP No. 14.

GROUND RADAR SITES, ASSAULT & BUILD UP STAGES.
OPERATION 'NEPTUNE'
PLAN FOR BRITISH SECTOR.



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presented a major problem of organisation. The following Commands and Groups were to be involved in supplying radar cover during the assault stage of the invasion :—

(*a*) Headquarters, Air Defence of Great Britain,[1] being responsible for the Home Chain Radar and the Fighter Direction Tenders.

(*b*) The Second Tactical Air Force, being responsible for the No. 83 Group Radar Stations to be landed during the Assault Stage on the Continent.

(*c*) Headquarters, No. 85 Group, which was to maintain an aircraft warning system in the Base Defence areas on the Continent.

(*d*) The United States Ninth Air Force—the policy for the provision of radar equipment for the Ninth Air Force was to be similar in principle to that of the Second Tactical Air Force and No. 85 (Base) Group.

The Air Commander-in-Chief, Headquarters, Allied Expeditionary Air Forces, delegated the radar responsibilities to his subordinate Commands and Groups. The details of the separate responsibilities not only involved the early warning radar but also radar Fighter Control and Airborne radar, and considerable dove-tailing was necessary to achieve an adequate organisation for such a large-scale military project.[2]

Ground Search Radar System and Equipments to be Employed

The general policy was for a radar system basically similar in principle to that used in the United Kingdom, but adapted to mobile field conditions, to be deployed on the continent as soon as possible. This involved the setting up of operations centres to which the various types of radar units, to be dispersed in Normandy as reporting stations, were to provide information on the air situation. On the basis of this information, supplemented by Intelligence and visual observation, the central operations rooms were to circulate raid information and control the Allied defensive fighter aircraft, thus co-ordinating the various types of defence. The radar equipments on the units themselves had to be allocated in accordance with the particular function which each formation was to perform, but the choice of radar equipments to be employed was also based on the assumption that there would be a considerable effort by the enemy to jam Allied radar stations. To allow for this possibility, alternative frequency equipments were issued to the radar units.

Type 15 G.C.I.

Generally, the Type 15 G.C.I. apparatus, working on the 200 megacycles per second frequency band, was to be used as the main equipment. This mobile G.C.I. station was designed to give good radar cover inland at heights above 10,000 feet, with height-finding facilities. The height-finding was dependent on the flatness of the site, the low cover it gave was poor, and the sets were limited to use by a single controller, since it was necessary to switch the transmitter over manually to one of two alternative feed points to obtain complete cover. It was quite the best mobile equipment the Allies had at the time for cover above 10,000 feet, but was very vulnerable to both "Window "[3]

[1] Headquarters, Air Defence of Great Britain (A.D.G.B.), was formed from Headquarters, Fighter Command, during November, 1943.

[2] The detailed radar responsibilities delegated by A.E.A.F. to subordinate Command and Groups are given in Appendix No. 39. (A.E.A.F. Air Signals Report on Operation " Neptune," Section VI, refers.)

[3] Volume VII, Part II, Chapter 9, gives details of " Window " interference.

and radio jamming because the frequency (209 megacycles per second) was comparatively low and was confined to a single spot value by the type of aerial array used. Perhaps the fairest criticism of the equipment from the Tactical Air Force point of view was that, in common with most British radar equipments, it had been designed for defensive purposes and the range it gave was adequate for defence. The provision of greater range involved the acquisition of far more information than could be handled by a single controller or Plan Position Indicator (P.P.I.) reader.

Type 11 Equipment

The first alternative equipment—supplied for use if the Type 15 G.C.I. were jammed—was the Type 11, which operated on the German radar frequency band of 500–600 megacycles per second. Thus, if the enemy were to resort to deliberate radio jamming of the Type 15 equipment, it was hardly to be expected that they would jam on their own radar frequency band as well.[1] The Type 11 apparatus had the additional anti-jamming advantage that it was easily tunable over the 500–600 megacycles per second frequency range. The apparatus gave plan position indications only: there were no height-finding facilities. The coverage it gave was not very satisfactory, however, and it was not independent of the site. Moreover, it was like the Type 15, vulnerable to serious interference by *Duppel*, the German "Window."

Centimetric Equipment

The G.C.I. units for Base Defence were also to be supplied with Type 21 equipment. This was composed of Type 14 Centimetre Plan Position equipment plus the Type 13 Centimetre Height-finding equipment. It worked on the ultra-high frequency of 3,000 megacycles per second and therefore had a very fine "beam," thus enabling it to see the target through "Window" by virtue of improved powers of discrimination. The Type 21 equipment was not available in quantity so it was hoped that by the date of the operation (6 June 1944) it would be possible to supply Type 13 height-finding equipment to the Second Tactical Air Force units. The combination of Type 11 and Type 13, giving plan-position and height-finding respectively, was termed the Type 22.

The alternative frequency policy for the equipment was so thorough that there was every reason for optimism that whatever radio countermeasures were adopted by the enemy, Allied radar would work successfully. In addition, C.O.L. stations to provide early warning against low-flying aircraft, Light Warning Sets which could be used in a very mobile role in forward positions, and Mobile Radio units (giving radio "floodlighting" of the base area) were also included in the equipments to be employed in the bridge-head.

Planning of Radar Units to take part in the Assault and Build-Up Stages of Operation "Neptune"

The types of mobile radar and Signals units chosen had to be capable of being landed over beaches. The whole radar organisation had to be designed in such a manner that it would fit in with, and act as an extension of the static radar early warning system in the United Kingdom, so that it could be transferred to the far shore without any break in the continuity of either warning or control. It also necessitated careful pre-selection of detailed sites on French soil, the selection of frequencies which could be used at sea and on

[1] A.E.A.F. Signals Plan for Operation "Neptune," Part V.

the near and far shores with the minimum probability of mutual interference, and an early definition in the planning stages of the shipping space required for the build-up of the mobile radar and Signals units to be transferred from the United Kingdom to the theatre of operations.

In considering these requirements it was necessary to differentiate between the roles of the radar units attached to the Air Forces operating in support of the Armies in the field and afloat and those which would be employed solely for defence. Thus the Headquarters Ships, the Composite Groups (Nos. 83 and 84), Control Centres and the Ninth U.S. Air Force Fighter Control Centres were designed from the air point of view for the control of air support, and the Fighter Direction Tenders and the Base Defence Sectors of No. 85 Group for the control of air cover over the bridge-head area and shipping lanes. The Royal Air Force radar units formed for the invasion may therefore be divided according to their three broad purposes :—

(*a*) The Fighter Direction Tenders (F.D.T.s). These were three Landing Ships, Tank (L.S.T.s) fitted with G.C.I. equipment, to extend radar cover across the English Channel as the Assault Forces moved towards the French coast, and then to provide radar early warning over the bridge-head until the time when the mobile radar units were adequately established on French soil.

(*b*) Base Defence radar units under the control of Headquarters No. 85 Group. As their title suggests, these units were to give cover to the bridge-head in protection of the beaches and the base dumping areas—and later the ports, as they were established.

(*c*) Mobile radar units under the 2nd Tactical Air Force in Nos. 83 and 84 Composite Groups for the control of aircraft and early warning in the respective Group areas in support of the 21st Army Group. This latter comprised the British Second Army and the Canadian First Army—generally No. 83 Group worked with the British and No. 84 Group with the Canadians.

A similar organisation existed in support of the United States forces.

Under the above broad division of the Radar Units to be employed in operation " Neptune " it is advisable to consider the function of each type in more detail, together with their formation and training in the United Kingdom to prepare them for their important invasion roles.

Royal Air Force Ship-Borne Radar—Fighter Direction Tenders Plans and Preparations

The idea of using ship-borne Royal Air Force Radar apparatus for raid reporting and the control of fighter aircraft was first put into effect during the Sicilian invasion in July 1943, when a Landing Ship, Tank, L.S.T. No. 305, had been fitted up with G.C.I. equipment in England and sailed for the Mediterranean. The results obtained in this campaign had been so encouraging that the Air Officer Commanding-in-Chief, Fighter Command, requested that four similar vessels should be ear-marked for fighter direction and air warning purposes for use in any combined operation launched from the United Kingdom against the Continent of Europe.[1] During October 1943 it was decided that three L.S.T.s should be provided and that they were

[1] H.Q., A.E.A.F., Report on the role of H.Q. Ships and F.D.T.s in Operation " Neptune."

to be fully equipped both as regards interception and radar reporting. The plans and specifications were produced within two weeks. All three were converted in eight weeks, being ready by the middle of February 1944.

The work was a major conversion involving the laying of a new deck over the original tank space, under which there was an Operations block comprising the Filter Room, Communications Office, Cypher Office, Air Control Room and Radar Receiving Room. Forward there was a Direction Finding Office in which a Naval Type D/F equipment could be operated. Aft on the tank deck were the Transmitter Room, Transreceiver Rooms, Aircraft D/F (R.A.F. V.H.F. equipment), Radio Counter-measures Office and W/T storeroom. Above, a Bridge Visual Direction position and a Bridge Plot House were constructed, above and aft of the compass platform.

Radar Installations

As soon as the constructional alterations were complete each F.D.T. was equipped with Type 15 G.C.I. apparatus. The aerial system for this was mounted on a gantry in the forecastle, as far forward as practicable, but the effective height was about 30 feet only, rendering accurate height-finding by the G.C.I. method impossible.[1] The transmitter was completely waterproof, installed forward in a room of steel-plating on the forecastle, with the shortest practicable aerial feeder system, while a standard receiver was fitted in the Radar Control Room with a remote cathode ray tube in the main Operations Room. As an alternative equipment for use if serious jamming were experienced on the 200 megacycles per second frequency band of the Type 15 G.C.I. equipment, Type 11 apparatus was also installed.[2] Its aerial system and transmitter were installed approximately amidships, sufficiently far behind the main G.C.I. aerial to ensure the minimum blind areas, both fore and aft. The receiver provision was similar to Type 15 arrangement. A frequency of 580 megacycles per second was selected for the Type 11 equipment with an alternative frequency of 520 megacycles per second in case of jamming. If this latter were also jammed, a further frequency change to any in the band 500–600 megacycles per second could be made without reference to higher authority.

Mark III interrogator/responser I.F.F. equipments[3] were installed in each Fighter Direction Tender for both the Type 15 and Type 11 G.C.I. apparatus. This I.F.F. equipment was to be used only to make deliberate interrogations to determine whether an aircraft was friendly or not after all Air Movement Liaison Section information had been considered—the apparatus was not to be left to transmit indiscriminately. In order to assist in the control of Night Fighter aircraft, A.I. beacons were also installed in the Fighter Direction Ships. For the communications, both V.H.F. R/T and W/T equipments were fitted to give adequate channels of communication.[4]

Planned Role and Disposition of F.D.T.s

The Fighter Direction Tenders, numbered 13, 216 and 217, were to have the dual purpose of a raid reporting role and the control of fighter aircraft during the assault stage of the operation. The early warning Radar information was

[1] A.E.A.F. Air Signals Report on Operation " Neptune," Section IV, p. 4.

[2] A.E.A.F. File S.14111, Encl. 1A, and A.H.B./IIM/683/1A, " No. 11 Group and IX Fighter Command Joint Air Plan for ' Neptune ' " (11G/TS.500/126/S.A.S.O.), Appendix " L."

[3] *See* Volume V, Part 1, Chapter 3, for details of Mark III I.F.F. interrogator/responser equipment.

[4] Appendix No. 40 indicates the telecommunications provided.

to be passed to Headquarters Ships, which were directly responsible for the issue of Air Raid Warnings and Anti-Aircraft Control. There were three Headquarters Ships, each with a stand-by, to take part in the operation, one for each of the three British landing beaches.[1] The stand-by H.Q. Ships were provided with sufficient communications equipment to take over from the H.Q. Ships in event of the latter becoming casualties. No Royal Air Force radar equipment was installed in the Headquarters Ships themselves but the standard Naval radar equipment was available for Fleet Air Warning purposes. This information was to be used to supplement Radar information received from the Fighter Direction Tenders, which were to pass their plots to H.Q. Ships by W/T. One F.D.T., No. 217, had, in addition, the latest type of Radar Console display just off production, the " Flicker " Console, which was expected to act as an anti-" Window " device if the enemy resorted to this counter-measure against the Allied raid reporting organisation.

During the assault phase it was planned that the three F.D.T.s should be positioned as follows :—[2]

(*a*) *No. 216 F.D.T.*—Suitably positioned seaward of the American beaches in the western half of the Assault Area ; giving raid reporting facilities and controlling American and British fighter aircraft detailed to operate in this area.

(*b*) *No. 217 F.D.T.*—Positioned seaward of the British beaches in the eastern half of the Assault Area for similar purposes to No. 216 F.D.T. This ship was to be the main co-ordinating F.D.T. or " Master " Control, having the Senior Air Representative on board, for reinforcing any part of the shipping lanes or beaches on receipt of raid reporting information by switching fighter aircraft from one Assault Area to another—depending on which part of the bridgehead was being attacked by the enemy forces.

(*c*) *No. 13 F.D.T.*—Was to be positioned in the main shipping route for early warning and control of fighter aircraft giving defensive cover to our shipping lanes.

Plans were very flexible in relation to the possibility of any of the F.D.T.s being put out of action. There was a policy of each being able to double its function with that of another, and, in addition, three other British vessels and one American—each with a Royal Air Force Controller on board—could be called upon to provide additional emergency control facilities.

Fighter Direction Tenders were to be under the command of the Allied Naval Commander-in-Chief, Expeditionary Force, or such other Naval Commander as he ordered. During the operation " Neptune " they were to be placed under the command of the Task Force Commanders while operating in the Assault Area. The Captain of each F.D.T. was to be responsible for placing his ship in the best position for her duties as stated by the Senior Royal Air Force Officer, subject to his Naval orders and considerations of safety of his ship permitting.

The Senior Royal Air Force Officer was responsible for the operation and efficiency of all the Royal Air Force equipment on board and had disciplinary powers over the Royal Air Force personnel operating the radar and communications equipment, and the Control Officers who were to control fighter aircraft.

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[1] Map No. 15 shows the locations of the Headquarters Ships off the three British beaches, " Gold," " Juno " and " Sword."

[2] Map No. 15 shows these locations on a map. The plans are given in A.H.B./IIM/683/1A, " No. 11 Group and IX Fighter Command Joint Air Plan for ' Neptune,' " p. 11.

The Senior Royal Air Force Officer on board No. 217 F.D.T. was to be the direct representative of the Air Officer Commanding, No. 11 Group, who was to be initially responsible for fighter cover in the Assault Area.

Trials of technical installations were carried out in the Ailsa Craig area during March 1944, when calibration of the radar equipment was undertaken and R/T and W/T tests of the communications channels were completed.[1] The Type 15 G.C.I. all-round coverage was good and, on the whole, the performance of the equipment left very little to be desired. The Type 11 results from an operational point of view were most disappointing, being "blind" whilst looking 20 degrees either side of the ship's bows. The only method of improving performance was to increase the Type 11 aerial height, and this modification was undertaken immediately.

Following the acceptance of the F.D.T.s after their technical trials, they were sailed round the north of Scotland to the Humber, giving an excellent opportunity for the Royal Air Force personnel to gain their sea-legs.[2] The ships were attached to the Flag Officer-in-Charge, Humber, so that working-up training could take place in that area. During April 1944, for this training, the ships operated under the requirements of the Senior Royal Air Force Officer on board each ship, the broad outline of the training of the Air Force crews being laid down by Headquarters, Allied Expeditionary Air Force.

Training exercises were carried out in conjunction with the Fighter Sector Station at Church Fenton, the aircraft employed being those of No. 85 (Base) Group Squadrons.[3] During these exercises, under the code-name "Driver," the ships operated as far as 40 miles out to sea. Day and night exercises were held, including some in which "Window" was used against their radar equipment. At the beginning of May, in the opinion of the Air Officer Commanding, No. 12 Fighter Group, the standard of Fighter Control of the F.D.T.s was not up to expectations and a number of minor technical troubles had limited the scope and usefulness of the training. Time was short—the target-date for all operation "Neptune" preparations was 31 May 1944—so the ships were moved south and placed under the Air Officer Commanding No. 11 Fighter Group for further training, exercises being arranged in co-operation with the Naval Commander-in-Chief, Portsmouth and the Flag Officer-in-Charge, Portland.[4]

In comparison with the mobile (ground) radar units, the training-time of the radar and signals personnel at sea in the F.D.T.s had been less than three months, of which a considerable portion had been spent ashore. The Air Officer Commanding No. 85 (Base) Group, from which Group aircraft had been co-operating with the F.D.T.s, was of the opinion in May 1944, that training had only progressed very slowly because of the dual responsibility of Chief of Combined Operations and the Headquarters, Air Defence of Great Britain for these exercises.[5] Whether the duration of the training had been adequate or not could only be estimated by the ultimate performance of the F.D.T.s in the initial stages of operation "Neptune," for which the ships were standing-by at the end of May.

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[1] A.E.A.F. File S.14111, Encl. 14A.

[2] The total complement of R.A.F. personnel on board was 14 officers and 164 airmen. The Naval crew consisted of eight officers and 92 ratings. (*See* Appendix No. 41.)

[3] A.E.A.F. File S.22269, Encls. 43A and 48A.

[4] A.E.A.F. File S.17042, Encl. 46A.

[5] A.E.A.F. File S.22269, Encl. 42A.

Radar Units in Second Tactical Air Force—Plans and Preparations

The ultimate requirement of mobile ground radar and signals units for invasion purposes had been foreseen by Air Ministry, and during 1942, under Headquarters No. 26 Group, mobile radar equipments had been produced and personnel formed into units at the Royal Air Force Stations, White Waltham and Chigwell. It was from this source that the mobile radar units for operation "Torch" (the invasion of North-West Africa) had been drawn. Units in excess of immediate requirements had been formed, including No. 2 M.O.R.U. (Mobile Operations Room Unit) and No. 102 M.A.R.U. (Mobile Air Reporting Unit)—this latter having G.C.I. stations and Wireless Observer Units to provide a radar air reporting system under mobile campaign conditions overseas.[1]

During the second week in February 1943 a composite Royal Air Force Group, termed "Z" Group, was formed to take part in a large-scale combined field exercise, "Spartan," with the First Canadian Army in the south of England.[2] The composite Group consisted of several Wings of aircraft and was completely mobile and self-supporting in the field, having its own equipment, servicing, administrative, operational control and air raid reporting organisations. No. 2 M.O.R.U. and No. 102 M.A.R.U. provided the last two facilities during Exercise "Spartan." The Group was kept in being after the exercise and re-named No. 83 Group, continuing until January 1944, in association with the Canadian Army in training in Southern England. A second composite Group, No. 84, was formed on 14 June 1943, for the British Second Army. The two Groups were interchanged in January 1944, No. 83 Group providing tactical air support for the British Second Army and No. 84 Group for the Canadian First Army, both intensively preparing for the impending invasion of North-West Europe. Both No. 83 and No. 84 Groups (Fighter and Fighter-Bomber) came under the control of Headquarters, 2nd Tactical Air Force, together with No. 2 (Medium Bomber) Group. The latter Group had no early warning and control radar units established in it.

Throughout the early training in 1943, the radar units were under the major parent unit, the M.A.R.U., which filtered all radar information and passed on the complete picture of aerial activity to the M.O.R.U. On the basis of this information the latter unit controlled fighter aircraft. This was following the then current practice adopted for the invasion of Sicily. No. 83 Group was fully operational in the field in south-east England while training, its squadrons operating under "mobile" conditions, initially under Headquarters, Fighter Command. During these operations, the air raid reporting system based on M.A.R.U. was found to be cumbersome in practice. Delays were occurring due to the involved telecommunications system necessitated by the segregation of the Filter Room from the Operations Room. Accordingly M.A.R.U. was abandoned on 1 August 1943, and its associated radar units were attached directly to No. 483 Group Control Centre—as No. 2 M.O.R.U., with its increased establishment, became termed.[3] The radar units reported directly to the Group Control (G.C.C.) for both raid reporting and interception purposes.

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[1] Royal Air Force Stations, Chigwell and White Waltham, O.P.B.s.
[2] A.H.B./IIM/684/1A, Encl. 1A.
[3] No. 483 G.C.C., O.R.B.

Both No. 83 and No. 84 Composite Groups had their own Group Control Centres, and the following radar stations with crews trained as mobile units in the field were established for each Group :—[1]

	Total Units.
Forward Director Posts	3
G.C.I. Units	1
Light Warning Sets	5

Each Forward Director Post, which was capable of taking over control of Allied fighter aircraft operating in support of the Army, consisted of Type 15 and Type 11 G.C.I. equipments. Type 13 Centimetric Height-Finding equipment was also to be supplied to these units, but only one such equipment was to be available before the operation " Neptune " began ; the remaining outstanding equipments, in production, were to be provided within two months of operations on the Continent. The Light Warning Sets were of the latest types (Type 6, Marks III and V, operating on 212 and 600 megacycles/per second frequency bands) mounted in signals trucks. These were highly mobile for use in forward areas to give the maximum warning of air attack, and augmenting the low cover of the Forward Director Posts. They had a range of approximately 60 miles on aircraft at 10,000 feet.

Radar Units in No. 85 (Base Defence) Group

In order to provide air cover over the beaches and approaches, including the shipping lanes, after our forces were established on the Continent, No. 85 Group was divided into three Base Defence Sectors. It was decided that the two G.C.I. Type 25 A.M.E.S. of the advance echelons of two of these sectors would land on D-day, one in the British (eastern) area and the other in the American (western) bridge-head. As the bridge-head was expanded the third Base Defence Sector could then be introduced. Each of the Base Defence Sectors was to be provided with the following radar crews :—[2]

	Total Units.
G.C.I. (A.M.E.S., Type 25)	3
C.O.L. Stations	2
Centimetre Plan-Position Stations (Type 14)	2
Mobile Radar Unit (A.M.E.S. G.T.)	1

In case of the Type 25 A.M.E.S. which, it will be recalled, provided three Radar G.C.I. channels, the crew was so constituted that all channels could be operated simultaneously. The policy for the provision of radar equipments for the United States Ninth Air Force was similar in principle to that of the Second Tactical Air Force and No. 85 (Base Defence) Group. The provision of this equipment was a British responsibility.

Detailed Plans of Radar Early Warning During the Assault and Build-Up Stages of Operation " Neptune "

It was planned that two complete G.C.I. Units of No. 85 Group were to land about mid-day on D-day, one in the British (eastern) Assault Area, No. 15083 G.C.I., and the other, No. 15082 G.C.I., in the American (western) Assault Area. Both were to have an associated L.W. Unit to be used to fill any gaps in

[1] Appendix No. 42 gives the Unit allocation to each Group in detail. These establishments are shown in the A.E.A.F. Air Signals Report on " Neptune," Section VI, p. 2.

[2] Appendix No. 42 gives the allocation of Units to each of the Base Defence Sectors. These are given in A.E.A.F., " Air Signals Report on Operation ' Neptune,' " Planning and Assault Phase, Section VI, para. 3.

the G.C.I. coverage and provide a degree of cover against low-flying enemy aircraft. The requisite Mobile Signals Units[1] to supply W/T and R/T communications were also included from No. 83 Group Units in the landing schedules. The G.C.I. stations were both to open watch as soon as possible and establish communications with their appropriate Fighter Direction Tenders.

The G.C.I. stations were to act initially as satellites to the " Master " Fighter Direction Tender, No. 217 F.D.T., in the Assault Area. The G.C.I. station (No. 15083) in the British area was to be built up with sufficient signals equipment as soon as possible to enable it to take over duties as " Master " Control Point in the Assault Area.[2] This was to be effected in two stages : firstly taking over Low Cover, *i.e.*, controlling by R/T British fighter aircraft providing defence against low-level attack on the beaches, leaving High Cover fighter aircraft under the control of No. 217 F.D.T.[3] After having taken over such control successfully they were to set up R/T facilities to take over also on High Cover. Full radar raid reporting and control would then pass to the G.C.I. stations sited in the Normandy bridgehead. When this take-over had occurred, the G.C.I. in the American area and the Fighter Direction Tenders were to act as satellites to the " Master " G.C.I. station in the British area.

During the initial phases, all No. 85 Group Units on the Continent were to be under the control of the 2nd Tactical Air Force until such time as No. 85 Group Headquarters was set up on the Continent.[4] No. 83 Group was being employed as the spearhead of the 2nd Tactical Air Force, so that the Air Officer Commanding, No. 83 Group, was given the responsibility for all Royal Air Force units in the bridgehead.[5] His Group Control Centre, No. 483 G.C.C., was phased in early and when it had been established on the Continent it was to act, in conjunction with the " Master " G.C.I., as the " Master " Control on the Continent.

The build-up of the radar units on French soil was to be as follows. Two Fighter Director Posts, Nos. 15053 and 15054 F.D.P.s, were phased to land on D + 1 and D + 4 respectively. These had full G.C.I. facilities, so the former unit was to act as stand-in for No. 15083 G.C.I. whilst No. 15054 F.D.P. took over the direction of fighter aircraft in the forward areas. Each had associated Light Warning Sets and Wireless Observer screens. Altogether, by D + 14 it was planned to have a total of nineteen radar units operating in Normandy, so the scale of provision for Royal Air Force raid reporting and control organisation could be said to be lavish in comparison with previous landing operations in North-West Africa, Sicily and Italy.[6]

Siting of Radar Units in Normandy

Close examination of the area in Normandy in which operation " Neptune " was to be conducted revealed that good radar sites were not plentiful.[7] The two main areas of high land were divided by the rivers Orne and Dives, with maximum heights of over 1,300 feet. In such undulating country radar

[1] The telecommunications to be provided for No. 15083 G.C.I. in the British Assault Area are given in Appendix No. 43.

[2] A.H.B./IIM/683/1A, No. 83 Group, R.A.F. " Neptune " Operations Plan, 83 Adv. /T.S.2382/Air Plans, 13 May 1944, p. 4.

[3] *Ibid.*, No. 11 Group and IX Fighter Command Joint Air Plan for " Neptune," Appendix " D," p. 14.

[4] A.E.A.F. File S.13441, Encl. 19A.

[5] A.H.B./IIM/683/1A, No. 83 Adv./T.S.2382/Air Plans, p. 4.

[6] A.E.A.F. File S.13441, Encl. 64A.

[7] The bridgehead area and the sites selected for radar units are shown in Map No. 14.

equipments would experience severe restrictions in coverage due to permanent echoes, unless well screened sites were selected. The two major requirements of a suitable site, good screening and sufficient flat ground for height-finding, were difficult to find together and in many cases a compromise of ideal conditions had to be accepted.[1] All sites planned for the early stages in the bridgehead had to be selected with only contour maps and aerial photographs for guidance. Not only had the problem of sites technically suitable to be faced, but also the question of approach roads, as the G.C.I. equipment, though mobile, was heavy and cumbersome.

The third controlling factor was the danger of mutual radio interference during the first few days of the invasion. A great many radar and radio stations of all types were to be operated within the narrow confines of an initially-small Allied bridgehead in Normandy and immediately off the beaches. For this reason intensive efforts were made during the planning stages to co-ordinate the initial siting requirements of all Services. Much assistance was forthcoming from the Mutual Interference Sub-Committee of the Combined Signals Board. The terms of reference of both the Board and Sub-Committee were extended to include provision for radar operation, because the Royal Air Force Air Signals Officer-in-Chief, A.E.A.F., unlike the Army Chief Signals Officer, was responsible for radar as well as for communications. In some cases it was necessary to reduce the spacing between a few units in the bridgehead below the distances normally acceptable as a result of exhaustive exercises on mutual interference between stations held previously in the United Kingdom. A firm regulation was therefore laid down that changes of site were not to be made up to D + 9 unless the need was found to be absolutely imperative from an operational view point. Even then the movement was to be kept to a minimum.

Of the sites selected by the Planning Staff for the original locations of the radar units involved in the assault and build-up stages, the only really good site was to be occupied by No. 15083 G.C.I. in the British area. This site was expected to give good height-finding facilities and very few permanent echoes, and using Type 21 G.C.I. equipment, cover and height-finding in face of enemy jamming. It was for this reason that this station was selected to take over "Master" control from Fighter Direction Tender No. 217 as soon as possible after landing. The responsibility for the selection of later sites rested with the Chief Signals Officers of the respective Groups, acting upon the advice of their radar specialist officers. Tactical Air Force Staff instructions laid down siting limitations conforming to operational requirements of these stations. The G.C.I. stations were the most difficult to site of all, so these were given priority over everything except airfields.[2]

The Early Warning System in the Bridgehead

All the sources of information for the control at No. 483 Group Control Centre were to be :—[3]

(*a*) G.C.I.s, including the Fighter Direction Tenders off the beaches and G.C.I./C.O.L.s in the bridgehead.

(*b*) Broadcasts from the United Kingdom dealing with long-range enemy aircraft movements observed by the Home Chain Radar Stations.

[1] 2nd Tactical Air Force Signal Instruction for Operation "Neptune," Part VII, Section 1.
[2] A.E.A.F. Signals Plan for Operation "Neptune," Part V, para. 411.
[3] *See* Appendix No. 44 for a schematic diagram of the radar reporting and air warning W/T communications.

(c) Warnings from warships via the liaison telecommunications channels.
(d) Light Warning sets in the bridgehead.
(e) Wireless Observer Unit posts in the bridgehead.

The build-up of the warning system in the British sector was to have all its essential elements installed by D + 5.[1] The W.O.U. posts and L.W. sets were to be phased in early so as to be available for deployment as soon as the tactical situation in the bridgehead permitted.

Functions of the Elements of the Early Warning System

For reporting purposes to the Group Control Centre the following were the functions of the various elements in the field :—

W.O.U. Posts	To recognise all aircraft within visual range and report their position, estimated height and direction of flight. Each post consisted of three airmen specially trained in Observer Corps recognition procedure. These posts were pushed well forward and reported back in a simple code by W/T.
L.W. Sets	To report the range and bearing of all aircraft, with particular reference to low-flying aircraft.
G.C.I. Stations ..	To report the range, height and bearing of all aircraft especially high-flying aircraft.

It was the intention that whenever possible G.C.I. and L.W.S. were to be sited in proximity and connected by landline to give " combined plotting " facilities through the G.C.I. station to the Group Control Centre.

Priority of Reports

In order that the maximum amount of useful information might be passed by the Radar Units to the Group Control Centre, the priority of information to be passed by each station was laid down as :—[2]

(a) Hostile aircraft approaching Allied territory.
(b) Aircraft showing a distress signal (S O S) by means of its I.F.F. equipment.
(c) Unidentified aircraft approaching Allied territory.
(d) Hostile and friendly aircraft intermingled.
(e) Hostile aircraft flying towards enemy territory.
(f) Unidentified aircraft flying towards enemy territory.
(g) Friendly aircraft flying towards Allied territory.

Use of I.F.F. in Operation " Neptune "

During the early stages of planning for operation " Neptune " it was evident that the only radar identification equipment which was to be available was the Mark III and Mark IIIG I.F.F. systems. All aircraft which were to be used in the operational area were therefore equipped with Mark III I.F.F. Transponders, arrangements having been made for the provision of Mark III I.F.F.

[1] A.H.B./IIM/683/1A, No. 83 Group " Neptune " Operations Plan, p. 13.
Appendix No. 45 gives details of the build-up of the early warning system and the units involved.
[2] A.H.B./IIM/684/1A, No. 84 Group Standing Operational Instructions.

Interrogators at all the ground radar stations of the Allied Expeditionary Air Force and in the Fighter Direction Tenders. These latter were highly beamed in an attempt to improve the identification system, as Mark III I.F.F. suffered from a number of serious technical limitations.

The Royal Navy relied entirely on the Mark III I.F.F. system for the identification of friendly surface craft at night. During the later stages of planning it became obvious that the identification system was likely to become completely saturated if all the transponders were switched on and the unrestricted use of interrogators was permitted.[1] It was feared that if the I.F.F. system were to become saturated, the Navy would be unable to determine the identity of enemy surface forces in sufficient time to prevent serious attacks upon our shipping during the assault phase. A Technical Working Sub-Committee of the Combined Signals Board was set up in April 1944 to go into the radar identification problem fully. Rules for the imposition of restrictions on the use of Mark III I.F.F. were drawn up for the Royal Air Force in an attempt to ensure that the Naval interrogation system would work satisfactorily during the opening phases of the invasion.[2]

Air Defence of the Bridgehead in Relation to Radar Reporting

The policy for the defence of the bridgehead in the early days of the operation was tempered by the fact that it was reasonable to expect that from the outset the Allies would have a measure of air superiority over the beaches and would be able to maintain strong fighter aircraft cover over vital areas during daylight hours. The primary form of defence by day was therefore to be fighter aircraft operated in accordance with information from the radar raid reporting system.[3] Light A.A. weapons and balloons were only required to assist in protection against low-flying enemy air attacks. All fighter aircraft, A.A. artillery, searchlights, balloons and smoke in the British sector were therefore to be controlled by the Air Officer Commanding, No. 83 Group as soon as :—

(*a*) Reliable communications had been established to effect operational control.

(*b*) The Royal Air Force early warning system was in operation.[4] During the initial stages, control was to be exercised by the " Master " Fighter Direction Tender, No. 217 F.D.T., through its Headquarters Ship H.M.S. *Largs*.

Based on information from the radar raid reporting organisation, the night defence of the bridgehead was to be by G.C.I. controlled night fighter aircraft using A.I. equipment, supported by high-level A.A. fire concentrations in vulnerable areas only.[5] Night raid warnings were given by searchlights making two complete revolutions clockwise followed by two complete revolutions in an anti-clockwise direction. The " Raiders Passed " signal was the search-light beams exposed vertically and blinked four times, repeated after a five-seconds pause.

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[1] A.E.A.F. Air Signals Report on Operation " Neptune," Section VII.
[2] The full account of I.F.F., Mark III, is given in Volume 5, Part 1.
[3] A.H.B./IIM/683/1A, British H.Q., 21st Army Group, Initial Joint Plan " Neptune," N.J.C. 1004, Appendix " X."
[4] *Ibid.*, No. 83 Group " Neptune " Operations Plan, p. 9.
[5] *Ibid.*, Appendix " F " to No. 30 Corps (Army) Operation Order No. 1, 3 May 1944.

Coast Defence Radar

The Army were to be responsible for the initial establishment of Coast Defence Radar against surface vessels on the far shore and for passing the information received at these stations to the Naval officers-in-charge and the U.S. port commandants ashore.[1] The Naval radar shore stations set up in the initial phase of the invasion were to operate only so long as they were required for Naval tactical purposes. During the assault and build-up stages on the Continent the Royal Air Force had no operational commitments for coast defence radar equipment.

Field Training of 2nd T.A.F. and No. 85 Group Units

Those radar units to be actively employed in the assault and build-up stages of operation " Neptune " were well trained to operate under field conditions. Many exercises were held, including amphibious operations, and the personnel were commando-trained at the Combined Operations School, H.M.S. *Dundonald*.[2] All personnel could be regarded as toughened fighting men as well as skilled technical tradesmen, and were well armed with automatic weapons. In addition, every man on each unit had been trained to drive all types of vehicles employed. This training involved " Wet-shod landings " —driving vehicles fully waterproofed, down the ramp of Landing Craft (Tank) into an average depth of three feet six inches of water and up the beaches—an accomplishment even for an experienced driver.

Servicing Organisation in the Field for Radar Units

Each radar unit establishment included sufficient mechanics among the personnel for normal day-to-day servicing of their equipment. For repairs and servicing beyond the capacity of the units, there was in each Group a Mobile Signals Servicing Unit with a radar section capable of handling all but the most major repairs to the radar equipments in use.[3] These M.S.S.U.s were trained in the field—the first of them, No. 307, being formed at the Royal Air Force Station, Chigwell in March 1943.[4] Each M.S.S.U. was linked by W/T, and often by telephone, so that Radar and Signals units could request assistance. A fleet of servicing vans was held on each M.S.S.U. and on receipt of a call for assistance, a servicing van carrying requisite spare parts and highly-skilled and experienced mechanics would visit the unit concerned.

Behind the M.S.S.U. organisation within each Group, a Base Signals and Radar Unit (B.S.R.U.) was formed under A.E.A.F.[5] This Unit, No. 1 B.S.R.U., was responsible for repairs beyond the capacity of the M.S.S.U.s and all major modifications to radar and signals equipment in 2nd T.A.F. and No. 85 Group. The B.S.R.U. was intended to move over to the Continent only after considerable ground had been gained by our forces. In the initial stages only one M.S.S.U., No. 307, was to land in Normandy and service all Royal Air Force ground signals and radar equipment irrespective of the Group to which it belonged, until such time as other M.S.S.U.s were phased into the bridgehead.

[1] A.H.B./IIM/683/1A, British H.Q., 21st Army Group Initial Joint Plan " Neptune," N.J.C. 1004, p. 19.

[2] A.E.A.F. Files S.14395, 14397, 14398, 14399 and 14400 give details of the exercises.

[3] These Units were No. 307 M.S.S.U. in No. 83 Group, No. 308 M.S.S.U. in No. 84 Group, No. 309 M.S.S.U. in No. 85 Group and No. 311 M.S.S.U. in No. 2 Group.

[4] No. 307 M.S.S.U., O.R.B.

[5] A.E.A.F. Signals Plan for Operation " Neptune."

Water Proofing of Radar Equipment

All the vehicles of the earlier radar units involved in the assault and build-up stages of the invasion would have to make wet-shod landings. This not only involved the complete water-proofing of the vehicle itself so that it would run with its engine and gear-box under water. The contents of the technical vehicles all had to be waterproofed too. Waterproof canvas bags were made to contain the equipment and sealed off round it. Cracks in floors, window-frames and doors were all sealed up with grease and Bostick, and every precaution was taken to ensure that when a wet-shod landing into more than three feet of water occurred, the equipment would be landed without damage from sea water.[1]

Concentration of Radar Units for the Operation

The waterproofing of radar equipment was completed during the last week in May 1944, and the radar units required for the initial stages of operation " Neptune " went into concentration at the Royal Air Force Station, Old Sarum, where the vehicles themselves had the major portion of their water-proofing completed. The personnel were " sealed off " from the outside world at Old Sarum and then briefed as to the date of the operation, their landing craft, date of sailing and probable locations if the initial struggle for the beaches went according to plan. During the first three days of June the units passed through Army transit camps en route for embarkation and eventually embarked with their equipment on Landing Craft (Tank) and Landing Ships (Tank) on 3 June 1944. The final 10 per cent. of the vehicle waterproofing was then applied ready for the landings on the far shore.

From the radar point of view everything was ready for the momentous days ahead in the Normandy bridgehead. The units were well trained, personnel were extremely keen, and morale was high. Nowhere did failure appear to be remotely contemplated ; the preparations had been so detailed and thorough that a deeply impressive atmosphere of quiet confidence prevailed, unimpaired by the tedium of the waiting days in the " Sausage Machine," as the Concentration, Transit Camp and Embarkation stages were called by the personnel passing through.

The long months of preparation and waiting since Exercise " Spartan " in February 1943 were over at last, as the greatest concentration of warships and transports in history sailed from British ports on 5 June 1944. Occupying what seemed an almost insignificant portion of the cargo-space in this formidable array of Naval strength were the radar units and their associated tele-communications Mobile Signals Units, selected to be the nucleus of the Royal Air Force radar early warning and control organisation on the Continent.

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[1] A.E.A.F. File S.14093.

CHAPTER 24

RAID REPORTING RADAR DURING OPERATION "NEPTUNE"

It will be recalled that during the original stage of the planning, the code name for the entire campaign to be undertaken in North-West Europe had been Operation "Overlord." Later the term Operation "Neptune" was introduced to cover the early phases of Operation "Overlord," namely, the assault and build-up of the Normandy bridgehead. The assault stage is generally regarded as being up to D + 3 from the aspect of heaviest Allied air activity, while Naval accounts used the same term to indicate the first two and a half weeks of the operation. It is therefore considered advisable in this narrative to avoid the rather indeterminate "Assault stage" in connection with the setting up of radar cover off the beaches and on the far shore. A more explicit chronological subdivision of Operation "Neptune" from the point of view of Royal Air Force ground radar will be used in this chapter, considering the early warning system in three phases :—

(*a*) On D-day.

(*b*) Between D + 1 and D + 6, during which period control passed from the Fighter Direction Tenders to No. 483 Group Control Centre on the far shore ; and

(*c*) The build-up of radar units in Normandy to give a complete raid reporting organisation.

Fighter Direction Tenders

D-day was planned originally for 5 June 1944 but adverse weather caused a postponement of twenty-four hours. The Fighter Direction Tenders sailed with the Assault Task Forces at 2200 hours on 5 June, in sea conditions which were not good initially.[1] It seemed that, making allowances for the smaller craft, H-hour[2] would be late. However, the sea improved towards the early morning so the Fighter Direction Tenders reached their anchor positions about 0430 hours on 6 June and there was no serious lag behind the planned times. In order to achieve surprise in the initial assault, complete "Radio Silence" was maintained on all vessels. Transmitters were not to be switched on until H-hour unless it was established that a successful air or surface reconnaissance had been carried out by the enemy ; the Allied Naval Commander of the Expeditionary Force was then to order the general use of radar.[3]

At the F.D.T. anchorages the sound of heavy night bombers of the Royal Air Force Bomber Command could be heard, accompanied by bomb flashes and enemy A.A. fire. The beaches were being bombed as the first traces of dawn appeared. Naval gunfire from cruisers and destroyers had by that time opened up on the beaches and was maintained continuously until the bombing by United States heavy bombers at approximately half an hour before the first beach assault landings were made. Amid this bedlam of noise, No. 217 F.D.T., the "Master Control" ship, had anchored some five miles off the three Eastern

[1] A.E.A.F. File S.24201, Encl. 16A, Appendix "B."

[2] H-hour is the time of the actual beach assault landing.

[3] A.H.B./IIM/683/1A, No. 11 Group and IX Fighter Command Joint Air Plan for "Neptune," Appendix "L," p. 10.

(British) beaches,[1] known as " Sword," " Juno " and " Gold," and No. 216 F.D.T. was at approximately the same distance from the Western (American) beaches " Omaha " and " Utah," while No. 13 F.D.T. had taken up its position in the shipping lanes in mid-channel. All three ships opened up full radar watch at H-hour, 0725 hours, and were receiving calls from the fighter aircraft providing the defensive air umbrella.[2]

The approach of the landing fleet in radio silence had achieved the element of complete surprise for which the planners had hoped. According to interrogations of German prisoners-of-war from their Signals Intelligence, the very strong radio jamming activity—which they attributed to No. 100 Group—against their ground Radar, led the enemy wireless listening service to assume that its purpose was to screen a fairly large formation of Allied vessels.[3] However, the landing areas were never anticipated and the assault shipping was undetected by enemy air reconnaissance or radar. Even after the assault had been launched, the enemy air reaction remained negligible until the latter part of the evening over the British beaches. A small scale of bombing effort was then put out by the *Luftwaffe* against the beaches, causing casualties to personnel but little damage to shipping or stores.

The F.D.T. No. 217 observed this raid coming in, although as it reached its objectives the enemy aircraft were lost to radar view in the large numbers of permanent echoes showing on the radar equipment from the coast and the huge concentration of shipping off the beaches. The Headquarters Ship, H.M.S. *Hilary*, off the central portion (" Juno ") of the British beaches complained that little help was received from the F.D.T. of warning of this attack. The Naval radar equipment of the Headquarters Ship worked well and was the mainstay for local air activity off " Juno " beach at that time.

D-day Landing of Radar Station in the British Sector

Meanwhile the advance element of No. 24 Base Defence Sector, which included No. 15083 G.C.I. and the associated telecommunications units drawn from No. 83 Group, landed without loss or casualty about 1200 hours in the British area, and the G.C.I. unit proceeded to its planned location near Meuvaines where it was intended that it was to be operational for the control of night-fighter aircraft that same evening.[4] At this stage, however, full implementation of the plan for the British Sector became impossible for two reasons. Firstly, technical difficulties were encountered with the Type 15 G.C.I. and only the Type 11 equipment was working satisfactorily on the night of D-day.[5] Secondly, the Mobile Signals Units allotted to No. 15083 G.C.I. did not actually reach the site until dusk on D + 1. They had landed on a different beach from the remainder of the G.C.I. and could not proceed to the site until an enemy strong-point covering their route had been liquidated.[6] Sufficient V.H.F. R/T air-to-ground channels and direction finding facilities had landed with the G.C.I. equipment, however, so this unit in the British Sector was able to operate on the night of D-day in a radar reporting role and as a controlling Interception Unit on the Type 11 equipment. It was therefore only able to handle one fighter aircraft at a time.

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[1] The locations of the beaches are shown on Map No. 15.

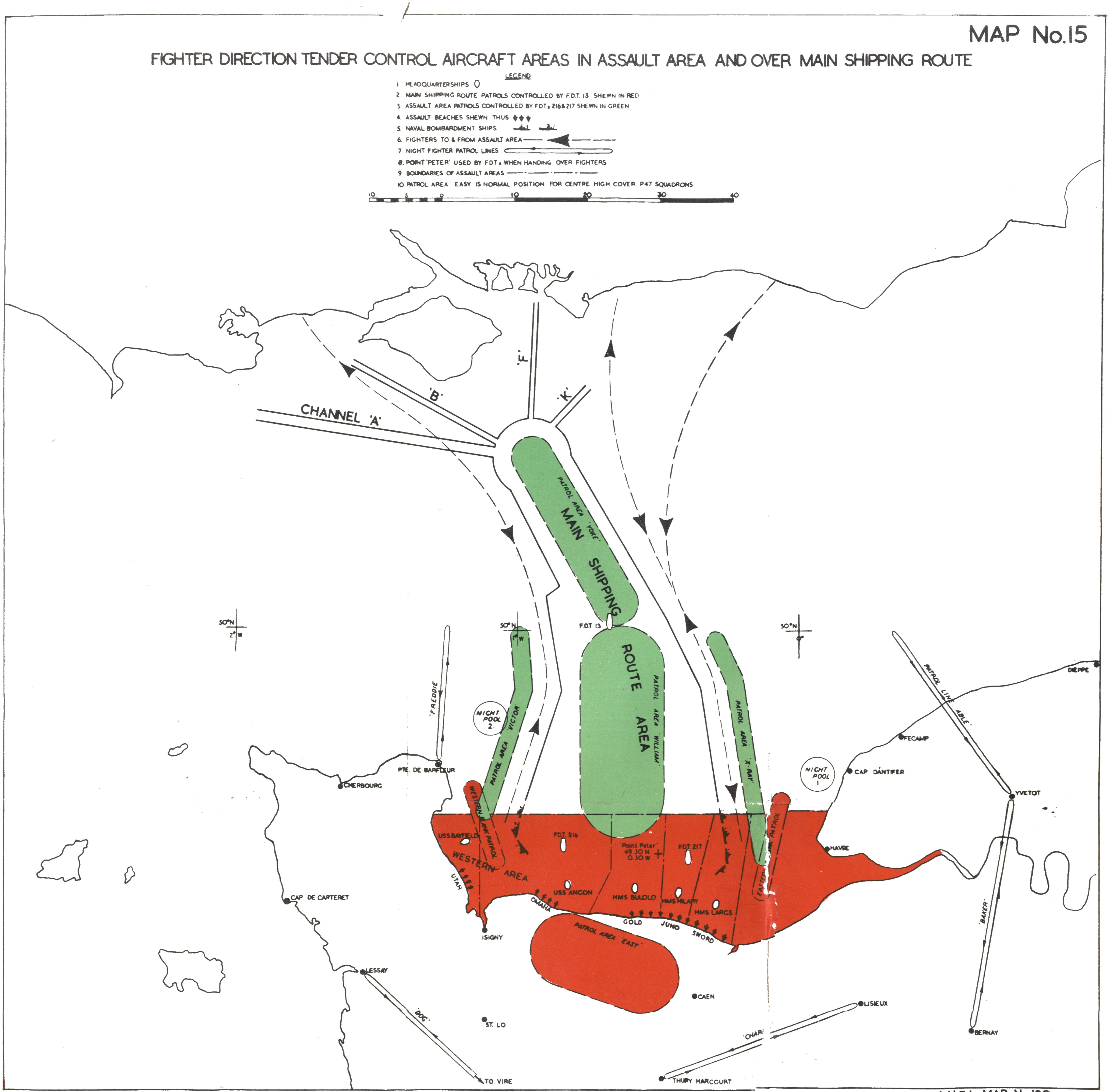
[2] A.E.A.F. File S.24201, Encl. 16A, Appendix " B."

[3] A.D.I. (K) Report No. 406/1945, " G.A.F. Signals Intelligence in the War—V," p. 10.

[4] No. 24 B.D.S., O.R.B., 25 June 1944. The location of this G.C.I. Unit is shown on Map No. 14.

[5] A.E.A.F. File T.S. 22543/Air, Encl. 3A, para. 25.

[6] A.E.A.F. File S.13441, Encl. 63A.



A.H.B.I. MAP No.190.

D-day Landings of Radar G.C.I. Station in the American Sector

At the American beaches, No. 15082 G.C.I. under the advance party of No. 21 Base Defence Sector, together with their telecommunications Mobile Signals Unit, were not so fortunate as their counterpart in the British Sector. Reaching the Normandy coast just after daybreak on D-day in five L.C.T.s, without any enemy interference throughout the voyage, the first attempt at landing was made at 1130 hours. As the convoy approached land the beach was observed to be under enemy machine-gun as well as heavy shell-fire and it was obviously impracticable to attempt to land a G.C.I. station under those conditions.[1] The convoy therefore withdrew until 1700 hours whilst the Navy shelled enemy shore batteries. Then the landing craft went in again, although the beach was still under accurate enemy shell-fire and United States Army vehicles were lined up at the head of the beach, unable to get away as both exits were blocked.

Into this semi-chaos a wet-shod landing of a large radar convoy took place. Four of the landing craft stopped in deeper water than had been anticipated—the vehicles had to be driven off into 4 feet 3 inches of water, with the result that only eight of the twenty-seven vehicles remained serviceable, though a number of others were salvaged later. Apparently due to a slight error of judgment on the part of its captain, the fifth L.C.T. was "landed" considerably further out to sea than the other craft, the depth of the water was over 4 feet, on to a sand-bank. As the vehicles drove towards the shore the water became deeper and, one by one, each of the vehicles from this landing craft became "drowned": all being lost in this landing attempt. The men scrambled on the roofs of their vehicles to avoid drowning and had great difficulty in swimming ashore.

Once on the shore near St. Laurent, the unit came under heavy shell-fire on the beach and dug fox-holes in the shingle until a place could be found to which the remainder of the unit could move. It appeared that the elaborate beach organisation, which should have been set up to deal with the speedy disembarkation of units and keep the beach-head exits clear, had not yet landed—this decision having been made because of the dangerous state of the beach. That it was considered a fit time to disembark the nucleus of a Base Defence Sector with its cumbersome radar equipment, indicated a radical weakness in the flexibility of the organisation for landings in the face of strong enemy opposition.

The price paid for this premature landing of No. 15082 G.C.I. with the advance element of No. 21 Base Defence Sector was heavy. Most of the telecommunications equipment and all the radar equipment except the Type 15 G.C.I. were lost.[2] The unit had received a severe mauling—the total casualties among its personnel were :—[3]

Killed	1 Officer,	9 Other Ranks.
Missing	—	1 Other Rank.
Wounded	5 Officers,	31 Other Ranks.

Under such losses the unit was therefore non-effective as far as implementing the original plan for radar raid reporting and control on the night of D-day was

[1] No. 21 B.D.S., O.R.B., Attached Report on D-day Landing.
[2] A.E.A.F. File S.13441, Encl. 64A.
[3] No. 21 B.D.S., O.R.B., Attached Report of D-day Landing.

concerned. The personnel spent that night lying along the edge of the road from the beach to a nearby village ; some shelter against sporadic shelling and continuous fire from snipers being given by a low wall on the side of the road.

Meticulous care had been taken in the United Kingdom during the preparations for Operation " Neptune " over the provision of adequate reserves of technical vehicles and equipment for the speedy replacement of losses such as No. 15082 G.C.I. had received. The radio technical vehicles were waiting, fully waterproofed, to be called forward and only required shipping across the Channel to make good the losses experienced in this disastrous landing.

Fortunately the scale of enemy air attack in the Normandy bridgehead during D-day and the following night was small. The Fighter Direction Tender No. 217, as " Master " control, was able to cope satisfactorily with these attacks. Some minor criticism of its early warning and control at that time was based solely on the fact that lone enemy aircraft, flying low, were able to bomb the British beaches.[1] With such a welter of friendly aerial activity over the bridgehead area, very low-flying enemy aircraft flying singly were bound to penetrate the lines before identification, but no major raid went undetected.

With D-day over and the small bridgehead successfully established by the Allied forces, military stores, equipment, and units of every type, including the planned follow-up of radar units, poured into the narrow confines of the bridgehead during the ensuing days. For the purpose of this narrative, a day-by-day chronological account of the build-up of the full raid-reporting organisation and the operation of the radar units themselves would not present a clear impression of the degree of success achieved. At this stage it is preferable to consider Royal Air Force ground radar employed in this operation near its three broad functional categories, namely :—

(*a*) Fighter Direction Tenders.
(*b*) Base Defence Radar Units.
(*c*) Mobile Radar Units in 2nd Tactical Air Force in support of the armies in the field.

Fighter Direction Tenders During the Operation

The directive given to the Fighter Direction Tenders was to protect the shipping, naval bombardment forces, landing craft and beaches during the initial stages of the operation until a suitable control organisation had been set up ashore. The measure of success achieved is best illustrated by the fact that during the first seven days (after which complete " Master " control was handed over to No. 483 Group Control Centre ashore), the damage to shipping or on the beaches through enemy air attacks was almost negligible.[2]

In the planning for operation " Neptune " a very heavy scale of enemy air attack during the first few days had been envisaged. At no time during the first week did the *Luftwaffe* make a really determined attack on the beachhead or shipping by day. The raids experienced were of the " tip and run " variety by fighter-bomber (*Me. 109s* and *F.W. 190s*) helped by weather and low cloud conditions. Some *Ju. 88s* were also employed at dusk. The estimated scale of enemy night attacks on the bridgehead varied from thirty to fifty sorties per night. It has been suggested that the lack of serious damage to Allied

[1] Headquarters, A.E.A.F. Report on British H.Q. Ships and F.D.T.s in Operation " Neptune."
[2] A.E.A.F. File T.S. 22543/Air, Encl. 8A, giving No. 11 Group Report on F.D.T.s.

shipping and beaches was due rather to the small scale of enemy attack than to the efficiency of the Fighter Direction Tenders. While performing their function of protecting the bridgehead and shipping, F.D.T.s Nos. 217 and 216 controlled fighter aircraft which destroyed fifty-two enemy aircraft by day and destroyed thirteen by night.[1] No enemy aircraft attacked Allied shipping lanes by day so No. 13 F.D.T. had no opportunity of successful control.

Comments on the Equipment in Fighter Direction Tenders

In view of the fact that the Type 15 equipment was not subjected to any jamming, it was used on all ships almost continuously; there was never any necessity to fall back on the Type 11, which was the standby equipment. The Type 15 G.C.I. performance on each of the Fighter Direction Tenders was considered very good. An outstanding example of this was a contact with an enemy bomber given to a night fighter from a Type 15 at a range of 120 miles at 15,000 feet by one Fighter Direction Tender. Generally, very long ranges were obtained and the plan-position display was excellent.[2] On each ship the Type 11 was considered a poor substitute for the Type 15 and was hardly used. The lack of accurate height-finding facilities was a definite limitation, but on the whole the normal C.H.L. station methods of height estimation can be said to have worked reasonably well. It was clear after the operation that stabilised centimetre equipment with height-finding gear was required for future operations whenever similar raid reporting and aircraft control vessels were to be employed.[3] This is in no way a criticism of the lack of provision in the planning of the Fighter Direction Tenders for the Operation " Neptune "; the centimetric equipment could not be used as it could not be made available at the time when the F.D.T.s were fitted out.

" Window," as used by the enemy aircraft, gave virtually no trouble. It was generally dropped at height of from 5,000 to 7,000 feet. " Window " used by Allied bomber aircraft returning from the bridgehead area gave rise to a certain amount of trouble in spite of the efforts to route bombers clear of the assault area generally. It will be recalled that F.D.T. No. 217 had been fitted with a new type of Console just off production, the Flicker Console, which was anticipated would be a successful anti-" Window " device. The Plan-Position Indicator presentation on this was excellent but the Flicker did not work and was quite useless.

The V.H.F. D/F equipment worked well and was an aid to identification of Allied fighter aircraft in view of the restrictions which had been placed on the use of Mark III I.F.F. The I.F.F. interrogation equipment was satisfactory, within the stringent restrictions which had been imposed on its use. Identification was generally a serious problem, as is evidenced by the number of contacts at night on friendly aircraft.[4]

The lay-out and equipment of the Fighter Direction Tenders had both been planned to meet intense air opposition. The fitting-out had been a " rush job " on the Clyde in order to push on with the training of personnel and testing of equipment. A number of obvious faults had been revealed during this training but it had not been possible to return the ships to dock for any

[1] The results achieved by the Fighter Direction Tenders are analysed in Appendix No. 46.
[2] A.E.A.F. File T.S. 22543/Air, Encl. 9A, para. 9.
[3] Headquarters, A.E.A.F. Report on H.Q. Ships and F.D.T.s in Operation " Neptune."
[4] Results analysis in Appendix 46 shows these figures.

major alterations.[1] In such circumstances, inadequate air-conditioning, unpleasantly high temperature in the various control rooms, overcrowding of the rooms themselves, and the lack of exits from the operations block to the deck were all sources of adverse comment among the personnel on board—fortunately, with their somewhat macabre sense of humour, these disadvantages were treated as a joke, " F.D.T." being defined by the airmen as " Floating Death Trap."

Relation between F.D.T.s and Headquarters Ships

In the original planning for Operation " Neptune " it will be recalled that the Headquarters Ship was responsible for issuing air raid warnings and controlling A.A. fire: it had been anticipated that these actions would be based largely on raid reporting information supplied by the appropriate F.D.T. Generally there was good liaison between the Flagship, the Headquarters Ships and F.D.T. No. 217 of the Eastern (British) Task Force, with the possible exception of H.M.S. *Hilary*, the Headquarters Ship off the central (" Juno ") British beach.[2] This ship did not appear wholly to appreciate the functions and limitations of a Fighter Direction Tender, and in consequence several complaints and criticisms were received from this source—most of which were unwarranted.[3] With the Western (American) Task Force the liaison was good, particularly with U.S.S. *Anson*, the Headquarters Ship responsible for issuing air raid warnings.

Plot Information Available for Air Raid Warnings

During the first week the plot information received in the Filter Rooms of the Headquarters Ships, on which raid warnings and A.A. control were based, came from the following sources:—[4]

(*a*) Home Shore Broadcast. This was from No. 11 Group Filter Room, Uxbridge, and gave hostile and unidentified aircraft tracks observed by radar stations of the Home Chain in Southern England.
(*b*) Far Shore Broadcast, from the G.C.I. stations ashore.
(*c*) The Fighter Direction Ships' radar information passed on the F.D.T./H.Q. Ships' liaison wave.
(*d*) Naval Assault radar (from certain Naval vessels).
(*e*) The Headquarters Ship's own Naval radar.
(*f*) Intelligence information.

A further source of information which had been expected to give useful information was visual plots of aircraft from trained ground observers on the H.Q. Ship bridge. This method was never called upon.

From these information sources tracks were built up, identified by the Air Movements Liaison Officer from his movements information, and displayed on the Headquarters Ship Filter Room table, whence they were told through to the Operations table and Bridge plot. The Home Shore Plot Broadcast did not supply as much information as had been expected, partly because of the smallness of the enemy's air effort and partly because the *Luftwaffe* flew their

[1] Report on H.Q. Ships and F.D.T.s in Operation " Neptune " by H.Q. A.E.A.F., paras. 78–81.
[2] The British beaches were divided into three areas, " Sword," " Juno," and " Gold," with three Headquarters Ships, H.M.S. *Largs*, *Hilary*, and *Bulolo* respectively off each beach; all receiving raid reporting information from F.D.T. No. 217.
[3] A.E.A.F. File T.S. 22543/Air, Encl. 8A, p. 5.
[4] H.Q., A.E.A.F. Report on H.Q. Ships and F.D.T.s, Part 1, para. 36.

sorties at a low height—therefore not being seen by the distant Home Chain radar stations. Of the sources of information on the far shore and off the beaches, during the early stages of the operation the information broadcast from the G.C.I. ashore was disappointing; continuity of tracks was lacking and only rarely was any ancillary information given with the plots. Information from Naval radar was patchy, too; sometimes some good tracking was produced by it, at others little value could be obtained from it. It was a weakness that the Royal Navy Radar Controlling Ship had no Royal Air Force Aircraft Movement Liaison Section on board, as this resulted in all aircraft tracks plotted and not showing I.F.F. being broadcast as unidentified. The Headquarters Ships' own Naval radar produced much useful close-range information and, generally speaking, worked far better than had been expected.

The Fighter Direction Tenders' information during the first week was not so full as had been anticipated. Criticism of F.D.T. No. 217 as a source of raid reporting information by the Headquarters Ship H.M.S. *Hilary* led to the reply that the H.Q. Ships were receiving "all available and necessary information."[1] Examination of the log of the F.D.T./H.Q. Ships Liaison Plotting wave for D + 6, for example, indicates that only one hundred and twenty-eight plots were received in twenty-four hours, while most of the time was taken up on this wave by chatter of exceptionally low priority. It was clear after the event that plotting and liaison should have had separate channels of communication.

Such criticism of the raid reporting role of the F.D.T. No. 217 tends to give a totally false impression of the efficiency of the vessel from the radar point of view. In assessing the strength of the handling capacity of the F.D.T. for night fighter aircraft, a comparison with the final type G.C.I. station ("Happidrome") in the United Kingdom and a co-ordinating night sector is of interest. During a busy night in southern England, a final type G.C.I. station would be called upon to handle twelve aircraft, and a large co-ordinating sector such as Middle Wallop up to twenty-four night fighter aircraft during the night.[2] On an average, thirty-eight to forty night fighters per night were handled and distributed to the various control points by F.D.T. No. 217 with a much smaller complement of Control Officers. Day activity was on a similar scale, so despite the fact that the raid reporting information passed to H.Q. Ships was apparently not as full as had been expected, the Fighter Direction Tenders were worked almost to capacity during their stay off the beaches.

Air Raid Warnings and the Control of A.A. Fire

From the information sources mentioned above, the Headquarters Ships issued air raid warnings and attempted to control A.A. fire. From the Royal Air Force point of view the Fighter Direction Tenders would have been the more ideal source for issuing air raid warnings. Owing to the much superior performance of the Royal Air Force radar equipment aboard the Fighter Direction Tenders as compared with any other ships, and to the specialist officers employed on filtering and Air Movement Liaison, the air situation picture was undoubtedly the most accurate available.[3] To pass this information on to the H.Q. Ships before decisions were taken whether a general warning

[1] Advanced H.Q., A.E.A.F. File S.24201, Encl. 16D.

[2] Report on H.Q. Ships and F.D.T.s in Operation "Neptune" by H.Q., A.E.A.F., para. 70.

[3] Advanced H.Q., A.E.A.F., File S.24201, Encl. 17A, para. 8.

should be given or not, introduced a time-lag in the warning system. This was manifest on several occasions when air raid warning " Yellow " was given in the British Sector, and immediately following, before a " Red " warning was given, the beach and anchorage had been bombed. The warning and defence systems were by no means perfect—even one Headquarters Ship, H.M.S. *Bulolo,* was hit by a 250-lb. bomb outside the Operations Room, resulting in casualties to the Royal Air Force personnel, on the early morning of D + 1 before a " Red " warning had been given.

The immediate reaction to the partial failure of the warning system was to criticise the Fighter Direction Tenders and aim at improvement in the quantity and quality of the information on enemy air activity, with particular emphasis on passing it quickly from the F.D.T. to the H.Q. Ships responsible for broadcasting air raid warnings to the Task Force.[1] Second thoughts on this topic suggested that it was for consideration whether or not the problem of air raid warnings, A.A. control, air support to the assault forces and reconnaissance could be collated and acted upon quite efficiently from the F.D.T.s alone.

Despite the apparent adequacy of the planning prior to this operation and the general efficiency of the ship-borne radar, during the first four days of the invasion A.A. gunfire control, both naval and military, from the anchorage and beaches, left much to be desired. Serious cases of firing at friendly fighter aircraft occurred in the British area. Usually it was started by the gun-crews of smaller vessels, coasters, L.S.T.s and L.C.T.s, but once it had started, even visual recognition was completely ignored and the firing was taken up strongly by shore A.A. and naval guns of all classes of warships, including cruisers—even the well-disciplined gun-crews were quickly out of hand.[2] The accuracy of gun-fire from naval guns in the Eastern Task Force area was very poor, otherwise there would have been heavy casualties to Allied fighter and fighter-bomber aircraft. The Naval Officer-in-Charge of each sector made strenuous efforts to stop this indiscriminate firing by ships.

It appears that the air raid warning system was not functioning satisfactorily and that the Royal Air Force briefing to ships' officers at their pre-convoy sailing conference had been inadequate.[3] This was due partly to the delay caused by controlling the warning system from the Headquarters Ships instead of directly from the appropriate Fighter Direction Tender, and also to the lack of an R/T channel to the A.A. Operations Room ashore. A broadcast R/T channel from the Controlling Ship, received by all ships carrying A.A. and operating in the assault area, was obviously necessary if full advantage were to be taken of the available radar information, and also so that on occasions when fire was opened on friendly aircraft it could be immediately stopped.[4]

This uncontrolled A.A. fire was one of the factors which aided the enemy on the few occasions when small enemy formations penetrated to the beaches and shipping. Allied fighter aircraft under control from the Fighter Direction Tender No. 217 had their attempted interceptions made more difficult and at times impossible by A.A. fire from ships, particularly when the weather was bad.[5] The control from the Fighter Direction Tender was also hampered by the permanent echoes on the radar presentation which partially obscured the screens for a distance up to twelve miles.

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[1] Advanced H.Q., A.E.A.F. File S.24201, Encl. 16A, para. 2.
[2] *Ibid.*, Encl. 16B, para. 8. [3] *Ibid.*, Encl. 17B, para. 6.
[4] H.Q., A.E.A.F. Report on H.Q. Ships and F.D.T.s in Operation " Neptune," para. 10.
[5] *Ibid.*, para. 49.

Movements of Fighter Direction Tenders

The F.D.T.s continued to operate in the D-day positions throughout the first week. Then F.D.T. No. 13, positioned in the shipping lane in mid-Channel, returned to port for refuelling and re-victualling.[1] On 15 June F.D.T. No. 216 had to return to port for repairs to damage she had suffered in collision. F.D.T. No. 217 therefore relieved her off the U.S. beaches as No. 15082 G.C.I., landed on the U.S. beach, was still not fully operational, whereas " Master " control had been taken over by No. 15083 G.C.I. in the British sector. At the same time F.D.T. No. 13 was positioned twenty miles east-north-east of Barfleur to intercept enemy mine-laying aircraft and torpedo aircraft which were attacking Allied shipping at night and approaching round the Cherbourg peninsula.

F.D.T. No. 217 was withdrawn from the U.S. Beach on 23 June after having been in continuous operation for seventeen days. Before the operation it was thought that the Fighter Direction Tenders would only be required in the assault area for a few days, after which the control and co-ordination of night fighter aircraft would be taken over by the G.C.I.s ashore and the day fighters by No. 483 Group Control Centre. As events turned out, all three vessels were continuously employed for a much longer period than had been anticipated and this imposed a very severe strain on their personnel, who were living in conditions of great discomfort. A large percentage of the men had been aboard the vessels for five months, from the beginning of the training period. To appreciate what this meant it must be remembered that the accommodation in the ships was originally designed for the crews of tanks on a short sea passage and not as semi-permanent living quarters for fourteen officers and one hundred and sixty airmen in addition to the ships' normal Naval complement.

On 27 June F.D.T. No. 216 relieved No. 13 off Barfleur but four days later shore-based G.C.I.s were working inland from Barfleur and so F.D.T. No. 216 was moved to a position on the other flank of Allied shipping some 23 miles west of Le Havre, to assist in the interception of enemy aircraft laying mines at night off the British Sector beaches. After a week operating in that area, at 0100 hours on the morning of 7 July, No. 216 fell the victim to an attack by a *Ju. 88*. The aircraft closed rapidly and headed straight for the Fighter Direction Tender, which attempted to force the aircraft off its course with A.A. fire. Radar held the enemy aircraft in contact the whole of its approach, but the enemy pilot fearlessly pressed home his attack on the first run-in and launched his torpedo.[2] It hit the Fighter Direction Tender on the port bow but she maintained her trim for some forty minutes before her pig-iron deck ballast[3] moved and she turned turtle. By that time personnel had taken to the water and the red lights on their life-jackets helped to guide rescuing small craft to them throughout the remaining hours of darkness. When the search for survivors was abandoned after dawn only five airmen could not be accounted for. The loss of life was remarkably low for such a sinking during the night.

With the torpedoing of F.D.T. No. 216, the part played by the Fighter Direction Tenders came to an end ; Nos. 217 and 13 had returned to home ports before the end of June. There is no doubt that the use of Fighter Direction Tenders in this operation was a great success whatever minor criticisms might

[1] H.Q., A.E.A.F., Report on H.Q. Ships and F.D.T.s in Operation "Neptune," para. 47.

[2] H.Q., A.E.A.F., Report on H.Q. Ships and F.D.T.s, Appendix " D."

[3] The pig-iron deck ballast had been added to compensate for the difference in weight between an L.S.T.'s normal cargo of tanks and the much lower weight of the R.A.F. radar equipment.

be levelled against them, and that they amply fulfilled all that was expected of them. The radar equipment had worked well, particularly when it is remembered that it was never at any time during the operation taken off the air for maintenance—in direct contrast to the practice with shore-based radar. Good experience had been gained in the operation of these Fighter Direction Tenders which, it was anticipated, would be of great value in the preparations for the much longer-range assault landings to be undertaken in the Far East under South East Asia Command.

While the Fighter Direction Tenders had been playing their important role off the beaches, the Ground Search radar units which had landed on D-day, were functioning in the bridgehead itself and being steadily augmented by other units, largely according to plan. Thus, a radar system was being built up in Normandy basically the same as that which had been used in the United Kingdom throughout the War, namely, in which a number of dispersed radar equipments were used as reporting stations, providing information on the air-situation to central Operations Rooms, where the information was filtered and identified. The remainder of this chapter deals with the setting-up of these reporting systems in the bridgehead—in the American Sector as far as the Royal Air Force radar units were concerned, and in the British Sector.

Royal Air Force Radar Units in the American Sector

The hazardous D-day landing of the first echelon of No. 21 Base Defence Sector and No. 15082 G.C.I. in the American Sector has already been described. The severe losses in equipment and personnel had prevented the immediate implementation of the original radar plan. However, the planning had sufficient flexibility for such a contingency. Reserves of both personnel and fully-waterproofed technical vehicles had been prepared for the Allied Expeditionary Air Force in the United Kingdom, and replacement action took place immediately.

In the bridgehead itself, the site planned for No. 15082 G.C.I. remained in enemy hands until 8 June 1944. On that day the unit moved to an American Transit Area to await the selection of a new site ; the time there being passed in erecting and checking the Type 15 equipment which had escaped serious damage.[1] Salvage work continued off the beach, as such items as clothing and drinking water had all been lost. Faded Royal Air Force blue uniforms appeared very similar to Wehrmacht (German Army) green uniform when observed from a distance, so the unit personnel had the additional discomfort of being continually sniped at by Americans.

During the twenty-four hours 8/9 June, there was a considerable improvement in the military situation in the American Sector as a result of an armoured division being landed. Orders were received on the evening of 9 June that No. 15082 G.C.I. were to proceed on the following morning to their original site planned for D-day. The unit moved with its serviceable equipment, leaving the No. 21 Base Defence Wing Operations Room behind. By the evening of 10 June the unit was operational on its Type 14 equipment and took control of night fighter aircraft. Altogether there were sixteen contacts during the first night, but seven of them turned out to be friendlies. One enemy aircraft destroyed and one damaged was recorded by night fighter aircraft under this G.C.I. control during its first night of operation.

[1] No. 21 B.D.S., O.R.B.

No. 15082 G.C.I. remained on the same site throughout the remainder of the month of June. Enemy air activity at night was much less than had been anticipated during this period. The night of 17 June proved to be a record as far as the German Air Force activity was concerned. Then some fifteen to twenty enemy aircraft operated over the Sector and seven were claimed as destroyed—nearly 50 per cent. success by night fighters under the control of No. 15082 G.C.I. Altogether during the twenty days of operations during June, this G.C.I. Unit controlled night fighter defence aircraft which destroyed twenty-one aircraft, an additional four being claimed as damaged—a very creditable performance in view of the light enemy night activity.

The Base Defence Sector build-up continued according to plan, the second echelon arriving on 14 June. As the bridgehead area increased up the Cherbourg peninsula, the radar cover was able to keep pace with the advances. No. 15072 G.C.I. was sited at Ravenoville, mid-way on the eastern side of the Cherbourg peninsula by 15 June, joined on 20 June by C.O.L. No. 15073 to give full low cover.[1] The low cover for No. 15082 G.C.I. was provided by C.O.L. No. 15074 at this date. Thus by 21 June, the essential elements of the Royal Air Force ground search radar for base defence were functioning in the American Sector.

Day cover and control in this United States IX T.A.C. area were supplied by an American G.C.I. equipment (M.E.W.) and three Forward Director Posts with associated Light Warning sets, all manned by American personnel.[2] Thus adequate Base Defence and Tactical Air Force radar was functioning in the American Sector within the first two weeks of the invasion, despite the almost catastrophic initial landing of radar equipment on D-day. The flexibility of the planning and the initiative of the personnel manning the equipment had proved equal to the task undertaken.

Base Sector Ground Radar Units in the British Sector

It will be recalled that the advance element of No. 24 Base Defence Sector with No. 15083 G.C.I. had set up at Meuvaines in the British area on the night of D-day, but that the Type 15 G.C.I. equipment had been unserviceable. Only the Type 11 and Type 13 were used during the first night. The Mobile Signals Units destined to provide the telecommunications for this Base Defence Sector had been held up near their landing beach by an enemy strong-point, eventually reaching their site at dusk on D + 1. The Type 15 G.C.I. equipment had been repaired through the day, so during the night of 7 June, control of Royal Air Force night fighter aircraft was effected using Type 11, Type 15 and Type 21 equipment, all of which worked extremely well.[3] The site, which had been pre-selected from map information only, proved to be exceptionally good. By the evening of D + 2 all No. 15083 G.C.I. W/T and R/T communications channels were working and traffic was also being handled for Advanced Main Headquarters, No. 83 Group, which had set up as the Royal Air Force authority on the Continent, located next to the British 21st Army Group Headquarters.

Although No. 217 Fighter Direction Tender was the "Master" control, No. 15083 G.C.I. took over the co-ordination of the night battle over the British Sector with effect from 8 June, handing over to No. 24 Base Defence Sector Operations Room on D + 6. Control of aircraft was carried out on all three Types 11, 15 and 21 equipments, sometimes simultaneously with separate

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[1] No. 21 B.D.S., O.R.B.

[2] A.E.A.F. File M.S. 13441, Encl. 64A, para. 11.

[3] *Ibid.*, paras. 2–5.

Controllers on each of the equipments. The Type 21 equipment worked extremely well with little or no fading, most enemy aircraft operating at night at heights of approximately 5,000 feet. This result was particularly gratifying in view of the very short time which had been available prior to D-day for the Type 21 crew to become familiar with this new type of equipment.

The British Airborne Force which had been dropped before H-hour on D-day to establish the Allied eastern flank on the River Orne were subsequently employed as infantry to support this flank during the first weeks in the bridgehead. The enemy reacted fairly strongly in this area in an attempt to confine the size of the bridgehead to a minimum and prevent it from expanding across the Orne river. The *Luftwaffe* supported the German ground effort at night and from the site at Meuvaines some 16 miles to the west, No. 15083 G.C.I. was unable to give adequate radar cover beyond the British lines to control night fighter aircraft in the defence of this area. Accordingly, to remedy this defect in the defensive system, No. 6091 Light Warning set was moved at night to a ridge overlooking the Orne river about a mile behind the British lines. The Light Warning set operated from this position during the night and retired to a safe location some 6 miles westward during the day. The L.W.S. Unit was augmented with Communications Units to provide a frequency-modulated R/T channel and W/T communication links back to No. 15083 G.C.I. An Operations Control Officer was added to the personnel and the L.W.S. was then able to function as a miniature forward G.C.I. in addition to its normal reporting role back to No. 15083 G.C.I., giving additional low radar coverage to the east.

The night operating forward position of No. 6091 L.W.S. attracted some attention from enemy artillery—at dusk, as the station was being set up, the aerials on this ridge site must have presented an obvious target. Shells fell dangerously near and there were casualties, among them the Controller, who was killed. Nevertheless, the station was able to maintain adequate radar cover at night over this important sector. Nine enemy aircraft were claimed as destroyed by Royal Air Force night fighter aircraft acting under No. 6091 L.W.S. control.

The base defence sector radar facilities in the British area, namely, the No. 24 Base Defence Sector Operations Room and the radar network of stations, continued to be built up largely according to plan. No. 15129 C.O.L. Unit landed dry-shod at Port-en-Bessin on D + 4 (10 June). Some slight delay occurred while arrangements were made for the de-mining of the site but the unit arrived on site by mid-day of D + 5 and set up its equipment, some 8 miles west of the " Master " control at No. 15083 G.C.I. at Meuvaines.[1] The bare essentials of base defence were all working by D + 5 therefore, namely the " Master " G.C.I., a C.O.L. station for low cover, and two Light Warning sets for gap-filling and additional low cover.

Tactical Air Force Radar Ground Search Units

The ground search radar facilities planned for the 2nd Tactical Air Force during the first two months of the operation were all drawn from No. 83 Group ; the No. 84 Group units being held in the United Kingdom until the Allied bridgehead expanded sufficiently to warrant any further augmentation of the

[1] A.E.A.F. File M.S. 13441, Encl. 64A.

radar network. The centre of this network was to be No. 483 Group Control Centre, so its advance echelon landed on the afternoon of D-day and work was started immediately to build up the telecommunications facilities necessary for the day control of fighter and fighter-bomber aircraft of 2nd Tactical Air Force over the forward areas.[1]

The first No. 83 Group Radar Unit to land was No. 15053 Forward Director Post. This was one of the most experienced G.C.I. Units in the Force, having had nearly two years deployed training in the United Kingdom. It landed wet-shod, efficiently and without losses, and reached its operational site at Crepon on D + 1 according to plan. By the following day the Type 15 and Type 11 equipments were both erected and serviceable and W/T contact had been established with the Group Control Centre in the late evening.[2] The station commenced its normal reporting role to the Group Control Centre on the early morning of 9 June.

The new Type 13 equipment, designed for height-finding and also giving cover against very low-flying aircraft, which it will be recalled was issued to the unit fully waterproofed, new and untried, in the Assembly Area in the United Kingdom, was found to be unserviceable on setting-up on D + 2. The radar technical officer began working on it but it took some two weeks effort to get this equipment into commission. The Type 15 equipment, however, was in first-class order and normal plotting started on 9 June, supplemented by information on low-flying aircraft from its associated Light Warning set, No. 6093 L.W.S. During the first full day's plotting the site was bombed by the enemy, two airmen were killed and one injured on the V.H.F. R/T link used for communication with the Group Control Centre. Despite this attack, the unit continued to function well and No. 483 Group Control Centre expressed appreciation of the standard of the plotting.

The day reporting network of Radar stations for tactical purposes grew rapidly. On D + 5 No. 15054 F.D.P. landed, but the planned site at Periers-sur-le-Dau was considered too dangerous, so an alternative location was selected at Beaupigny and the unit became operational by the evening of 12 June.[3] No. 6092 L.W.S. worked in association with this G.C.I./F.D.P. On the evening of 17 June an off-shore gale sprang up over the Normandy beaches. For six days this storm in the Channel continued, causing roughly a six-day lag in the landing schedules. The third Forward Director Post, No. 8024 F.D.P. and its associated L.W.S. No. 6113 were thus delayed from landing until 23 June, when they set up immediately on a site allocated by the Group Control Centre at Esquay-sur-Seulles, the originally planned site for this unit being in enemy hands.[4] It became operational that same day and maintained a 24-hour reporting role for the remainder of the month.

The last of No. 83 Group ground radar units, No. 8007 G.C.I., landed on D + 26 (2 July) and proceeded to No. 483 Group Control Centre.[5] Since the advance of the Army was slower than expected, the bridgehead area was relatively small on the arrival of this unit and was amply covered by the Fighter Director Posts which had already landed. In addition, night fighter aircraft were being controlled by No. 24 Base Defence Sector with No. 15083

[1] No. 483 G.C.C., O.R.B., June 1944.
[2] No. 15053 F.D.P., O.R.B., June 1944.
[3] No. 15054 F.D.P., O.R.B., June 1944.
[4] No. 8024 F.D.P., O.R.B.
[5] A.H.B./IIE136, No. 83 Group Signals Report, 1944, Appendix " H."

G.C.I. so there was no immediate operational need for No. 8007 G.C.I. It was set up near to the No. 483 Group Control Centre so that its equipment could be checked for serviceability. The unit was given an operational site at the end of July, mainly to provide operational practice for the personnel and improve their morale, since they had been so long without operations in England and in Normandy. Several high-level day patrols were controlled without incident, and the unit really played a completely negligible role in the bridgehead, being quite superfluous to No. 83 Group ground search radar requirements.

During the first fortnight of the campaign No. 483 Group Control Centre used the Forward Director Posts in a reporting role only. From their information, together with that from the fifteen Wireless-Observer Unit posts, the raid reporting information was summarised and raid warnings, A.A. control, and the control of day fighter aircraft were all carried out. On 20 June, however, control of fighter aircraft for specific periods was handed over to No. 15054 F.D.P. By 22 June the first successes were achieved, Royal Air Force pilots under this control claimed six enemy aircraft destroyed in a successful interception[1]. Such direct radar control was not limited to one Forward Director Post only. During the first three weeks in July, No. 15053 F.D.P. had periods of control of fighter aircraft each day when the weather permitted. Pilots under this control claimed fifteen enemy aircraft destroyed and seven damaged during this period.[2] In the same month No. 8024 F.D.P. was given a similar periodic control of Allied fighter aircraft as a regular routine procedure.

This No. 83 Group radar network was quite adequate to deal with the size of the British Sector during June and July. A similar network existed under the United States IX Tactical Air Force in the American Sector for day control of fighter aircraft. The enemy air effort was much smaller during the whole of this period than had been anticipated but the warning organisation was able to deal with such air attacks quite satisfactorily. The paucity of enemy attacks must not be allowed to detract from the efficiency of the radar networks for night defence and tactical support.

Telecommunications for the Radar Network

In the relatively small confines of the bridgehead in Normandy the communications, both line telephone (installed by Air Formation Signals)[3] and radio (R/T and W/T), worked very well. As a result, the number of dispersed radar equipments, G.C.I., C.O.L.s and L.W.S., used as reporting stations were able to provide adequate information on the air situation to the Mobile Operations Rooms concerned. In reciprocal manner, the Group Control Centre had been able to communicate easily with the G.C.I. stations used to carry out local close-control functions, namely, the Forward Director Posts, as directed by the Group operations requirements. It cannot be stressed too strongly that the success of the radar system planned for and implemented in the invasion, as far as the establishment of a firm bridgehead on the Continent was concerned, was largely dependent on successful telecommunications. The traffic-handling capacity of the radar system was limited too by these

[1] No. 15054 F.D.P., O.R.B., June 1944.
[2] Nos. 15053 and 8024 F.D.P.s, O.R.B.s, July/August 1944.
[3] Air Formation Signals was formed out of, and was part of, the Army Royal Corps of Signals and was responsible for the provision, maintenance and manning of Royal Air Force telephones and teleprinters down to Wing level.

communications, since the multiplicity of stations both in reporting and for interception leads to delays, and indeed confusion, unless the full amount of available information could be fed verbally down communications lines between the various control and reporting centres.

The planning had been so effective that a smooth co-ordination of the Group Control Centre, the separate radar units in the field, the associated Mobile Signals Units and the Air Formation Signals was achieved in the Normandy bridgehead. Whether this could be maintained, as the mobility of the units increased with the expansion of the bridgehead and the distances between the various reporting units and the Control Centres lengthened, was yet to be put to the test.

Success of the Anti-Jamming Measures

It will be recalled that the anti-jamming measures employed in operation " Neptune " consisted of :—[1]

(a) The location of enemy ground jamming stations and subsequent air attack upon the stations.

(b) The provision of alternative frequency equipment, the Type 11 for all radar stations, so that if the Type 15 standard equipment were jammed the Type 11 could be employed.

(c) The provision of centimetre wavelength equipment, as an "anti-Window " measure at certain ground radar stations.

During the planning stage of the operation, information concerning enemy ground jammers, including details of suspected sites, had been provided by the Anti-Jamming Unit of No. 80 Wing. Very careful photographic reconnaissance had then been necessary in order finally to locate the sites and identify the jammer installations. Subsequent attacks on these installations by Bomber Command (using " Oboe ") were so successful that all known jammers between Calais and Cherbourg were destroyed by D-day. A measure of this success is clearly indicated by the fact that during the first seven weeks in Normandy no enemy jamming of Allied radar stations in Normandy had been experienced, and the use of the alternative frequency Type 11 equipment was rendered unnecessary. This equipment was used, however, at certain G.C.I. stations simultaneously with the Type 15 equipment as an additional channel for the control of night fighter aircraft.

" Window " was used by the enemy in such small quantities as to render the use of the centimetre equipment unnecessary—and was a help rather than a hindrance in that it provided a means of identifying enemy aircraft, especially as the use of Mark III I.F.F. was very severely restricted.

Servicing Organisation in the Field

During the first nine days of the operation each radar unit had to exist on its own resources. For technical servicing beyond the capacity of the units, No. 307 Mobile Servicing Unit became operational on its Normandy site on 17 June.[2] During the first six weeks on the Continent, signalled requests for assistance in the bridgehead for servicing radar equipment, telecommunications equipment, and electrical power supplies amounted to 417 of which 82 only were directly concerned with the radar equipment. Generally, the radar equipment in use stood up well to the field conditions in Normandy,

[1] A.E.A.F. File M.S. I.3441, Encl. 64A, Appendix " A."
[2] No. 307 M.S.S.U., O.R.B., June/July, 1944.

and the daily servicing by the units' mechanics was of a high standard. The real test was yet to come after the Allied break-out from the bridgehead—when the equipment would have to be moved many miles over roads pot-holed by shelling and bombing and worn out by the tractors of tanks.

Supply of Spare Parts

The supply of spare radio parts for replacement purposes through the Equipment Air Stores Parks was more than ample to meet the demands of the radar units. If anything, the Air Stores Parks in Normandy were carrying an excessive supply of the necessary spares. This over-insurance by the Equipment Branch planning staff was a good fault in the early stages of this operation, for no matter how efficient a radio mechanic might be, his efforts could be nullified by the absence of essential spare parts.

All units (Air Stores Parks, Mobile Signals Servicing Units and Radar Units) carried spares holdings based on experience in the field and not on rigid scales,[1] with the result that they were able to take with them all essential requirements and were not loaded with any unnecessary bulk of items. Orthodox methods of demand and supply were employed at the earliest possible moment in order to exercise the correct channel of supply and avoid calls to the United Kingdom for items in short supply.

General Observations on Performance of Radar Equipment

The main Light Warning equipment in use (Type 6, Mark 3) worked well and with little trouble. No. 6091 L.W.S. in particular produced excellent results as a forward controlled interception post on the Orne river flank within the No. 24 Base Defence Sector organisation. The Controllers were very pleased with the performance of this equipment—which reflected great credit on the technical personnel.

Both the Type 11 and Type 15 G.C.I. equipments gave steady and reliable service, the latter type being used as the principal equipment. The big transmitters in the Type 15 equipment (T.3079) were gradually replaced by the Light Warning Set transmitter (T.3154B), which could be housed on the aerial vehicle itself. This enabled the Forward Director Posts to increase their mobility and speed of erection by dispensing with the heavy transmitter vehicle, without any loss in the range of performance of the stations—in fact several units reported increased efficiency.

The Type 22 equipment on No. 15053 F.D.P., which had been issued to the unit in the Army marshalling area immediately prior to embarkation, had numerous production faults and unserviceable items requiring replacement.[2] Much credit was due to the perseverance and skill of the unit's technical officer in pursuing and clearing fault after fault in apparatus with which he and his staff of mechanics were little acquainted. The apparatus became serviceable on 22 June. Towards the end of the repair period assistance was lent by two members of the Post Design Service[3] of the Allied Expeditionary Air Force—experts on new types of equipment, established in A.E.A.F. against just such a contingency.

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[1] A.H.B./IIE/136, No. 83 Group Signals Report, 1944, Appendix " C." [2] *Ibid.*, para. 14.

[3] The Post Design Service consisted of personnel from the Telecommunications Research Establishment and the Royal Aircraft Establishment, who provided specialised technical assistance on British radar equipment, irrespective of whether it was manned by British or American personnel. It operated on the Continent under Headquarters, 2nd Tactical Air Force.

During July, the Type 22 equipment for No. 15054 F.D.P. arrived from the United Kingdom and was put into operation without any difficulty. Confidence in the equipment grew and operational results were encouraging towards the end of the static period in Normandy. Nevertheless, the initial experience of No. 15053 F.D.P. during its early days in Normandy with the Type 22 equipment as issued showed that it was really useless to take new radar apparatus into the field for immediate operation unless a reasonable time had been allowed beforehand for testing it and unless the unit was given at least some opportunity to set the apparatus up and get it working properly before going into action. Teething troubles invariably occur with new and untried equipment, so eleventh-hour changes in equipment should always be avoided.

General Comments on the Radar Organisation for Operation "Neptune"

The shipment and wet-shod landings of all the No. 83 Group Units and No. 24 Base Defence Sector were carried out without any incident worthy of special record and no technical vehicles were lost. The setting-up of these units and their operation in Normandy was largely according to plan. Though some slight delays occurred, units generally set up with commendable speed—a satisfactory indication of the care with which they had maintained their equipment during the months of preparation for the operations.

One source of delay was the splitting up of operational units such as G.C.I.s during transport over the sea. Although No. 15083 G.C.I. was actually operating on the night of D-day and had contact on one R/T channel with the "Master" Fighter Direction Tender, it was not until all its communications were going that it achieved any success ; from then on the unit added very materially to the effective defence of the bridgehead.[1] This delay was due to the separation of the Mobile Signals units from the parent G.C.I. at sea and the consequent landings on different beaches.

The G.C.I. for initial night defence of the American Sector met conditions on landing that no advance planning could have foreseen. The beaches were not safe enough for a G.C.I. to land, nor had the beach organisation been set up to facilitate the landings.[2] The decision whether or not the vehicles were to drive off the landing craft rested with the senior Royal Air Force officer on board, known as "Officer Commanding, Troops." No blame could be attached to the Royal Navy for the loss of so many technical vehicles ; the Naval Captain was responsible for the safe passage to the far shore but had no responsibility in ordering the vehicles off the ship. An even more amazing incident was that the new replacement equipment sent from England was also "drowned" on landing and a further issue had to be secured.[3] The nature of the beach was not to blame, as many United States Army units landed successfully on the same shore. It could only be due to the inexperience of drivers in this type of operation. It appears that the only preparatory exercise the unit had prior to embarkation was at the end of April 1944.[4] No. 83 Group units had already done more than a year's training by that time.

The plan of putting the G.C.I.s for base defence from No. 85 Group under the control of No. 83 Group, which represented the Royal Air Force Headquarters in the bridgehead during the first weeks, was not a good one. Although No. 83

[1] A.H.B./IIE/136, No. 83 Group Signals Report, 1944, p. 16.
[2] No. 15082 G.C.I. Unit, O.R.B.
[3] A.H.B. /IIE/136, No. 83 Group Signals Report, 1944, Appendix "H."
[4] No. 15082 G.C.I. Unit, O.R.B.

Group had to some extent a working acquaintance with No. 15083 G.C.I. in the British Sector as a result of pre-D-day exercises, it had no knowledge whatsoever of No. 15082 G.C.I. in the American Sector, which had been trained, equipped, and despatched by No. 85 Group. Every attempt was made to help No. 15082 G.C.I. and to make up their casualties, but it must be admitted that there was not the spirit of liaison and mutual trust between this G.C.I. and No. 83 Group Headquarters which could only have come with association and mutual acquaintance.[1]

The Wireless Observer Units (W.O.U. Posts) which, it will be recalled, had been planned to operate in the Tactical Air Force as visual support to the radar screen against low-flying aircraft, play no important role in the operation. In the absence of any serious enemy activity by day over the battle area, the W.O.U. screen did not justify its existence during the bridgehead phase of the campaign in North-West Europe. The restricted area of operation mitigated against its effective use, and only once in the first month did a W.O.U. Post provide an identification which materially assisted interception.

The extension of radar cover from the United Kingdom, first by the Fighter Direction Tenders, and then by the landing of G.C.I.s and F.D.P.s had proceeded largely according to plan. The operation of ground search radar in the bridgehead, before the break-out of the Allied forces during the first week of August 1944, was very satisfactory—if anything an over-insurance of equipment and units had occurred as losses were much smaller than had been anticipated. The small scale of enemy air activity tended to flatter the impression of efficiency which the radar network gave, up to the end of July 1944.

The static period in Normandy came to an end during the first week in August when the United States forces brought off their astonishingly rapid advance in the St. Lo Sector and the British 2nd Army slogged its way through the Villers Bocage area. The radar network had now to assume its full mobility and give cover to a rapidly expanding front continually receding from the radar sites.

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[1] A.H.B./IIE/136, No. 83 Group Signals Report, 1944, p. 16.

CHAPTER 25

GROUND SEARCH RADAR IN THE CAMPAIGN FROM NORMANDY TO THE BALTIC (OPERATION "OVERLORD")

The original radar system of early warning and fighter control employed in operation " Neptune " was essentially a defensive system, and utilised G.C.I. equipment which had been designed in the first place principally for air defence purposes in the United Kingdom—having been converted to its mobile form for use with the 2nd Tactical Air Force. By the time the assault phase of the invasion was over, however, it became apparent that a large degree of air superiority had been attained by the Allies and therefore the main role of the Tactical Air Force would henceforth be still greater co-operation with the ground forces, mainly on offensive missions in close support of the Armies in the field. Thus the main function of the ground search radar units had also to change from a defensive system to one largely concerned with controlling Allied aircraft on offensive sorties.

Such a change was not one of role only. For adequate radar control of offensive air operations it was hardly to be expected that equipment designed originally for a defensive function could be expected to fulfil its new task adequately—changes in the radar equipment itself were therefore to be anticipated. It had been an established policy in the planning for Operation " Overlord " that the United States Army Air Force Radar Units in the North-West European theatre of operations were to be equipped with British ground radar. Headquarters, United States Army Air Forces in Washington, decided finally to supply limited quantities of U.S. radar to the Ninth (U.S.) Air Forces. Although this led to non-standardisation of equipment within the Tactical Air Commands under the Headquarters, Allied Expeditionary Air Force, it eventually affected the radar system employed by the Royal Air Force on the Continent to a marked degree because of the superior performance of the new American equipment for close control of aircraft.

Occasioned by the addition of new types of radar equipment right up to the cessation of hostilities in North-West Europe and the progressive improvement in operational tactics, the radar early warning and fighter control systems underwent a continual change from the time the original plans for Operation " Overlord " were made. The principal aim of this chapter is to indicate the causes for, and the improvements from, these rapid changes as the campaign in North-West Europe progressed and, finally, to give an impression of the ground search radar organisation when hostilities with Germany came to an end.

The Break-out from the Normandy Bridgehead

At the end of July 1944 the American ground forces were making excellent progress in the western sector of the front, south of the Cherbourg peninsula. This was followed by the British Second Army advancing against tough enemy opposition south and then east through Tilly and the Bocage country. The Canadian First Army were pushing due east at this time on the northern coastal flank. The Canadian Army had its appropriate Royal Air Force composite Group to support it, as No. 84 Group Headquarters had moved to

France from the United Kingdom on 6 August 1944, followed by its Group Centre, No. 484 G.C.C., two days later.[1] The ground search Radar Units of this Group was phased in to set up the raid reporting network during August.

The almost static days of the radar system in Normandy were over after August began. The Allies broke through from the bridgehead, and after the encircling movement of the Falaise gap ended the German hopes of a stabilised front, the Allied armies began to sweep across France. The very fluid nature of the war at that stage meant that ground targets for the Allied Expeditionary Air Forces were targets of opportunity, and were discovered by the eye and bombed almost immediately.[2] Missions were not of the type which would lend themselves to detailed previous operational planning for close control by ground search radar stations, because of the difficulty of maintaining adequate telecommunications and the ability of the pilots to pick out their own targets with greater efficiency than anyone could do from the ground.

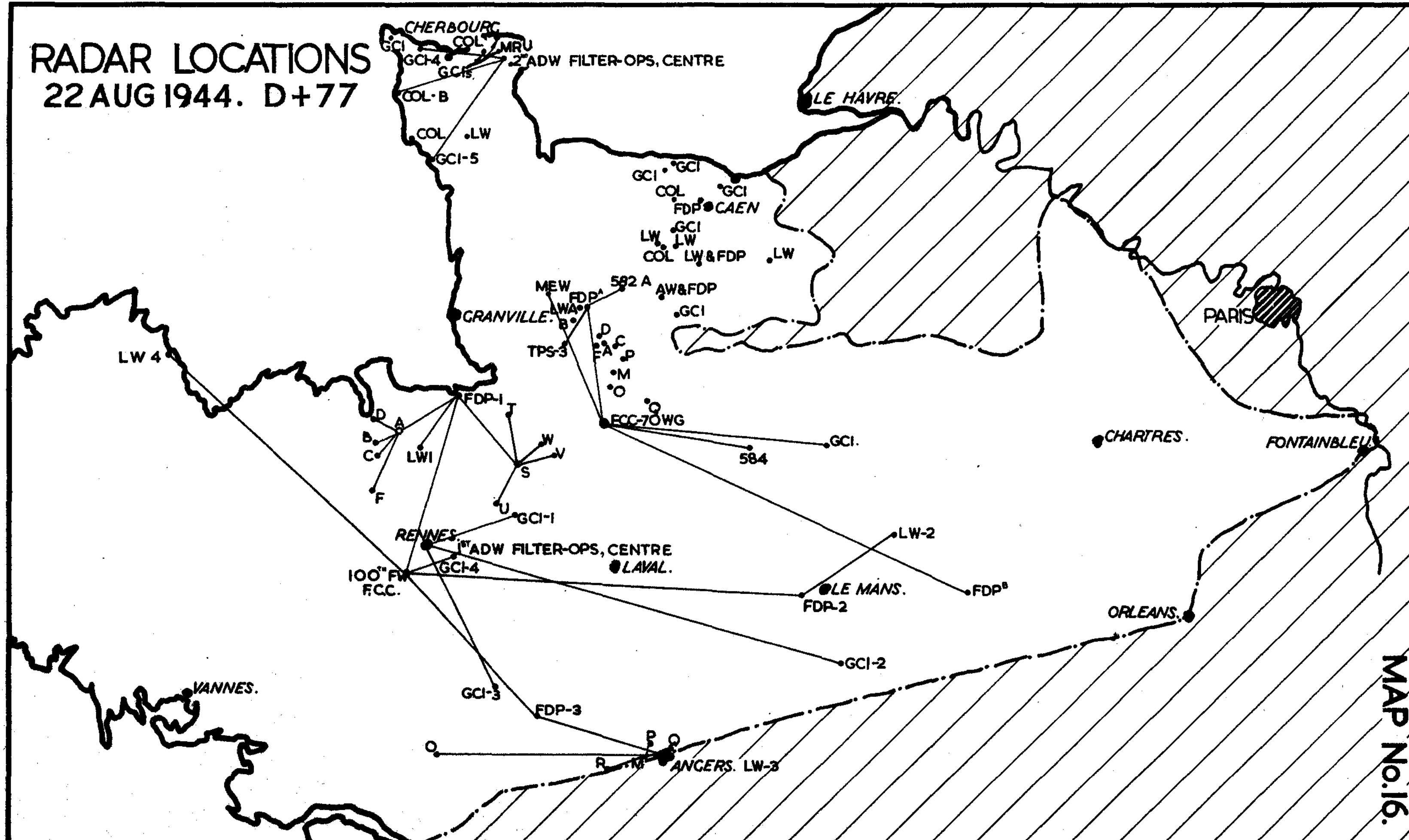
Nevertheless, the radar units maintained a standard of mobility not surpassed by any other Royal Air Force field units. The tactical Composite Groups, Nos. 83 and 84, pushed their F.D.P.s forward in an attempt to keep up with the rapid movement of the ground forces. The Group Control Centres divided into two echelons so that they could leap-frog forward while still maintaining control of their aircraft. The radar ground stations had also to utilise an echelon principle, moving the Type 15 equipment forward while leaving the Type 22 apparatus behind to continue operations.

Some idea of the degree of movement achieved by these radar units can be gained from the fact that two Forward Director Posts in No. 83 Group, Nos. 15053 and 15054 F.D.P.s, each had four different operational sites during the last two weeks in August.[3] In similar manner, No. 15071 F.D.P. in No. 84 Group had four different locations during the first ten days of September. In spite of the high standard of mobility of the units they often found themselves too far behind the front on occasions, and yet too far in advance of the Group Control Centre to fulfil their control functions, and merely maintained a raid reporting role in case early warning were necessary.[4]

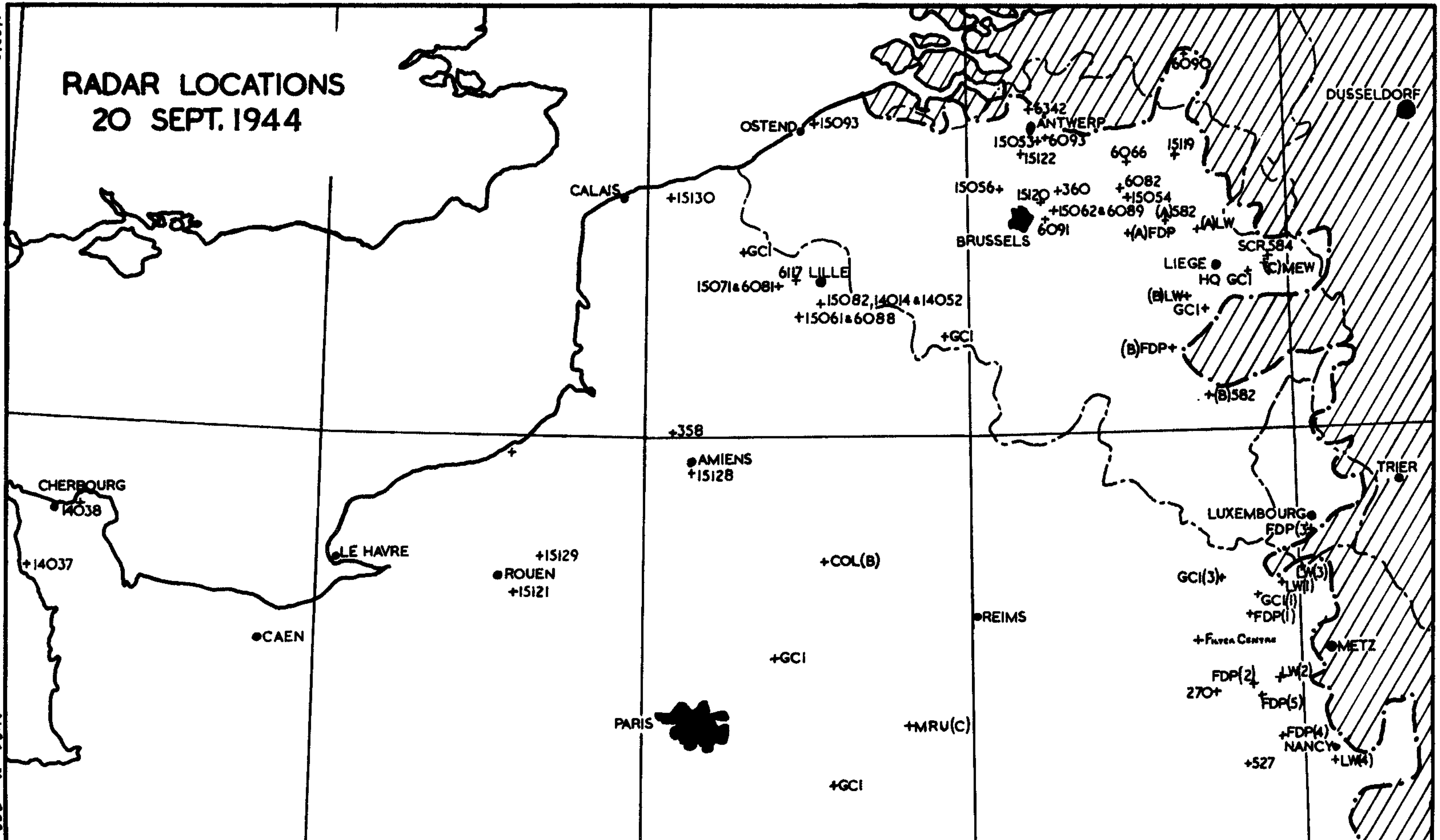
With such rapid movement and increasingly wide dispersal of the ground search radar units from the Group Control Centres, the provision of landlines for reporting purposes was impossible. Even the W/T contact between G.C.C. and the F.D.P.s was at times weak and difficult, due to interference. The inherent limitations of a ground radar system which depended on dispersed units reporting in to a Control Centre—that is, the extension of the Home radar system in principle to an overseas campaign on a mobile basis—were beginning to show themselves. The Forward Director Posts were also unable to function fully because such G.C.I. stations, for the purpose of carrying out local control functions, in their turn required much information from the Group Control Centre—usually of an Intelligence or Army liaison nature.

An attempt was made to overcome this difficulty by moving additional communications facilities, together with Intelligence and Army Liaison officers from the G.C.C. to the most forward F.D.P. and associated Light Warning

[1] Headquarters, No. 84 Group, and No. 484 G.C.C., O.R.B.s, August 1944.
[2] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation "Overlord," Section XXI, Chapter 3, p. 7.
[3] Nos. 15053, 15054 and 15071 F.D.P.s, O.R.B.s for August/September 1944.
[4] The relative distances of the mobile Radar units from the front line on D+77 (22 August 1944) are shown on Map No. 16.



A.H.B.I. MAP No. 223.



MAP No. 17.

A.H.B.1. Map 222

1/33/9

Sets, and then to carry out direct control of aircraft from it until a second F.D.P. had been leap-frogged past it towards the ever-receding front line. By this method the rapid advances during August and September 1944 right across France and into Belgium were completed.[1]

The No. 83 Group F.D.P.s did some useful control work on the western bank of the River Seine giving cover to the British Second Army crossing, while No. 84 Group operated with the Canadian First Army on the Northern flank and assisted in the winkling-out operations against the enemy pockets which remained behind in the Channel ports of Le Havre, Calais and Boulogne. The enemy air reaction at that time was weak, and by day was largely confined to attempting to give cover to their badly harassed ground forces involved in a partially disorganised retreat. The limitations of the telecommunications between the Allied Central Operations Rooms and their deployed radar stations was therefore not turned to good account by the enemy because of the marked superiority in air power possessed by the Allies at that time. Nevertheless the weakness in the 2nd Tactical Air Force radar organisation under conditions of highly fluid warfare was apparent to its staff officers, and the problem was given immediate attention.

Development of New Radar Equipment for the 2nd Tactical Air Force

A laboratory pre-production model of an American radar equipment known as M.E.W.,[2] originally designed for early warning purposes, had been used during May and June 1944 for control purposes by the United States Army Air Force in England at Start Point, Devon with great efficiency. It had been borrowed complete with its American crew by Headquarters, Air Defence of Great Britain for use against the new enemy weapons, Flying Bombs, launched from the French coast, becoming operational at Fairlight, near Hastings, on 29 June 1944. Its long-range facilities, high discrimination, and multi-control positions enabled it to be used for control purposes and raid reporting simultaneously.[3]

As the Flying Bomb attacks increased in intensity, the Telecommunications Research Establishment began construction of a new radar set to take the place of the M.E.W. so that the latter might be released for use on the Continent by the U.S. XIX Tactical Air Command. This new British set had the aerial turning gear from an A.M.E.S. Type 20, the aerial and transmitter from an American M.E.W. (transported by air from the United States) a modulator from A.M.E.S. Type 16, and receiver and display units from other Royal Air Force centimetre radar equipment. This set, known as A.M.E.S., Type 26, was completed by 14 August, being set up at Fairlight on 26 August 1944. The equipment gave excellent results during its first months of operation.

Meanwhile, the American M.E.W. equipment, which had been progressively mobilised while at Fairlight and had a Type 13 centimetre height equipment added to provide height-reading facilities, was moved to the Continent during the latter part of September. It was an immediate success with the American forces, giving reporting and control facilities, both offensive and defensive, with an appreciably increased range over the F.D.P.s. This one set added to

[1] Map No. 17 shows the location of the Radar Units on 20 September 1944.
[2] Details of the American M.E.W.—Microwave Early Warning—in use in U.K. are given in Chapter 26 of this volume.
[3] Air Ministry File C.M.S. 202, " Diver Countermeasures," Encl. 151A.

a Group Control Centre would therefore give the major portion of the radar facilities required by it, thus eliminating the necessity for a network of separate radar stations.

On 22 September 1944 a definite request was forthcoming from the 2nd Tactical Air Force Headquarters in Belgium for radar facilities to meet its new requirements for offensive operations, laying down a minimum performance for a new radar mobile equipment of 100 miles range on a single Mosquito aircraft at 10,000 feet, with low and high coverages of a good order.[1] This requirement was passed on to the Telecommunications Research Establishment immediately to develop such equipment. The problem was largely to produce equipment very similar to the new Type 26 Stations but in mobile form, and T.R.E. started working at high pressure to achieve this in a convoy of thirty vehicles which were given the nomenclature of A.M.E.S., Type 70 station.

Almost simultaneously with the success of the American M.E.W. and the beginning of the development of the British Type 70 Station, another United States radar equipment was proving distinctly useful in its application to Tactical Air Force close control work. This was the SCR. 584, originally designed as a radar gun-laying equipment with a maximum range of 32,000 yards. At the British Branch of the Radiation Laboratories, Massachusetts Institute of Technology, which had been set up at the Telecommunications Research Establishment at Great Malvern, this set was modified for close support work. Its output power was boosted and the pulse repetition rate lowered to make its performance satisfactory for a modification to the range unit giving it a new maximum of 96,000 yards (54·5 miles).

The United States Ninth Air Force had formed a board during April 1944 to investigate the possibilities of the modified SCR. 584 as applied to close control work. One equipment was moved to France on 16 July 1944 and used by the Americans with no conclusive results from their bridgehead sites. However, with the Falaise gap, the first four operational missions flown under radar control using this set proved to be a moderate to good success. Headquarters, Allied Expeditionary Air Force anticipated a Royal Air Force requirement for such a set in the 2nd Tactical Air Force and started training a team to man it from 10 July onwards. This unit was termed a Mobile Radar Control Post (M.R.C.P.).

Two ground search radar projects destined for use in the 2nd Tactical Air Force were therefore developing in the United Kingdom namely, the Type 70 Station to replace the radar network of F.D.P.s and improve aircraft control in both performance and range, and the M.R.C.P. for accurate close control air operations in support of the Army. Meanwhile on the Continent the two Tactical Air Force composite Groups, Nos. 83 and 84, accompanied the Army advance into Belgium and Holland, with the No. 85 Base Defence Sectors moving up behind to provide the essential aerial defence of the base areas. The ground search radar network system had to be adapted to meet the conditions then obtaining, pending the arrival on the Continent of the new radar equipments. It is therefore necessary to revert to a consideration of the activities of the radar units during the stirring days of September and October 1944 which preceded the stabilisation of the front on the River Maas, before the winter of 1944 set in and caused a comparative lull in military progress.

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[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation "Overlord," Section XXI, p. 23.

Ground Search Radar in Support of the Airborne Forces Operations at Arnhem and Nijmegen (Operation " Market ")

On 18 August 1944 the Commanding General of the First Allied Airborne Army had stated that in future operations airborne forces might have to be landed considerably forward of the main Allied field forces. In such an operation it was obvious that effective fighter aircraft cover was essential and that it could not be controlled from F.D.P.s moving up with the main field force. In order to achieve this control some form of ground search radar equipment landing with the airborne force was therefore necessary.[1] Headquarters, Allied Expeditionary Air Force were requested to produce Air Transportable Forward Director Posts (incorporating point-to-point communication with a range of at least 70 miles) capable of being transported by glider. The equipment was to be ready for 1 September 1944.

With only two weeks available and very little previous experience of airborne operations as far as ground radar equipment was concerned, this was rather a tall order. The former occasions on which ground search radar had been transported by air as an operational requirement were in the Middle East after the break-out from El Alamein. Then, a Light Warning Set and crew specially trained for the task of air lift in Bombay or Hudson aircraft had been flown in from the rear area to the landing ground at Marble Arch[2] on 18 December 1942. The unit was able to give some radar early warning cover to the landing ground within 45 minutes of landing. This method was again applied during January 1943 when access was not possible by road.

Air Transportable Ground Search Radar Units

After specialist officers of Headquarters, Allied Expeditionary Air Force had had consultations with Air Ministry and D.C.D. design authorities, air transportable Light Warning Sets and air transportable G.C.I.s were designed and produced.[3] The crewing-up of these units and subsequent technical training was done by Headquarters, No. 60 Group. On completion of the rushed technical training, two Light Warning Sets and one G.C.I. were transferred to Headquarters, No. 38 Group—the Royal Air Force Group which operated with the Airborne Forces. The radar units began their operational training for operation " Market," which was to be an attempt to outflank the Siegfried Line with airborne operations across the Lower Rhine along the Eindhoven–Nijmegen–Arnhem axis.

Two glider-borne transportable F.D.P.s were supplied to the Ninth U.S. Army Air Force for training with the 82nd Airborne Division (U.S.) in case of Control of the IX Air Force fighter aircraft being required. Each team consisted of Controllers, Technicians, Operators, lightweight radar equipment (AN/TPS–3), communications radio (S.C.R. 118 and 624) and a portable V.H.F. Direction Finding set (S.C.R. 634 D/F).

At a meeting at Bentley Priory on 15 September, it was stated by a representative of the First Allied Airborne Army that, despite the preparations already made, air transportable ground radar equipment would not be required for this operation after all. This last-minute cancellation caused

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI, Chapter 4, p. 8.
[2] Chapter 12 of this volume gives details of this operation.
[3] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord."

disappointment to the trained Royal Air Force crews, and largely due to the intervention of Wing Commander L. G. Brown at a meeting with General Browning at the Royal Air Force Station, Harwell, on 16 September, the decision was over-ruled.

On the morning of 18 September 1944 the Light Warning Units, Nos. 6341 and 6080 were airborne in four gliders, with Wing Commander Brown in command, destined for Arnhem to take part in what has since been described as " the bloodiest battle of the War." The four gliders containing the Light Warning Sets and their crews came under accurate enemy A.A. fire as they approached the Landing Zone, and severe mortar fire when they landed. Conditions and casualties were so severe that the radar equipments were never erected, and the surviving personnel fought as ground troops.

No. 83 Group F.D.P.s' attempt to give Radar Cover over Arnhem and Nijmegen

The major portion of the airborne attack along the Eindhoven–Grave–Nijmegen–Arnhem axis was successful, and the British Second Army pushing up from Belgium established by hard fighting what was termed the " Dutch Corridor," linking up with the airborne forces as far as Nijmegen. The final linkage to be attempted between Nijmegen and Arnhem, however, met with extremely tough enemy opposition. With the failure of the air transportable Light Warning Sets at Arnhem, radar cover over that area had still to be established as quickly as possible, so No. 15053 F.D.P., which had been located since 12 September at Boechout near Antwerp, was moved up to Eindhoven airfield in Holland on 21 September. There was faint W/T contact only with the Group Control Centre, No. 483, then sited near Brussels, so the F.D.P. was augmented with an additional four channels of V.H.F. ground-to-air R/T an Intelligence detachment, Army Liaison Officer and a Wing Commander Planning from the G.C.C.[1]

The unit took over control of all No. 83 Group aircraft for the remainder of the Battle of Arnhem period. It was worked to capacity, and although weather conditions were by no means ideal for flying, there were no complaints from the Army that they had been beaten up on the ground by the enemy air force—one sign that the F.D.P. was functioning really well. Some indication of its success may be gained from the claims of pilots flying under its control for the period 25–27 September. In three days these were :—

	Destroyed.	*Damaged.*
	34 *Fw. 190.*	21 *Fw. 190.*
	41 *Me. 109.*	32 *Me. 109.*
	1 *Me. 410.*	1 *Me. 262.*
Totals :	76 enemy aircraft.	54 enemy aircraft.

In order to improve the radar cover as much as possible as the ground forces extended their linkages with the airborne troops holding strategic points and bridges, a forward echelon of No. 15054 F.D.P. with its Type 15 equipment moved up immediately behind the tank squadrons with army armoured recce. units. Its first site in the " Dutch Corridor " was between Uden and Nijmegen and it was able to relay its plots to Eindhoven and G.C.C.—the latter was achieved through aircraft R/T. On 27 September this forward echelon was

[1] No. 15053 F.D.P., O.R.B., 12–30 September 1944.

given control responsibilities and claims of success under it amounted to forty-six enemy aircraft destroyed, two probably destroyed and twenty damaged —the most successful day for No. 83 Group aircraft since D-day.[1]

The Evacuation from Arnhem

Despite heroic resistance by the airborne forces at Arnhem and tremendous efforts by British ground forces trying to link up with them in a push from Nijmegen, the enemy resistance was too strong, and it was decided to evacuate the survivors from the untenable Arnhem position. This took place on the night of 25/26 September, and the survivors of the Royal Air Force Radar Section of the First Allied Airborne Army which originally comprised five officers and forty airmen, were returned to the United Kingdom. This party consisted of three officers and one airman. Wing Commander L. G. Brown, Royal Air Force Commander, was amongst the killed.[2]

Although the Air Transportable Radar had been a casualty and had not worked at all, reports from the survivors of operation " Market " proved invaluable in formulating the requirements for any future airborne operations. It was considered that such units were in future to comply with the following conditions :—

(*a*) The complete radar equipment must travel with its crew in one glider.

(*b*) The equipment and crew must be able to move swiftly from the glider to cover on a pre-selected site immediately upon making a landfall.

Planning was recommenced at Air Ministry, reviewing the requirements for any future operations in which the landing zones might be so sited that radar cover of the area could not be provided by radar units within the main Allied lines. New air transportable units were devised and crews began technical and operational training under No. 60 and No. 38 Groups respectively.

The Radar Networks at the End of Autumn 1944

No. 83 Group

After the evacuation from Arnhem, No. 483 G.C.C. again took over control of No. 83 Group aircraft, No. 15053 F.D.P. moving up to a very good site covering the north-east of the Allied lines, just south-west of Nijmegen, and No. 15054 F.D.P. forward echelon rejoining the main unit at Wauberg in north-east Belgium, covering the south-eastern flank of the British Second Army area.[3] Melancholia set in amongst the Controllers on the F.D.P.s., as their units were used in a radar reporting role only, all controlling being kept at the G.C.C. then located at Erp, midway between Eindhoven and Nijmegen.[4] A big rail interdiction programme behind the enemy lines was started by No. 83 Group aircraft, supplemented by barge and road transport targets, and this continued steadily until the middle of December 1944.

The experience of No. 83 Group on the continent up to the end of September had proved that the radar operational requirements had never been such as to necessitate the deployment of their establishment of three F.D.P.s and one G.C.I. station as well as their associated Light Warning Sets. Accordingly during the advance of the ground forces into Belgium, No. 8024 F.D.P. and No. 8007 G.C.I. unit had been lodged with No. 85 (Base Defence) Group and

[1] No. 15054 F.D.P., O.R.B., 24–27 September 1944.
[2] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI.
[3] No. 15054 F.D.P., O.R.B.
[4] No. 483 G.C.C., O.R.B., September/December 1944.

subsequently, in September, these units being surplus to operational requirements, were returned to the United Kingdom and the establishment of No. 83 Group amended accordingly.

No. 84 Group

The other composite Group of the Second Tactical Air Force, No. 84 Group, was operating chiefly over north-western Belgium and south-western Holland during September. Although the city of Antwerp had been liberated in the victorious British Twenty-First Army Group advance, its port facilities, so vital for Allied supplies, could not be used as the Germans occupied commanding positions overlooking the outer West Scheldt estuary. The most serious threat to Allied shipping was from the island of Walcheren, where the enemy had large-calibre guns covering the approaches to the Scheldt estuary.

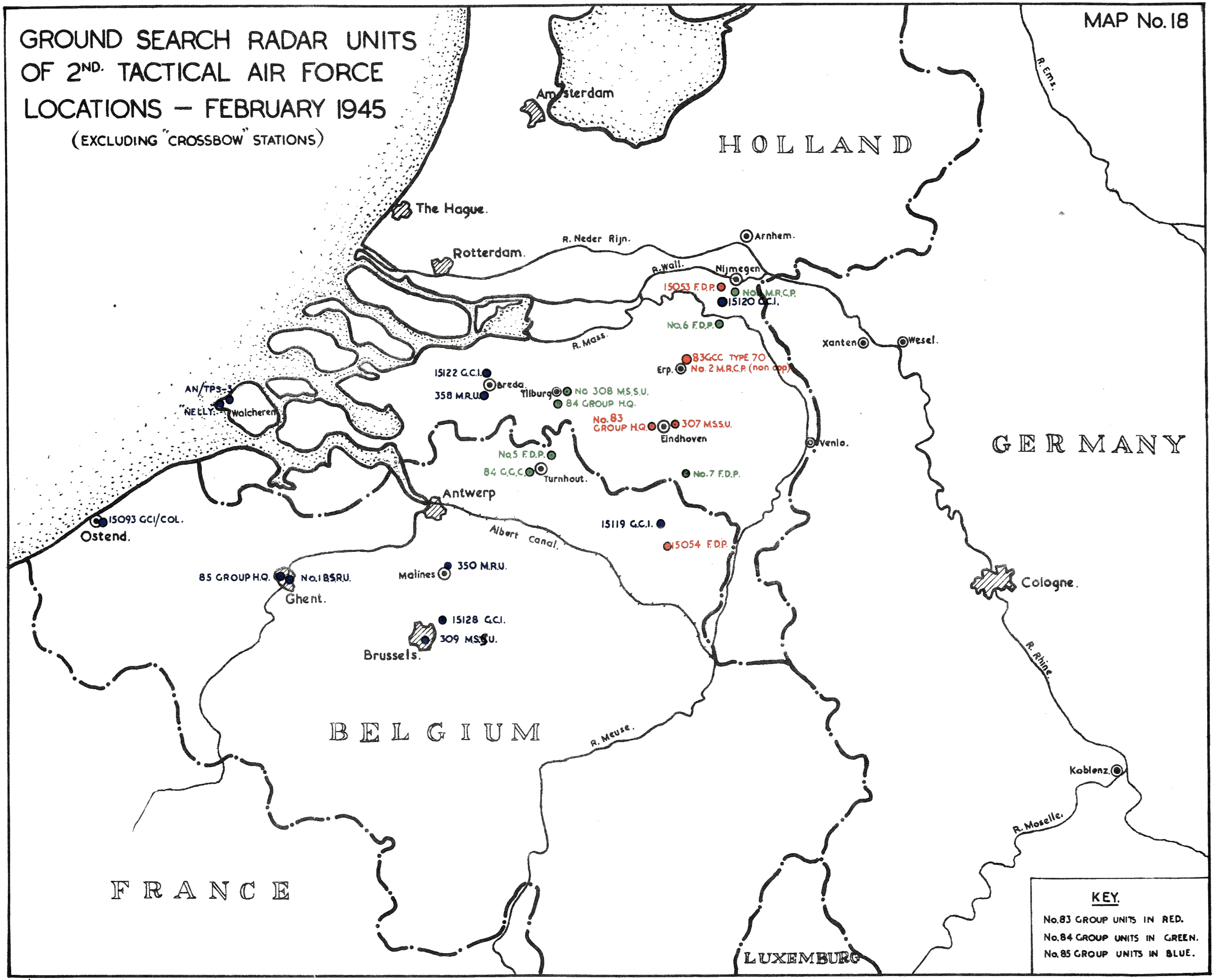
Commando landings by the Army were undertaken against the island on 7 November 1944 and No. 84 Group Control Centre, located at Wondelgem, near Ghent in Belgium, was called upon for all available air support from the Group. The landings on Walcheren were made against very formidable enemy resistance, and initially the air support given was much less than had been planned—weather conditions limiting operations to about half the potential maximum effort. Flying in weather that would normally have been regarded as unflyable, pilots under the G.C.C. control put in a total of more than 400 sorties, mainly against the strong enemy defence positions which were causing considerable damage to assault personnel and shipping. The Forward Director Posts associated with No. 84 G.C.C. were used in a radar reporting role and accurate plotting was achieved. The operations against Walcheren lasted a week before the enemy resistance finally ended. During this period the F.D.P.s were also used for direct control of aircraft assisting the Canadian First Army in clearing out the enemy pockets south of the lower Maas.

No. 85 Base Defence Group, Reorganisation

While the British Twenty-first Army Group was stablising its front on the Maas river, the Base Defence Group, No. 85 Group, which had followed in the rear of the Allied advance into Belgium and Holland, was organising the night defences of the new base areas. This was achieved by having phased in the reserve Base Defence Sector, No. 25, from the United Kingdom into Normandy, at the end of August 1944. This sector was leap-frogged past Nos. 21 and 24 Base Defence Sectors, driving across France in twelve convoys, finally taking up a position east of Brussels at Everberg. There it was entrusted with the air defence by night of the Second British and First Canadian Army fronts on 14 September 1944, having deployed its G.C.I. stations for this purpose in Holland and Belgium.[1]

No. 24 Base Defence Sector also moved up into north-east France during September. The inability of the *Luftwaffe* to attack Allied bases on the scale which had been anticipated in the planning stage, made it possible for the base areas, ports and harbour installations to be adequately defended by Nos. 24 and 25 Base Defence Sectors of No. 85 Group. The Ninth United States Army Air Force released No. 21 Base Defence Sector, which had provided the night radar control in the American Sector in Normandy, and accordingly the decision was taken by No. 85 Group on 23 September to return the major

[1] No. 25 Base Defence Sector, O.R.B., September 1944.



1/3434

Map No. 227 drawn & compiled at A.H.B.1.

portion of this Base Defence Sector to the United Kingdom.[1] This decision resulted in a reduction of three A.M.E.S., Type 25; two A.M.E.S., Types 14 and 15, and one Mobile Radio Unit on the establishment of No. 85 Group.

It will be recalled that No. 83 Group had also found from experience on the continent that its establishment of radar units had never been fully deployed as an operational requirement, and had returned two units to the United Kingdom as surplus to requirements. Throughout the entire operations in north-west Europe under the Allied Expeditionary Air Force, there was never any attempt to hold on to units unnecessarily. The number of radar units deployed was continually being reduced to a minimum consistent with operational requirements. The advantages so gained were increased mobility of the radar networks, conservation of personnel of the radar trades required for other commitments, and an appreciable reduction of requirements for communications.

Criticism of Deployment of Radar Units

When the F.D.P.s of Nos. 83 and 84 Groups and the G.C.I.s of No. 85 Group had taken up their positions in Holland and Belgium for the semi-static phase of the war in north-west Europe during the winter of 1944–45, their deployment gave rise to much criticism from scientific observers not fully conversant with the functions of these Groups.[2] At Breda (south-west Holland) the G.C.I. No. 15122 of No. 85 Group was very near F.D.P.s Nos. 15056 and 15061 of No. 84 Group. At Nijmegen the G.C.I. No. 15120 of No. 85 Group, F.D.P., No. 15062 of No. 84 Group and F.D.P. No. 15053 of No. 83 Group were all situated within a circle of 5 miles radius, and near Helchteren (north-east Belgium) G.C.I. No. 15119 of No. 85 Group was approximately 5 miles away from the F.D.P. No. 15054 of No. 83 Group.[3]

At first sight it appeared that this duplication of radar cover in the environs of Breda, Nijmegen and Helchteren signified an incorrect deployment of the radar resources of Second Tactical Air Force. However, an appreciation of the function of the three Groups concerned indicates that this deployment was not necessarily incorrect. No. 85 Group was the base defence group, and in order to fulfil that purpose it required radar cover over as wide a front as possible; consequently the radar units deployed at Breda, Nijmegen and Helchteren thus covered the northern and eastern limits of the British Twenty-First Army Group area. The important bases of Antwerp and Brussels were not far removed from the tactical areas, hence the deployment of the No. 85 Group G.C.I.s was not only based on sound practice but was also theoretically correct.

The presence of F.D.P.s of both Nos. 83 and 84 Groups at Nijmegen also arose from the nature of the tactical area. No. 83 and No. 84 Groups required radar cover on their left and right flanks respectively and consequently each Group had to have a radar unit at this point. It may be argued that had telecommunications permitted, the same radar unit might have reported to both No. 83 G.C.C. at Erp and No. 84 G.C.C. at Turnhout. That again would have had the disadvantage that in event of an advance, when radar cover over a wider front might have been required, two F.D.P.s would again have

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation "Overlord," Section XXI, Chapter 1, para. 5, and No. 21 Base Defence Sector O.R.B., September 1944.

[2] A.H.B./IIE/167, "Report on Radar Equipment for Tactical Air Forces," by Wing Commander Jackson, para. 28.

[3] These sites are all shown on Map. No. 18.

been needed at different positions for the left flank of No. 83 Group and the right flank of No. 84 Group. In short, the need for maintaining mobility, and the similarity of the tactical and base areas during the early part of the winter of 1944–45 resulted in an unavoidable overlap of radar cover, but nevertheless criticism of the deployment of the radar units at that stage was quite unjustifiable.

Light Weight Radar Equipment for Coast Defence—" Nelly "

The advance of the British forces through the Low Countries had revealed the possibility of making improvements in the arrangements for providing the Royal Navy with surface-vessel watching radar cover and also detecting enemy low-flying aircraft operating as minelayers.[1] German E-boats were engaged both in mine-laying and in attacks on Allied shipping convoys. With most normal radar equipment such cover could only be obtained by using sites on high ground or by the use of high towers. No good sites for No. 85 Group C.O.L. Units using Type 14 equipment were available owing to the low-lying nature of the coastline, consequently the ranges obtained from these stations were short.

Headquarters, No. 85 Group, saw the possibility of installing some form of radar equipment in a building on the coast, such as a lighthouse or tower, in order to increase the range of low radar cover to the seaward. What was really needed was a very transportable form of equipment which could easily be manhandled into position in such high buildings. The idea of using a modified SCR. 720[2] equipment was first projected by the Operational Research Section representative at No. 85 Group Headquarters about 12 September 1944.[3] Arrangements were made to carry out trials at Trouville between 18 and 22 September 1944. These trials proved so successful that it was decided to install the Mark X (SCR. 720) equipment, suitably modified, in the tower of the Casino at Blankenberghe. The main modifications made to the Mark X equipment were the elimination of the vertical scan and a reduction in speed of the horizontal sweep. Thus modified, the set gave satisfactory performance though it had the disadvantage of no Plan Position Indicator display and lacked certain definition due to an unnecessarily wide horizontal beam.

Under the code name " Nelly," the equipment operated at Blankenberghe on 27 September 1944. It was found after practice that the operators were able to read their " B "-Scope[4] very accurately, and the plots passed on compared favourably with those of No. 15081 C.O.L./G.C.I., located near Zeebrugge, and by the Naval radar. The results achieved were considered by the Royal Navy to be very valuable, and in at least one case plots passed from the equipment led to a naval action in which German E-boats were sunk.

It was apparent that there was a real requirement for a light-weight radar equipment, each section of which was portable at the most by two men so that it was capable of installation in sites inaccessible to normal radar equipment, such as lighthouses, water-towers and high buildings.[5] The dimensions of each separate section or unit when contained in its case were to be such as

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report, Section XXI, Chapter 9.
[2] SCR. 720 equipment was the aircraft Mark X A.I. apparatus.
[3] Air Ministry File C.25115, Encl. 27D.
[4] The " B "-Scope was the radar display in the SCR. 720 which showed the position of the target in bearing, horizontally, and in range, vertically.
[5] A.H.B./IIE/159, S.H.A.E.F. Signals Report on Operation " Overlord," Section XXI, Chapter 9, para. 86.

to allow passage through narrow doors, corridors and staircases. For sharp definition a narrow horizontal beam-width of the order of 3 to 4 degrees was required. In order to achieve this and at the same time keep the aerial within the limits of size necessary for portability, " X " band (3 centimetre wavelength) equipment would be necessary.

Immediately after the enemy had been driven from Walcheren Island in the British drive to clear the approaches to the port of Antwerp, radar low cover of the Scheldt Estuary was essential to prevent enemy light surface craft and aircraft from interfering with the Allied shipping. The Radar Officer of No. 85 Group carried out an initial reconnaissance of the island between 7 and 10 November 1944. It will be recalled that Bomber Command aircraft had breached the dyke walls to flood the German defences prior to the British ground forces' amphibious assault, so although there was a very suitable site for ground radar at Domburg on the north-west side of the island, it was impossible to establish a C.O.L./G.C.I. unit on it because of the lack of mobility of the heavy Type 25 equipment. The only approach, due to the flooding, was by the amphibious troop-carriers (called " Ducks "), thus again there was a demand for a light-weight portable radar equipment.[1]

It was decided to use the modified Mark X A.I. equipment, and the lighthouses on the west coast of the island were visited to select a suitable site. The Naval representatives were most interested in the West Kapelle site, on the south-west of the island, stating that they would be entirely dependent on the proposed Royal Air Force radar installation for early warning cover. The siting was not completed until the end of November. Then " Nelly," the set from Blankenberghe, further modified to scan alternately from left to right and right to left over an angle of 180° out to sea instead of the normal 360° rotation, was installed at the top of the West Kapelle lighthouse during the second week of December 1944.

Many domestic problems presented themselves to the crew manning the equipment and some difficulties were experienced with spare parts for their apparatus. On two occasions supplies were dropped by air—not by an airborne supply mission on the stereotyped Allied Airborne Army scale, but by enthusiastic Royal Air Force officers in an Auster aircraft dropping the necessary " bits and pieces " by hand, using home-made parachutes.[2]

The Royal Navy was very satisfied with the information passed to them from this radar cover and praised the assistance it gave in the defence of the Scheldt Estuary. Although the success of this radar station reflected great credit on the initiative of the Radar Section at No. 85 Group Headquarters, it also demonstrated a deficiency in the scale of Royal Air Force standard radar ground equipment available for deployment on the Continent—there remained a requirement for the development of a standard radar apparatus of the light-weight type, easily hand-portable and suitable for installation in sites inaccessible to the normal heavier mobile equipment.

Close Support Operations with the Mobile Radar Control Post (Modified SCR. 584)

The first Mobile Radar Control Post (M.R.C.P.) for use with the Royal Air Force had been formed and started training during July 1944. It arrived as a complete unit at No. 83 Group Control Centre at Erp in Holland during the third week in October and was set up and carried out a number of test runs

[1] A.H.B./IIE/167, " Report on Radar Equipment for Tactical Air Force," para. 19.
[2] Air Ministry File C.25115/45, Encl. 27D.

from a site near Erp.[1] It was used for the first time operationally to direct rocket-firing Typhoon aircraft on to targets in close support of Army operations on 11 November 1944. The targets were in the Venrai area and were heavily defended by enemy A.A. guns—that is, the conditions were such that low-level visual attack by Second Tactical Air Force fighter-bomber aircraft was virtually impossible. The results achieved on the first day of operation are the clearest indication of the initial success of the equipment :—[2]

(*a*) *Target :* Church tower.

Six aircraft of No. 247 Squadron at 10,000 feet. No. 1 M.R.C.P. was successful in putting the aircraft on the target. The rockets missed, however, due to a wrong meteorological forecast of the wind and the rocket fusing.

(*b*) *Target :* Two guns in the corner of a wood some five miles south-west of Goch—across the river Maas.

Five aircraft of No. 137 Squadron. The run under No. 1 M.R.C.P. close control was successful. The target was hit and later reports confirmed that the mission was entirely successful.

During the next two weeks, adverse weather conditions prevented any further work from being carried out with the M.R.C.P. other than practice tracking. Test flights during that period showed accuracy of control up to thirty miles range. Apart from the value of this practice period to the ground controllers on the M.R.C.P., it also gave experience to pilots of the No. 83 Group Typhoon squadrons—the building up of confidence in the pilots that such radar ground control in poor flying weather was a great advantage over their own visual navigation was a most essential factor in its successful operation.

Between 3 and 10 December several more operational flights were undertaken under No. 1 M.R.C.P. in conjunction with the Army ground operation " Blackcock " (the straightening of the British line near Roermond in south-east Holland). All these flights were undertaken under conditions of poor visibility and observation of results achieved was only possible on one—when the accuracy of the bombing was good.[3] After No. 1 M.R.C.P. had this month's trial with No. 83 Group, it was transferred to No. 84 Group so that pilots in that Group could also have practice and operational experience of flying under its control on close support missions, pending the arrival of further M.R.C.P.s on the continent.[4]

As a result of its period of use in No. 83 Group, Staff Officers of that Group reported that in certain tactical conditions and in poor visibility, the Mobile Radar Control Post had a definite value. Its limitations at that time were principally its relatively short range and the limited type of target against which it could be used with reasonable prospects of success.[5] Its mean error of 350 yards indicated that its best application with Tactical Air Force Fighter Bomber Groups was the blind level bombing of targets such as villages containing concentrations of enemy troops in forward areas behind the enemy lines, under conditions when visual attack by fighter-bombers was impossible. Although bombs dropped with this accuracy were of some effect, it in no way replaced the value of bombing by fighter-bombers under good visual conditions, when

[1] Air Ministry File C.25115/45, Encl. 8A. [2] *Ibid.*, Encl. 16A.
[3] A.H.B./IIE/167, Report on Radar Equipment in Tactical Air Forces, para. 32.
[4] Air Ministry File C.25115/45, Encl. 24A.
[5] A.H.B./IIE/136, No. 83 Group Signals Report, 1944, para. 38, and A.E.A.F., O.R.B. (Signals Branch), Part II.

an accuracy possibly as good as 20 yards was obtained.[1] Since the bombs dropped by fighter-bombers were of relatively small size, the value of their bombing depended to a great extent on the high degree of accuracy which was achieved when the bombing was visual.

Notwithstanding the very complicated nature of the SCR. 584 M.R.C.P. equipment, the serviceability was very good indeed, and breakdowns were almost unknown. Although the equipment itself was very mobile, its absolute mobility as an operational unit was limited by the need for accurate siting. None of the crew manning the equipment was capable of doing this, so for siting it was necessary to contact an Army Survey Company of the Royal Engineers, the map-making specialists.[2] This question of surveying on change of site was always a problem—getting hold of the survey personnel in forward areas in the middle of a war was not an easy matter. Once the survey personnel were on site, however, it only took one day to survey and set up the equipment. The M.R.C.P. was therefore more successful when the front was static than when it was fluid.

Radar Servicing during the Winter 1944-1945

During November 1944, under severe winter conditions, there was a relative stability of the war situation in north-west Europe. This did not mean any respite in the raid reporting work of the radar units, deployed in the main in exposed and remote localities in Holland and Belgium. Opportunity was taken of the comparative lull in air operations to overhaul the radar equipment and carry out minor modifications which were detailed by Command Headquarters.[3] This was achieved by taking one complete set of G.C.I. equipment off the air at a time, the unit continuing to operate on the remaining types at their disposal. The Mobile Signals Servicing Units (M.S.S.U.) carried out these servicing tasks, which were beyond the capacity of unit mechanics, during their quarterly overhauls. The M.S.S.U.s were able to cope successfully with the work, even changing unserviceable turnables of the rotating aerial systems of some two tons in weight, by hand.[4]

It had originally been planned before Operation "Neptune" that the Base Signals and Radar Unit (B.S.R.U.) would be phased in as soon as the Normandy bridgehead had expanded sufficiently for the base area to be regarded as safe for such large units. However, the speed of the advance across France had been so great and the M.S.S.U.s were functioning so well that the B.S.R.U. was held in the United Kingdom until a suitable site could be selected in Belgium. Meetings were held both at Air Ministry and at Headquarters, Second Tactical Air Force, during October 1944, when consideration was given to the question of whether the B.S.R.U. was really necessary. A decision was taken that the unit was required in the base area on the Continent but its establishment was revised and decreased from 450 to 303 personnel.[5]

After considerable delays, occasioned in the first place by weather and later by the Walcheren Island operations to clear the approaches to Antwerp, the main body of No. 1 B.S.R.U. and the greater part of its vehicles and equipment

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[1] A.H.B./IIE/167, para. 32.

[2] Narrator's interview with Squadron Leader A. L. D. Fussell, Senior Signals Officer, No. 483 Group Control Centre.

[3] Headquarters, A.E.A.F., O.R.B. (Signals Branch), November 1944.

[4] No. 307 M.S.S.U., O.R.B.

[5] 2nd T.A.F. (Main) Signals Branch, O.R.B., October 1944.

were embarked in a Landing Ship, Tank (L.S.T.) for Ostend. Heavy seas were running on 7 November when the unit sailed and, within sight of Ostend, the vessel struck a mine at 1500 hours and sank quickly. Of the B.S.R.U. complement on board, 14 officers, 224 other ranks and 50 vehicles loaded with equipment were lost—only five officers and 26 other ranks were saved.[1] This heavy loss was rendered more tragic when considered in relation to the very large number of signals personnel and the enormous quantities of radar and signals equipment which had been transported to the Continent during the five months since D-day without loss. When it is recalled that the total revised establishment of the unit was 303 personnel the magnitude of the loss can be appreciated. In effect it meant that the unit had to be reformed completely in the shortest possible time.

It was agreed that the unit should be reformed on the Continent and not in the United Kingdom. The work was started immediately, the personnel rendered surplus by the earlier reduction in the B.S.R.U. establishment were recalled, so that the unit began again with a good nucleus of experienced personnel. A site was selected at Ghent in Belgium and the task of setting up static workshops and moving in quantities of equipment and spares proceeded steadily. It was obvious that the unit, No. 1 B.S.R.U., could not function fully as an integral part of the radar and signals organisation of 2nd Tactical Air Force before the early part of 1945, so the Mobile Signals Servicing Units in each of the Groups continued to do all major servicing of the deployed radar units throughout the winter months—a task not rendered any the easier by the heavy snowfalls and ice-bound roads.

The Enemy Offensive in the Ardennes

On 17 December 1944, the Germans under Field Marshal Von Rundstedt launched a surprise offensive in the Ardennes of much greater strength than the Allies had anticipated the enemy was likely to employ. Initially it was very successful, cutting through the American lines to establish a deep salient. The armoured spear-head of the German forces penetrated deeply into Belgium but the width of the salient was contained by the Allied forces, in the south by an heroic American stand at Bastogne and in the north by the British forces. One No. 85 Group Light Warning Set and five associated W.O.U. posts were operating in the area north-east of Bastogne when the enemy offensive started and were in grave danger of being over-run.[2] No. 85 Group R.A.F. Regiment detachments succeeded in organising an orderly and timely evacuation in very difficult circumstances, and no radar equipment fell into enemy hands.

The weather favoured the enemy ground offensive. For more than a week conditions of poor visibility from the air generally persisted so the air support for Allied ground forces was seriously hampered. The United States IX and XXIX Tactical Air Commands were placed under the operational command of the Commander-in-Chief, 2nd Tactical Air Force.[3] This necessitated the provision of additional telecommunications facilities from 2nd Tactical Air Force to those formations; the relative ease with which these were provided clearly demonstrated the high degree of flexibility of the Signals organisation in

[1] 2nd T.A.F, (Main) Signals Branch, O.R.B., November 1944.
[2] Headquarters, 2nd T.A.F. (Main), March 1945, R.A.F.R., Appendix No. 1.
[3] *Ibid.*, December 1944.

the 2nd Tactical Air Force. No re-arrangement of the Royal Air Force Radar Units was necessary as the mobile radar units of the two American Air Commands were able to cover the northern flank of the salient.

No. 83 Group Control Centre moved a forward echelon from Erp to a point on the outskirts of Liege to establish full liaison with the American Operations Centres and to control Wings of No. 83 Group aircraft, which were switched from their intensive rail interdiction programme to provide additional air support to the Allied troops in this new battle area. The Royal Air Force radar units in Belgium were able to give adequate cover over the northern and central salient rear areas and navigational aid to 2nd Tactical Air Force aircraft, but played no really vital part in the ultimate Allied success in straightening out the salient with heavy losses to the enemy.

Luftwaffe Mass Attack on 1 January 1945

On 1 January 1945 the German Air Forces employed some 700 aircraft between 0900 and 1000 hours in one desperate effort to cripple the 2nd Tactical Air Force by striking simultaneously at its airfields in Holland and Belgium. These surprise attacks were well planned and implemented by the *Luftwaffe*. The enemy aircraft hedge-hopped all the way in, flying at tree-top height to avoid detection by radar, and inflicted considerable damage at the British airfields—127 Allied aircraft were destroyed, 133 damaged, but only eleven pilots were lost as the vast majority of the aircraft were destroyed in their dispersals on the ground.[1]

There was no radar early warning of this attack. The enemy aircraft had flown at ground level for the specific purpose of avoiding observation by the composite Group Forward Director Posts. It will be recalled that in the original planning, the early warning network linked to the Group Control Centre incorporated five Wireless Observer Units for each F.D.P.[2] Had these been deployed in the forward areas of the British Second Army front in accordance with their planned use, visual observation of the very low-flying enemy aircraft would have given some short advance warning of the attacks—though whether this would have had any value is a debatable point. However, the No. 83 Group Wireless Observer Unit screen had been disbanded in mid-October 1944, as they had served no really useful purpose in raid reporting to the Group Control Centre since the landings in Normandy and certainly had no part in the predominantly offensive policy of the Group.[3]

Despite the lack of early warning of this large-scale enemy attack, the German pilots met strong opposition from the ground Anti-Aircraft defences. Three hundred and sixty-three aircraft destroyed were the total confirmed claims of the Allied A.A. defences. When the remnants of the German attacking forces began their return journey, the F.D.P.s plotted their route. The Group Control Centre had summoned all 2nd Tactical Air Force aircraft airborne at the time to intercept the retiring enemy force, and had also called upon reinforcements from the American Tactical Air Commands. The enemy raiders had a severe mauling on their journey back to their bases, a total of one hundred and sixty German aircraft were claimed as shot down in the air by Allied fighters.[4]

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[1] S.H.A.E.F. Report on Allied Air Operations, 1 October 1944–9 May 1945.

[2] The originally-planned early warning system for a Composite Group of the 2nd Tactical Air Force is shown diagrammatically at Appendix No. 44.

[3] A.H.B./IIE/136, No. 83 Group Signals Report, 1944, p. 37, para. 174.

[4] S.H.A.E.F. Report on Allied Air Operations, 1 October 1944–9 May 1945.

Even allowing for undue optimism in both A.A. and Air Force claims of enemy aircraft destroyed, it is estimated that this attack cost the *Luftwaffe* some two hundred and fifty pilots, sixty of whom were taken prisoner, compared with an Allied loss of only eleven pilots. An ambitious and skilfully planned German air operation, which had evaded radar detection on the way in, had been turned into a major victory for the Allies.

Ground Search Radar—Continental V-Weapon Intelligence Organisation

All ground search radar units in the 2nd Tactical Air Force had plotted enemy V-weapons during their normal raid reporting duties, particularly units located like No. 15061 F.D.P. of No. 84 Group at Gilseinde in Belgium, giving all round radar cover for the No. 84 Group area, with special reference to the Scheldt area.[1] However, the sporadic reporting of 2nd Tactical Air Force Radar Units was by no means adequate for Intelligence purposes in the location of enemy launching sites. As early as 11 September 1944 the advisability of setting up on the Continent a rocket-watching organisation similar to that in the United Kingdom was apparent, because the latter was unable to detect the exact launching sites in Holland.[2] The inauguration of this Continental "Crossbow"[3] Intelligence Organisation took place at a meeting at Headquarters, Air Defence of Great Britain (A.D.G.B.) on 11 September 1944. A second meeting at Versailles on 17 October was held to discuss an improvement in the radar cover for Brussels and Antwerp, which were also being subjected to V-weapon attacks.[4]

Initial Organisation

For the initial organisation, No. 105 Mobile Air Reporting Unit (M.A.R.U.) was formed during the last two weeks in September. This was to operate on the Continent under the operational control of Headquarters, Air Defence of Great Britain, and was to be made up of :—

3 Army G.L. sets.
2 A.M.E.S. Type 9 Mark II equipments.
A No. 80 Wing Radio Countermeasures Detachment.
No. 365 Wireless Unit.

In addition, working in close association but not under Royal Air Force operational control, there was the Army Unit, No. 11 Survey Regiment. This was used for Flash Spotting and Survey Ranging duties.[5]

The first Type 9 equipment became operational in south-west Holland on 9 October, followed a few days later by the second set. The fixing of the V2 rocket-launching sites was dependent upon accurate range-cuts from two stations. For these to have any value, most accurate timing was necessary. Land-lines were provided to each station and time signals were passed from a master clock to the Continental and Home stations from No. 11 Group Filter Room, so that all station times were synchronised.[6]

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[1] No. 6 F.D.P., O.R.B.
[2] Details of the organisation in the United Kingdom are given in Chapter 27 of this volume.
[3] "Crossbow" was the codeword for all V-weapon operations—against rockets and flying bombs.
[4] Air Ministry File C.M.S. 636, Encl. 27A.
[5] *Ibid.*, Encl. 106A.
[6] *Ibid.*, Encl. 89A.

Formation of No. 33 Wing

During October the port of Antwerp became a target for enemy V-weapons. This port was being developed as rapidly as possible as the principal supply port for the Allied forces on the Continent, so Supreme Headquarters, Allied Expeditionary Forces (S.H.A.E.F.)[1] were naturally concerned and asked the Chief of Air Staff to transfer the Continental "Crossbow" Organisation to S.H.A.E.F. control.[2] A team of officers from A.D.G.B., experienced in the "Crossbow" work, was also requested on loan to advise on detailed organisation and the handling of the information obtained within that organisation. With all these facilities granted, S.H.A.E.F. extended the organisation, giving instructions to the 2nd Tactical Air Force on 24 November 1944 that it was to form a special "Crossbow" Wing to co-ordinate all the efforts on the Continent against rockets and flying bombs. This was formed as No. 33 Wing in No. 85 (Base Defence) Group, absorbing and taking over the functions of No. 105 M.A.R.U. The number of Type 9 equipments was increased by a further four, all the sets being of improved type—fitted with the special photographic console "Oswald"[3] which recorded the range of the V2 rocket against the time. The siting of the Type 9 sets to give best range-cuts was so satisfactory initially that they all remained in their original locations throughout their period of operation—two in Holland, three in Belgium and one in Luxembourg, except one which was moved slightly to a safer site during the Rundstedt push in December, 1944.[4]

Final Organisation

The Type 9 equipments formed the most reliable of the various V2 detection devices, gave extremely useful service, and played a major part in the location of V2 launching sites. The range-time data on incidents of which they had visual record was passed immediately to the Forward Reporting Centre (F.R.C.). At these units all field information from Type 9 sets, Radio Countermeasures sections, Gun Laying Radar sets, Sound Ranging and Flash Spotters, was correlated.[5] The F.R.C.s passed their information to the Continental "Crossbow" Forward Unit (C.C.F.U.) which was at Malines (Mechlin) between Antwerp and Brussels. The C.C.F.U. was composed of two sections :— (*a*) an Analysis Section, having plotting room facilities, and (*b*) a Forward Intelligence Unit (C.F.I.U.). This latter section sifted and collected all available information on rocket trajectories and sites and passed it on to S.H.A.E.F.

At S.H.A.E.F. the responsible department was termed the Continental "Crossbow" Collating Section (C.C.C.S.) and in that section collation and statistical analysis of all C.C.F.U. information, pilots' reports from 2nd Tactical Air Force, IX U.S. Army Air Force "Diver" plots, 2nd Tactical Air Force Radar Units' plots and A.A. claims all occurred. As a result of the work in C.C.C.S., another section of S.H.A.E.F. termed "Crossbow" Intelligence (Interpretation and Operational Recommendation) Section was able to present to Air Staff

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[1] Headquarters, Allied Expeditionary Air Force was disbanded on 15 October 1944, the personnel being absorbed into Supreme Headquarters, Allied Expeditionary Force (Air) Staff.

[2] S.H.A.E.F. Air Signals Report on Operation "Overlord," Section XXI, p. 11.

[3] Details of "Oswald" appear in Chapter 27 of this volume, together with an account of how the radar information was interpreted.

[4] Locations and range coverage of the Continental Type 9 equipments are shown on Map No. 19.

[5] Air Ministry File C.M.S. 204, Encl. 10A.

recommendations of areas for aerial reconnaissance and specific targets for attack of launching sites. In the case of the V2 rocket, attack on the launching sites and lines of supply of these missiles was the only effective Allied counter to the serious menace of this new German weapon. The work of the " Crossbow " Intelligence Organisation was therefore of great importance.

Application of the SCR. 584 for Tracking V2 Rockets

The modified American Gun Laying equipment, the SCR. 584, had been used effectively by United States forces on the location of enemy mortar firing points and it was suggested that this technique could be applied along similar lines to determining V2 launching sites. In event of a launching area being discovered within range of the automatic tracking and plotting features of the SCR. 584, it would be possible to obtain a rapid and accurate determination of the trajectory and launching site, and it was hoped that it might then be possible to control aircraft from the SCR. 584 to strike the site.[1] To carry out experiments and trials, a unit called the Special Radar Party was formed, manned and controlled by the Army through the Special Defence Headquarters at Brussels. Small modifications were made to enable the equipment to " lock on " the fast moving rockets, and at the beginning of February 1945 the unit was set up at Steenbergen in Holland and commenced a rocket watch over the enemy's principal launching area, The Hague.[2] In order to record the results a special Westex recording van was connected to the output of the SCR. 584. This van incorporated remote bearing, range and elevation dials which could be automatically photographed. The exact time was also recorded by including a stop-clock in the photograph—this being synchronised with the standard time at the Continental " Crossbow " Forward Unit at Malines. Analysis of the results achieved by the unit operating the SCR. 584 for the period 26 February–11 March 1945 showed that it was capable of detecting nearly 90 per cent. of the launchings within the area covered by the equipment.

Once it had been established that the SCR. 584 was able to locate the launching sites accurately, the possibility of controlling aircraft by the equipment to strike at or photograph these sites was investigated. The plan was never put into effect, chiefly because the last V2 was launched on 28 March 1945—firing from the Hague site was abandoned by the enemy while the proposals were still under consideration. However, even superficial examination of the possibilities indicated that the scheme might not be worth pursuing, since (*a*) only 10 per cent. of the launchings were from sites within the range at which the SCR. 584 could control aircraft, and (*b*) 70 per cent. of the launchings of rockets by the enemy were at night.

During the enemy's V-Weapon operations against Allied targets on the continent several mobile radar units had very near misses to record. The most serious incident occurred at No. 15061 F.D.P. of No. 84 Group, deployed at Gilseinde in Belgium. On 2 January 1945 it was hit by a V2 rocket. Nine of its vehicles were written off but fortunately the casualties to personnel were miraculously slight—only three airman suffered superficial wounds. This unit again received damage from a V1 on 26 February at Gilze–Rijen in Holland when the airmen's billets were damaged. Several airmen had superficial wounds.

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI, p. 12.
[2] 2nd T.A.F., O.R.B., March 1945, Appendix No. 47.

Occasioned by Allied military successes, the last V2 was launched on 28 March 1945. The Continental "Crossbow" organisation continued to maintain its watch until 19 April before the stations were closed down. In no sense could ground search radar have claimed mastery of the V-weapon, though the V1 flying bomb was an easy problem compared with the V2 rocket. Nevertheless, the activities of the Continental "Crossbow" Organisation under S.H.A.E.F. could claim to have rendered valuable assistance in the location of enemy launching sites as targets for Allied aircraft to attack. Ground search radar had provided sufficient early warning to put guns and fighter aircraft on to V1, and had undoubtedly reduced the toll which would have been taken by these enemy secret weapons in the Home Counties and on the Continent.

The Master Control Radar Station—A.M.E.S. Type 70

It will be remembered that a definite request had been forthcoming from the 2nd Tactical Air Force Headquarters in Brussels on 22 September 1944, for a mobile radar station which would centralise the Group Control Centre together with its Fighter Director Posts, early warning and reporting Stations in one entity.

The technical development of this equipment had been made the responsibility of the Telecommunications Research Establishment, and work began at high pressure during October 1944. In view of the urgency of this requirement, existing basic items of Radar equipment had to be used in its construction where possible. The resulting A.M.E.S., Type 70 consisted of a modified Type 14 equipment for scanning in azimuth (position-finding) and of a modified Type 13 (C.M.H.) for scanning in elevation (height-finding).[1] The principal modification of the Type 14 equipment consisted of an entirely new design of the aerial system giving a much improved coverage. This was achieved without any increase in transmitter power or receiver sensitivity—two aerial systems were used, one for low cover (up to about 2½ degrees elevation) and one for high cover (up to about 35 degrees in elevation). Each aerial was common for transmission and reception, with electronic switching. It was found that the 2nd Tactical Air Force demand for 100 miles range[2] at 10,000 feet on a single Mosquito aircraft could be met in this manner.

The set worked on the 10 centimetre (3,000 mc/s) band with a transmitter peak power of 500 kilowatts. On its pulse recurrence frequency of 500 cycles per second, the corresponding maximum possible range was 185 miles. The most important factor affecting range was the size of the aircraft observed. The following table indicates this for a British Mosquito and an American Fortress (B.17) aircraft—the lower and upper beams combined :—

Altitude.	*Mosquito.*	*Fortress.*
5,000 feet.	2–80 miles.	1–100 miles.
10,000 feet.	4–95 miles.	3–135 miles.
15,000 feet.	3–54 and 58–100.	3–91 and 96–170.
20,000 feet.	36–58 and 58–100.	6–165.
25,000 feet.	0 and 58–100.	170.
30,000 feet.	0 and 58–100.	9–95 and 126–162.

[1] Air Ministry File S.23777, Part II, Encl. 30A.
[2] Appendix No. 47 gives a Range Height Chart for the Type 70 equipment.

The range accuracy was within the order of $\pm$ 1 mile. With such an improved performance over the Fighter Director Posts, the A.M.E.S. Type 70 was a dual purpose set, being effective both for early warning and the direction of air operations, including the ground control of interception.[1] Five Plan Position Indicators were in use, thus enabling the simultaneous control of several missions by different controllers.

Mobility was of prime importance, since it was necessary for the equipment to keep pace with the ground forces in order to work with maximum effect over enemy territory. The requirement was that the whole station should be capable of being dismantled and erected on a new site within 24 hours—exclusive, of course, of travelling time between the sites. It was intended that while such a move was being carried out, a form of radar cover would be provided at a forward site by a Fighter Director Post and a detachment of personnel from the Group Control Centre. This mobility was achieved by housing all the equipment in eighteen technical vehicles[2], with nine electrical power generating vehicles and three 3-ton general purpose vehicles which carried a very large Operations Room tent together with its furnishings.

The Operations Room tent lay-out was required to be very similar to that used in fixed G.C.I. stations in the United Kingdom and was to accommodate, in addition to the Controllers and the various officers co-ordinating the radar information, all the planning and liaison personnel normally associated with a Group Control Centre—namely, combat or tactical planning officers, Army and Air Movement Liaison officers, intelligence and telecommunications personnel. A complete picture of the air situation was presented in the Operations Room which was to be clearly visible to all these officers. This was achieved by having the appropriate plexi-glass-sided vehicles under the Operations tent,[3] arranged so that the personnel would have a good view of the main plotting-screen and other displays, consisting of details of raid heights and strength, plan of attack, movements of friendly aircraft, V.H.F. "fixes," aircraft state, frequency allocations and details of the weather. Display of operational information of this nature was only a normal requirement in central operations rooms, and in this respect the A.M.E.S., Type 70 did not differ from standard practice. A departure however from G.C.I. procedure was the incorporation of the Radar Controllers themselves in this Operations Room. Although one of the objections to this had been that the noise level in the Operations Room might be so high as to outweigh the advantages of such a scheme, this was not found to be the case in practice.

Arrival on the Continent

The Telecommunications Research Establishment completed the first Type 70 station in thirteen weeks—a remarkably fine achievement. The convoy crossed from the United Kingdom and reached the No. 83 Group Control Centre at Erp in Holland on 23 January 1945.[4] It was erected immediately on a site which had been previously prepared near Erp. To get the accurate bearing, the services of a Royal Artillery Unit Section were employed.[5] The winter in Holland had been severe, so there was initial

[1] A.H.B./IIE/93, Appendix "B."
[2] Appendix No. 48 gives a brief description of the contents of the Technical Vehicles.
[3] A diagram of the lay-out of the Operations Room tent is given at Appendix No. 49.
[4] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation "Overlord," Section XXI, para. 75. [5] No. 483 G.C.C., O.R.B., January 1945.

difficulty in the erection of the large operations tent—pegging it down on ground which was frozen hard to a depth of eight inches was no easy matter.[1] The transfer of operations from the old site to the Type 70 took place during the night 28/29 January, but it was not possible to operate on the Type 70 radar equipment immediately due to " teething troubles." Plots were taken from the F.D.P.s, Nos. 15053 and 15054, while members of the Post Design Service cleared the technical faults on the Type 70—these being largely concerned with the stabilisation and improvement of the Plan Position Indicators (P.P.I.) and improvement in the I.F.F. interrogation equipment. The success in clearing these faults proved how essential it was to have the assistance of specialist engineers in an overseas theatre of war when new and untried equipment was introduced into operational use.[2]

The weather at that time was extremely poor and hence the number of test flights which could be carried out was limited. Of the flights undertaken during the first fortnight in February 1945 the results were reasonably satisfactory—the ranges being within 10 per cent. of those obtained with the American M.E.W. equipment.[3]

Initial Operations on the Type 70

During the latter half of February approximately 300 missions were tracked and controlled by the Type 70 Radar Controllers. Only loose control was exercised, such as passing information to pilots on enemy activity and the giving of " fixes " and " homing " courses on request. Much useful experience was gained on the wide scope of application of the Type 70 with a Tactical Group and its value appraised. Good continuity of tracking was being experienced—a decided advantage over the F.D.P. Identification of all aircraft tracks appearing on the operations tables remained the major operational difficulty, aggravated by the fact that the Type 70 located at Erp was in the midst of and close to a number of very active 2nd Tactical Air Force airfields. The positive sorting out of all aircraft radar plots in the area in close proximity to the station was a considerable problem.

At the outset, all missions were allotted to Deputy Controllers, with the result that close control was automatically made impossible due to overload of the Controllers. It was soon realised that a decision had to be made as to which types of missions should be close-controlled from the Radar tubes and which could be adequately dealt with by loose control using only R/T.[4] It was decided by No. 83 Group that most close support missions were of too short a duration to obtain much value from close controlling unless the weather was bad. Armed reconnaissance missions, if not too distant, were thought to derive most benefit from close control—especially as they were always more liable to changes of target as a result of fresh information coming in from Army sources whilst the aircraft were already airborne.

Of the five controlling P.P.I. tubes available, four were allotted for close controlling, with orders for not more than two missions per Controller at one time. The fifth tube was reserved as an emergency channel with a Deputy Controller responsible only for this channel and sitting beside the Chief Controller, so that the latter could always take over any aircraft in emergencies.

[1] Air Ministry File C.25115/45, Encl. 34B. [2] *Ibid.*, Encl. 35A.
[3] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI, para. 75.
[4] O.R.S./2nd T.A.F. Report No. 23 dated July 1945, " The Type 70 Group Control Centre."

In addition to these five positions there were two loose control R/T positions at which Deputy Controllers could handle two frequencies at a time and any reasonable number of missions. Standing aircraft patrols were usually farmed out to an F.D.P. where no careful co-ordination of the fighter action was required, the two No. 83 Group F.D.P.s both being retained in service for such control and raid reporting functions.

Under the existing conditions of air superiority it was found that generally defensive commitments should be handed over to an F.D.P. Then by means of close control from the Type 70 it was possible to concentrate upon offensive air operations, maintaining a high rate of feed of aircraft to a Visual Control Post[1] or No. 2 M.R.C.P., which had arrived at the Group Control Centre on 24 February 1945, from the United Kingdom. With the use of such close control from the Type 70, No. 83 Group Control Centre found a substantial reduction in the number of missions abortive due to difficulty of finding targets : close control was particularly effective in taking missions out above cloud over enemy flak areas and then letting the aircraft carry on from a known position.[2]

In general, the facilities provided by the Type 70 were considered good ; the radar cover was of the order originally requested by Headquarters 2nd Tactical Air Force, and the Display Units and other facilities were adequate to deal with all the missions requiring close control for the number of aircraft in each Group. A metamorphosis in radar operational technique had occurred —the bringing of radar control to the Group Control Centre had solved the difficult liaison and telecommunications problems that had existed with the dispersed radar network of mobile F.D.P.s, and had enabled the Radar Controllers to have an up-to-the-minute knowledge of all information affecting air operations. This, in turn, had engendered a greater confidence and knowledge of radar control potentialities with resultant greater use of its services.

No. 84 Group—No. 1 M.R.C.P. Operations

Although a second Type 70 of slightly improved form was under construction at the Telecommunications Research Establishment for the second composite Group, No. 84 Group, of the 2nd Tactical Air Force, it was not expected to be available before April 1945. No. 84 Group Control Centre had therefore to continue operations using the radar network of deployed F.D.P.s. It will be recalled that No. 84 Group had not given up any of its radar units when Nos. 83 and 85 Groups had submitted several as being surplus to operational requirements during September 1944. Certain of the No. 84 Group units had been amalgamated during January 1945 to form three F.D.P.s known within the Group as Nos. 5, 6 and 7 F.D.P.s.

No. 84 Group squadrons had been training in the close support operations with No. 1 M.R.C.P., during January 1945 at Bergen-Op-Zoom, chiefly in trial runs of level blind bombing with Typhoon and Spitfire aircraft.[3] On 6 Feb. ruary the Mobile Radar Control Post moved to Hatert, south of Nijmegen, to take part in Operation " Veritable "—the Canadian First Army and 30th British

[1] A Visual Control Post consisted of an armoured vehicle (usually a " White " half-track Scout Car) or a Sherman Tank, fitted with four Channels V.H.F. R/T and a Collins 18Q W/T set by the Royal Air Force. In it, a Royal Air Force Controller (and W/T Operator), from a forward position on the front, was able to take over aircraft control from the G.C.C. and direct the pilots by visual description on to specific tactical targets.

[2] Air Ministry File S.23777, Part II, Encl. 68A.

[3] Air Ministry File C.25115/45, Encl. 35A, Appendix " C," para. (iv).

Corps drive through the Reichswald Forest area (between the rivers Maas and Rhine in the region of Goch and Cleve). The weather was not favourable for the Visual Control Post method of close support from the air to these Army operations which began on 8 February.[1] The M.R.C.P. was therefore used in conjunction with No. 15062 (No. 6) F.D.P. The latter controlled the aircraft on a " cab rank " principle before handing over to the M.R.C.P. The aircraft were then close controlled by the M.R.C.P. for blind level bombing of enemy troop concentrations, and good results were obtained in the two days of " softening-up " operations on 8 and 9 February.[2] The M.R.C.P. continued to be used until 13 February on targets at ranges between 14 and 32 miles, all attacks being made above 7/10 to 10/10 cloud.[3]

After the Canadian Army's successful sweep through the Reichswald Forest, involving very bitter fighting against really formidable enemy opposition, the No. 1 M.R.C.P. moved to the eastern side of the forest at Matterborn, from which location it could control across the River Rhine. In order to increase the weight of the bombs dropped, medium bomber aircraft of No. 2 Group of the Second Tactical Air Force were also operated frequently under this M.R.C.P. control with satisfactory effect.[4]

American Light-Weight Radar with No. 85 Group

While the Allied Armies were closing on the River Rhine on the northern and southern extremities of the British Second Army front, the Base Defence Group, No. 85 Group, made minor re-deployments to give improved radar cover to the port of Antwerp. In addition, one set of American equipment, AN/TPS.–3, had been provided for No. 85 Group in February 1945. This set was a light-weight radar of transportable form which had been used by several American Tactical Air Commands instead of the British Light Warning Set, Type 6, for providing low radar cover in forward areas.[5]

This equipment was deployed by No. 85 Group as A.M.E.S., Type 63,[6] on the north-west coast of the island of Walcheren at Fort Flenxburg. The site chosen was on top of sand dunes in a former enemy gun emplacement some 50–60 feet above sea-level. Its purpose was to extend the radar cover seawards to the north, thus increasing the defensive cover already available to the Scheldt Estuary from the Mark X A.I. equipment, " Nelly." This extended to the range of Royal Air Force night fighter control and enabled Coastal Command aircraft to be controlled in their patrols north of Walcheren Island. Ranges of slightly over 50 miles were obtained on these aircraft operating at 3,000 feet—this additional range and also the surface cover the equipment gave against approaching enemy E-boats contributed materially to the defence of the approaches to the port of Antwerp.[7]

Air Transportable Ground Search Radar Preparations for Operation " Eclipse "

There was every indication during February 1945 that with the opening of a strong Allied offensive in western Europe in the early spring, the German resistance in the west would crumble. Planning had therefore been pushed

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[1] No. 84 G.C.C., O.R.B., 8 February 1945.
[2] Air Ministry File C.25115/45, Encl. 35A, Appendix " C," para. 2 (i).
[3] A.H.B./IIE/167, Report on Radar Equipment in Tactical Air Forces, para. 32.
[4] Air Ministry File C.25115/45, Encl. 35A, Appendix " C," para. (iv).
[5] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI, p. 28.
[6] The Radar Unit concerned was No. 63116 A.M.E.S.
[7] Air Ministry File C.25115/45, Encl. 35A, Appendix " A."

ahead during the winter to speed on the end of the war with Germany. The Second Tactical Air Force had practically all the radar equipment and units it required for its role in support of the Army and no further vital changes of radar could be visualised.

However, it might have been necessary to employ strong airborne forces well in advance of the main body of the Army as in the advance into Holland. Profiting by the experience gained on that former occasion, new equipment had been developed and units had been formed and trained. In addition, airborne Visual Control Posts (V.C.P.s) in Jeeps and trailers, fitted with V.H.F. R/T, W/T equipment and power supplies had also been produced. In this manner any airborne force operating beyond the radar range of the Group Control Centre, would have its own raid reporting and control organisation for close support—all in miniature and completely air transportable with the airborne forces.[1] The following airborne radar units had been formed and trained by March 1945 :—

Nomenclature	*Description*
A.M.E.S., Type 6, Mark IX.	A light warning set mounted in a four-wheel drive vehicle with trailer H.F. communications equipment. Four-channel V.H.F. R/T was supplied. Radar equipment worked on 209 mc/s frequency and gave an equal performance to the Standard Light Warning Set. An A.I. beacon for the use of night fighter aircraft was included. The whole unit was carried in a Hamilcar glider and could be brought into use within 30 minutes of touch-down. Four such units were formed and two additional equipments were made as reserves.
A.M.E.S., Type 6, Mark VIII (Air Transportable G.C.I. Station).	A light warning Set in a G.C.I. cabin. The performance of this set was approximately equal to that of a mobile G.C.I. Mark III I.F.F. facilities were provided. The unit required four Type C–47 (Dakota) aircraft for transport, so it was unlikely to be brought into operation in less than 24 hours after touch-down. Three such units were formed prior to operation " Market " (Arnhem and Nijmegen) and were kept available.
A.M.E.S., Type 65.	This equipment, known as " Dinner Wagon," consisted of a Light Warning Set and AN/TPS–3 early warning radar equipment in a Horsa glider, with a special operations room incorporating additional displays with facilities for linking up H.F., V.H.F. and extended external land-lines. In order to avoid tying up unnecessary experienced radar personnel this equipment was treated as alternative equipment for the Air Transportable G.C.I. crews. Two " Dinner Wagon " equipments were constructed.

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report on Operation " Overlord," Section XXI, p. 9.

These different types of equipment were produced in order to meet the varying operational requirements that might arise in a large-scale airborne operation. After a successful landing in the dropping zone their functions were to be :—

(*a*) To take over from the Visual Control Post the interception of enemy aircraft during daylight.

(*b*) To direct fighter aircraft on to Army Support targets beyond the range of V.C.P.s.

(*c*) To give "homing" courses to Allied fighter aircraft in need of assistance.

(*d*) To assume control of night fighter aircraft.

(*e*) To provide early warning to the ground troops and A.A. units of the approach of enemy aircraft.

(*f*) The reception and dissemination of friendly aircraft movements, as received by the Movement Liaison network.

(*g*) When air activity was low or another unit had taken over this responsibility, the pin-pointing of enemy mortar firing locations by the plotting of mortar shell trajectories.

Experience at Arnhem had shown that gliders after landing, even when apparently deserted, became targets for enemy ground and air forces and could be quickly set on fire. The A.M.E.S. Type 65 (" Dinner Wagon ") was not to be employed therefore in any operation until a site could be chosen in the landing zone which would be reasonably secure against observation and the fire of enemy ground troops.

The crews had been trained technically under Headquarters, No. 60 Group, from which formation volunteers to man the Air Transportable Radar stations had been obtained.[1] On completion of training, the units were transferred to Headquarters No. 38 Group, which operated the glider-towing aircraft used in airborne operations. The operational training the crews received was carried out under the most realistic conditions that could be arranged.

When the plans for the crossing of the River Rhine were made, it was decided that the Allied airborne forces would not drop deep into enemy territory, merely concentrating behind the enemy front line to sever his supplies and communications. This was to take place therefore under the radar cover of the No. 83 Group ground search units well forward with the main forces. The Air Officer Commanding, No. 83 Group, ruled that the Air Transportable Units were not to be employed east of the Rhine after all.[2] Subsequently it was thought they might be required later as the Allied forces over-ran the north-west of Germany and their operational training continued. During an exercise " Conway " in the United Kingdom, between 17 and 30 April 1945, an accident took place in which one A.M.E.S., Type 6, Mark IX, was lost, two of the radar crew being killed and others injured. The rapid advance of the land forces and the end of enemy resistance in North-West Europe rendered these units redundant to the Allied Expeditionary Air Force in May 1945.

Ground Radar Units During the Rhine Crossing

The first two months of 1945 had been a period of intensive preparations for the British Second Army in anticipation of the crossing of the River Rhine. During the first three weeks of March the massing of the forces involved took place. This necessitated a re-deployment of the ground search radar units

[1] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report, Section XXI, p. 10.
[2] Headquarters, 2nd T.A.F., O.R.B., March 1945, Appendix 6.

and control organisation of the composite Groups of the 2nd Tactical Air Force in order to give radar cover as deeply as possible over the enemy territory on the east bank of the river. No. 15054 F.D.P. of No. 83 Group was moved up to Bonninghardt, near the west bank of the River Rhine some five miles due south of Xanten, on 17 March 1945. This unit was then able to give good cover over a front from Emmerich to Wesel where the main British Second Army effort was planned to occur a week later.[1] For control purposes an advance echelon containing essential elements of No. 83 Group Control Centre moved up to a site near the west bank of the river at Xanten, while No. 2 M.R.C.P. was sited some two miles south of this G.C.C. site, between it and the F.D.P. at Bonninghardt.[2] The M.R.C.P. was set up orientated to cover Wesel.

The Type 70 equipment was left at Erp, about 28 miles from the Rhine where it could give good cover over the impending assault area. The intention was that No. 15054 F.D.P. would give radar cover over the forward areas during the crossing and No. 15053 F.D.P., held in reserve, should cross the river as soon as possible—taking over responsibility for radar cover of the area beyond the receding front line until it was safe for the Type 70 equipment to be leap-frogged past it and set up in a tactical position to give effective radar control over the newly-developing front deeper inside Germany.

Although No. 83 Group had the more spectacular task of accompanying the British Second Army to provide the tactical air cover during its push eastwards, the impending Rhine offensive was by no means a single Group effort. In addition to No. 2 (Medium Bomber) Group which was to give direct bombing support to the Second Army effort, No. 84 Group was heavily engaged with the First Canadian Army in a push northwards deeper into Holland against the V.2 rocket sites. Nevertheless, No. 84 Group were able to provide excellent left flank support to the No. 83 Group area. No. 15071 F.D.P. of No. 84 Group was moved forward on 17 March to Matterborn to give low cover up to 5,000 feet in height on its Type 13 equipment between dawn and dusk. This was a special radar watch against enemy low-flying reconnaissance aircraft which might be used against troop concentrations prior to the launching of the attack.[3] The radar cover on the northern flank of the intended Rhine offensive area was increased by the re-siting of another F.D.P. of No. 84 Group, No. 15062 F.D.P., which was re-deployed midway between the Reichswald Forest and the Rhine on 20 March.[4]

The Rhine crossing was timed for dawn on 24 March 1945. This major operation was a skilfully planned variant of previous similar efforts in that the ground troops were to make their initial attacks before the airborne forces were dropped. Commando forces crossed the river after dark at Rees, Xanten and Wesel on the night of 23 March, followed by amphibious forces at dawn on 24 March. The airborne drops occurred some two hours later behind the German forward troops. As the area Xanten to Wesel on the eastern bank of the river was very heavily defended by the enemy with numerous gun positions, the softening-up of the area by the Royal Air Force had to be extremely thorough. At the same time, it was necessary to concentrate such bombing into a short period of time so that the enemy would not be able to turn to his

[1] No. 15054 F.D.P., O.R.B., 17 March 1945.
[2] No. 83 G.C.C., O.R.B., 21 March 1945.
[3] No. 15071 F.D.P., O.R.B., 17 March 1945.
[4] No. 15062 F.D.P. (No. 6 F.D.P.), O.R.B., 20 March 1945.

advantage the knowledge of the localities in which the attacks would fall. Gun positions in the environs of Wesel had been mapped very carefully. No. 2 M.R.C.P. had been sited to cover this area and was employed to control No. 140 squadron night-reconnaissance photographic aircraft in a highly successful manner.[1] The night before the dawn attack was due to begin, medium bombers of No. 2 Group flew under M.R.C.P. control over Wesel targets throughout the night 23/24 March. Flights of aircraft had been arranged for the radar close control every half-hour between dusk and dawn, bombing against enemy gun concentrations with good accuracy.[2]

A large force of Bomber Command heavy bombers flew in from the United Kingdom on a concentrated mass raid of the Wesel area during the night and virtually tore Wesel apart, area bombing with great accuracy so that the British commando forces already across the river were unharmed, although less than 1,500 yards from the bombed areas.[3]

From dawn onwards there was a maximum effort by No. 2 Group medium bombers on enemy gun sites, flying under the M.R.C.P. control, followed an hour before the airborne forces were due to drop, by No. 83 Group rocket and fighter-bomber aircraft straffing the few remaining active enemy guns. No radar close control was employed with the fighter-bomber aircraft. The weather was fine and clear and the pilots were able to select their targets visually—these being targets of opportunity at that stage.

No. 2 A.S.S.U.,[4] the British Second Army unit responsible for Army calls for air support by operating the " tentacles " with the British ground reconnaissance forces, was located next to the advanced G.C.C. near Xanten—so the principal control exercised that day, from the early morning of 24 March onwards, was visual. Nevertheless there was a substantial increase in the use of radar for the control of offensive missions during the Rhine crossing operations. The M.R.C.P.s were ideally suited for use in such a break-out from static positions, and this operation was a magnificent opportunity for a convincing demonstration of their accuracy within their restricted range. Medium bombers of No. 2 Group flew under the control of No. 2 M.R.C.P. on many missions on the 24, 25 and 26 March, both by day and night. On 26 March there was a very powerful demonstration of the effectiveness of this close control, when 38 out of 40 enemy guns were silenced while they were harassing the newly established Allied bridgehead on the east bank of the Rhine.[5] Further north, fighter-bombers of No. 84 Group were also flying under close control—that of No. 1 M.R.C.P.—on blind bombing missions against important tactical targets across the Rhine in Holland. It can be fairly said that it was in this operation of the Rhine crossing that the operational value of the M.R.C.P. was finally established beyond all doubt.

The Final Advance from the Rhine into North-West Germany

During the last week in March, the other F.D.P. of No. 83 Group, No. 15053 F.D.P., had been held non-operational at Labbeck some two miles west of Xanten, ready to leap-frog forward and cross the river Rhine as soon as it

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[1] 2nd T.A.F., O.R.B., Main Air Staff, Appendix 21, May 1945.
[2] No. 83 Group, O.R.B. [3] 2nd T.A.F., Main, O.R.B., 22 March 1945.
[4] No. 2 Air Support Signals Unit. Its function was to operate " Tentacles," armoured cars fitted with adequate communications equipment, both Army and R.A.F., to call for air support on behalf of the Army Reconnaissance Units.
[5] 2nd T.A.F., O.R.B., March 1945, Signals Appendix, Part 2.

could be phased over the newly-constructed temporary Bailey bridge.[1] The crossing occurred on the last day of the month. After bivouacking at Rhede, it became operational at Neiunkirchen on 3 April as the Forward Radar Control, augmented by No. 2 M.R.C.P., and additional Signals facilities. Very little enemy air activity was seen and only loose control of No. 83 Group aircraft was undertaken.

The composite Group aircraft at this time were principally engaged on armed reconnaissance, with German armour, road transport and railway interdiction as chief targets in order to paralyse movement in the enemy rear during his disorganised retreat. Typical of the air activity during the first two weeks of April was the No. 83 Group effort of the 7 April—six hundred and sixty-seven sorties were completed that day without loss, on patrols, immediate support, and armed reconnaissance.

The Type 70 and main Group Control Centre moved across the Rhine from Erp on 9 April, setting up at Enkter, near Osnabruck on 11 April. Although busy all the time with control of fighter-bomber aircraft, it was not until 20 March that the German Air Force displayed any considerable energy. Then the Type 70 control showed good dividends, thirty-eight enemy aircraft being claimed as destroyed, with three probables and thirty-nine damaged.[2] Only five British pilots were lost in this effort. The Type 70 centimetric equipment was also used during the advance across Germany to assist in the meteorological knowledge of the G.C.C., as it was able to follow the course of bad weather and rain-storms. In April, in fact, No. 83 G.C.C. was able from knowledge of the meteorological conditions obtained direct from the radar tube, to carry out successfully what would otherwise have been abortive missions.

During these last days of the war in Europe, the F.D.P.s were moving across north-west Germany along the route (Osnabruck—Hanover—Celle—Luneberg) of the No. 83 Group general movement. The individual sites are of no interest as the F.D.P.s were used only in a plotting role for raid reporting or else left non-operational for a few days. The Type 70 and G.C.C. moved to Schneverdingen, between Celle and Hamburg, about 40 miles south of the latter, on 22 April and continued to control air operations. The *Luftwaffe* increased its air effort during the last week of April—showing up in some strength, inspired no doubt by the hopelessness of the German position as they were driven back into Schleswig Holstein. During that week, some forty-two enemy aircraft were destroyed by No. 83 Group aircraft flying under the Type 70 control.

At the end of April it was obvious that the cessation of German resistance was only a matter of days. Their ground forces had been beaten thoroughly on their own soil and the *Luftwaffe* driven from its skies. During 3 and 4 May 1945 the major German air activity was of *Fieseler Storch* aircraft. These small light communications/reconnaissance planes were being employed in the movement of important personages of the *Nazi* hierarchy who were attempting to reach areas they considered were safe. There was a touch of ironic comedy that the Type 70 Radar Station, designed for offensive air operations, was employed in tracking down these small aircraft. Good work was done by the Type 70 on this, although not much success accompanied the night operations. The British night fighter aircraft were too fast to achieve interception of these slow enemy aircraft, which were operating at a height of only 500 feet.

[1] No. 15053 F.D.P., O.R.B., 29 March–10 April 1945.
[2] No. 83 G.C.C., O.R.B., April 1945.

Hostilities ceased in north-west Europe at 0800 hours, 5 May. Five minutes before this time the Type 70 control achieved its last success of the war, a No. 83 Group day fighter aircraft on early morning patrol was vectored to an enemy aircraft and shot it down. This last victim was yet another *Fieseler Storch*.

Only one day later, 6 May, No. 15054 F.D.P. reached its final location at Travemunde in Lubeck Bay, followed some three days later by the Radar Servicing Unit, No. 307 M.S.S.U., at Timmendorfer Strand on the Baltic coast.[1] The ground radar units had completed their journey from Normandy to the Baltic, all No. 83 Group units settling down in the Schleswig Holstein area. Only the Type 70 equipment was then kept operational as a navigational aid to Allied aircraft. The second Type 70 equipment, A.M.E.S. No. 70,001, actually arrived at No. 84 Group Control Centre on 6 May 1945—the day after hostilities ceased. No. 84 Group took over the Celle–Hanover area for occupation purposes, and the second Type 70 equipment became operational at Wesendorf when No. 84 G.C.C. moved there on 14 May. The equipment was kept working to give navigational aid.

Reflections on the Role Played by Ground Search Radar During the Campaign

In view of the possible future development of ground radar for Tactical Air Force purposes, it is advisable to recapitulate briefly its major applications with the Second Tactical Air Force, together with observations on difficulties encountered and probable extensions of these methods. It is necessary, however, to remember in such considerations that throughout the whole campaign in north-west Europe, the Allied Air Forces had such a marked superiority over the *Luftwaffe* that very little attention had to be paid to such features as the vulnerability of the radar system to air attack by the enemy—though this requires due emphasis for any similar future operations.

The backbone of any future system would invariably be a Master Control Radar Unit similar in function to the Type 70 station for a composite Group.[2] The campaign in France and the Low Countries had demonstrated the unwieldy features of the Group Control Centre and dispersed radar stations network. The policy of centralisation of the main radar equipment of a Tactical Group at the G.C.C. had been justified, for the Type 70 A.M.E.S. added to the operational efficiency of the G.C.C. and did not introduce any insuperable difficulties of either siting or mobility.

There was need for the better dispersal of the Type 70 to minimise its vulnerability to air attack—the aerial systems and the Operations tent particularly require to be sited more remotely from one another, as radio aerials are invariably a secondary target in enemy air operations. The large tent used for the Operations Room was sufficiently mobile for the conditions experienced between February and May 1945 in north-west Europe, when the Type 70 had a total of only three moves, none of them being rush moves dictated by overriding conditions of operational urgency. It is doubtful if such a tent were suitable for all weathers. It was the opinion of technical officers with the Type 70 equipment that consideration should be given to a reduction in the size of the Operations tent and its possible replacement by some light-weight, sectional, waterproof roofing to house the operations equipment.[3]

[1] No. 15054 F.D.P. and No. 307 M.S.S.U., O.R.B.s, May 1945.

[2] O.R.S./2nd T.A.F. Report No. 23, July 1945, "The Type 70 Group Control Centre."

[3] Narrator's interview with Squadron Leader A. L. D. Fussell, Senior Signals Officer, No. 83 Group G.C.C.

In common with other centimetric radar, the Type 70 suffered from optical screening; hence in the horizontal plane the low cover may be affected by the surrounding terrain. During the campaign, the sites selected were chosen with very little screening by local topography so the results were, in consequence, really good. In particular, the Controllers expressed great satisfaction with the results obtained from the hill-top sites at Enkter, near Osnabruck.[1] In addition to the natural features, screening occurred from the Operations tent and associated vehicles. This was found to be effective over an arc of about 15 degrees for the low beam (up to 3 degrees elevation) so it was arranged that this would lie towards a non-operational area.

To fulfil the offensive and defensive requirements of a Tactical Group, certain other equipments were required in addition to the Type 70. To achieve complete mobility and still maintain radar cover, the leap-frog technique must be employed, so there was a need for a less elaborate "repeat" of the main apparatus. This would also act in the static phase as a standby equipment for breakdown and maintenance purposes.

For close support operations over the enemy lines the M.R.C.P. type of equipment was required to assist when the weather was too bad for visual selection of the target. The M.R.C.P., as used with the Tactical Groups, was never exploited to its maximum capabilities.[2] This was occasioned partly by the Allied superiority in the air—there was no vital need for the economy in the use of fighter aircraft which can be achieved by the correct use of satisfactory ground search radar. The other factor which militated against the fullest employment of close support radar was the very high degree of confidence in the Tactical Groups in the ability of their pilots to navigate without making mistakes—a confidence which was apparently generally justified by the results achieved.

After three months use of the M.R.C.P.s for controlling fighter-bomber aircraft of the Tactical Groups, Headquarters, 2nd Tactical Air Force were of the opinion that the future better application of this radar equipment would be for controlling the medium bomber aircraft of No. 2 Group.[3] After trials it soon became apparent that the chief limitation was that of range of control was only approximately thirty miles. It was considered that this could best be overcome at that stage by the installation of a radar beacon in the aircraft, thus enabling the S.C.R. 584 to "observe" the aircraft at greatly increased ranges. Owing to the inability to provide suitable beacons, this limiting factor was not overcome during the war, and for all targets beyond the 30-mile range the No. 2 Group medium bombers continued to operate under Gee-H control technique.

Although centralisation of the Type 70 at the G.C.C. was an excellent step forward in ground radar technique, over-centralisation is invariably a danger. There was still a requirement for light-weight radar equipment, both of the highly mobile form like the Light Warning Set and the readily transportable type similar to the American AN/TPS-3 equipment.[4] In the interest of economy in spare parts, for future operations both mobile and transportable sets should be different versions of the same basic equipment. These are

[1] Air Ministry File C.S. 23777, Part II, Encl. 68A, para. 4 (vi).
[2] A.H.B./IIE/167, Report on Radar Equipment in Tactical Air Forces, paras. 26 and 30.
[3] A.H.B./IIE/159, S.H.A.E.F. Air Signals Report, Section XXI, pp.19 and 20.
[4] *Ibid.*, p. 28.

necessary to fill in any gaps in the cover of the larger radars, to provide both low cover and control facilities, and also for employment in sites inaccessible to the heavier equipments.

When enemy air opposition exists, the advent of high-flying aircraft necessitates that the high cover of the Type 70 should be supplemented at the G.C.C. by other radar apparatus capable of reporting and controlling up to heights of 50,000 feet.[1]

In tracing the changes which had occurred in Royal Air Force ground search radar technique during the campaign in north-west Europe, reference has been made on more than one occasion to the influence of American radar equipment of superior performance. In fairness to British designers, it must be pointed out that the United States was able to concentrate largely on offensive radar whereas in the United Kingdom, within easy reach of enemy air attack, there was always the problem of static defence as well as the provision of offensive radar. As a result, the development of mobile radar for offensive operations in the United Kingdom was more gradual than that of our Allies.

Nevertheless, the mobile field radar organisation in the 2nd Tactical Air Force always provided a sound raid-warning system which would have been invaluable if the Allied air supremacy had not been so great. This potential value of the radar system continued throughout the whole campaign. In any consideration of Allied air superiority, the potential aid of radar should not be overlooked, as the ground search radar units were part of this air supremacy.

[1] Air Ministry File C.S. 23777, Part II, Encl. 68A, para. 3 (*x*).

CHAPTER 26

RADAR IN RAID REPORTING AGAINST "V"-WEAPONS— THE FLYING BOMB ("DIVER" OPERATIONS)

Reference has been made previously to the possibility of attacks on the United Kingdom by the enemy, employing new types of aerial weapons, and to the radar preparations made in anticipation of these attacks by the Royal Air Force.[1] Intelligence sources indicated that the weapons would be of two types —pilotless aircraft and long-range rockets. Plans to counter the new threat to the United Kingdom were initiated in June 1943 and much thought was given to the question of adapting the radar system to meet the enemy's new technique. It was not anticipated that the pilotless aircraft would present any undue difficulty to the Home Chain, and no radical changes were carried out as regards equipment and operational methods to counter their use.

During 1943 the term " Bodyline " had been used in reference to both pilotless aircraft and rockets, but in November 1943 it was superseded by " Crossbow." This general term was adopted to refer to all activities relating to V-weapons. In February 1944 " Diver " was adopted as the code-word for all operations connected with the pilotless aircraft or V1—generally known as the " flying bomb " or, more familiarly, as the " buzz-bomb " or " doodle-bug." Preparations made on intelligence information against the V-weapons had not long to wait for a practical trial.

General Resumé of Flying Bomb Activity, June 1944–March 1945

Phase One

The first flying bombs sent against this country were launched in the early morning of 13 June 1944. The first sign was at 0405 hours, when a motor torpedo boat in mid-Channel between Dungeness and Cap Gris Nez spotted a bright horizontal moving flame starting from north of Boulogne, with a similar effect five minutes later from Cap Blanc Nez. These bombs passed over the vessel at a speed of approximately 220 miles per hour, and at a height of about 1,500 feet. The alarm was given at 0407 hours by the Royal Observer Corps centre at Maidstone, two of their posts having given visual identifications of " Divers " flying at 1,000 feet.[2] Ten flying bombs had been reported from visual sources by 0440 hours. Filter Room records state that not one was seen by the South Coast radar stations, though no explanation is offered for this lapse, as even if the flying bombs had not been recognised as such, they should have been reported as ordinary aircraft tracks, by some at least of the stations.

A second burst of activity began at 0458 hours and lasted until 0520, when thirteen flying bombs were plotted between Dungeness and South Foreland, at 2,000 feet. On this occasion all these tracks were seen by radar stations in the neighbourhood, who themselves gave the identification from the type of track observed on the cathode ray tubes. All radar stations had previously been warned that the track of a pilotless aircraft would most probably be straight, without any sudden variations in height. These features became known subsequently to all radar operators as characteristic differences between

[1] *See* Chapter 16 for details of these preparations.
[2] Headquarters Fighter Command, O.R.B., June 1944, Appendix " K."

tracks of flying bombs and of piloted aircraft. Four incidents were reported as a result of this second attack—at Swanscombe (4½ miles west of Gravesend), Sevenoaks, Cuckfield, and Bethnal Green. The only casualties were at the last-named town, where six persons were killed and nine seriously injured.

The next activity was on 15/16 June, when one hundred and fifty-one bombs were reported by the defences between 2230 hours on 15 June and 2239 hours on the next day. One-hundred and forty-four flying bombs crossed the coast, seventy-three getting through to the London area. Twenty-two "Divers" were destroyed outside London (fourteen being brought down by Anti-Aircraft fire, seven by fighter aircraft, and one by joint action between guns and a fighter), and eleven "Divers" were shot down by gunfire in the London area. The enemy kept up his bombardment almost continuously and on only two occasions in June were there lulls in activity of more than twelve hours' duration. During the first month the average rate of bombardment was one hundred and twenty-seven missiles every 24 hours. The main target was obviously Greater London, but on the 25 June, the same night, and again on the following day and night, a small proportion of effort was apparently directed against the Southampton area. The liberal spreading of the missiles over a large district of the Channel and South-East England could be attributed to inaccuracy of aim and defects in the control mechanism. Two other bombs fell away from the main target area on 20/21 June, falling near Luton. One had been discharged south-west of Calais (140 miles away) and the other from the estimated direction of Le Trépport (range 165 miles). These bombs were fitted with a D.F. transmitter and were probably deliberately aimed ranging shots. The majority of these flying bombs flew at altitudes between 1,000 and 3,000 feet, with a minority at heights up to 5,000 feet. The average speed was 360 miles per hour, rising on occasion to 400 m.p.h.

Throughout the summer of 1944 the operational records of the radar stations on the south-east coast show constant activity on "Diver" tracks, as the following instances show. Beachy Head C.H.L. Station noted in July 1944 that they were very busy plotting "Diver" tracks, that there was constant activity of large forces of bombers and fighters going out to raid the launching sites, and constant fighter patrols were maintained over the "Diver" lanes. Many "Divers" were plotted coming in with returning bombers. During one five-hour watch period fighter aircraft under Beachy Head Forward Control accounted for fourteen "Divers." Information from the recently installed Type 13 gave invaluable aid in the early recognition and identification of "Divers." Fairlight C.H.L. Station recorded two thousand one hundred and thirty "Diver" tracks plotted between 25 June and 30 July, and North Foreland C.H.L. Station plotted one hundred and ten flying bomb tracks in one watch period, 2300–0800 hours on 2/3 August.[1]

A few tracks were seen as far west as Ventnor C.H. Station early in the attacks, but observation of flying bomb activity generally was confined to stations in the south-east of England; and as the Allies advanced on the Continent, so the activity gradually worked round to the eastward. With the capture of the V1 launching sites in the Pas de Calais area, "Diver" operations over the south coast virtually ceased early in September 1944. By the end of

[1] These details are from the relevant radar stations' O.R.B.s.

the flying bomb assault the east coast radar stations were dealing with the majority of the tracks, the south-east coast gradually fading out of the picture as far as this type of activity was concerned, though they remained busy in other directions.[1] The Norfolk radar stations of Stoke Holy Cross, Hopton and Happisburg first began to see flying bomb tracks in August, and from then onwards stations in this area found themselves dealing with increased activity of this nature.

Phase Two

The second phase of flying bomb activity began in July 1944 but did not reach any intensity until September 1944. The enemy then took to launching the missiles from piloted aircraft, the bomb being carried underneath the main aircraft, generally an obsolete *Heinkel* or *Junkers*. The new enemy tactics were to approach the United Kingdom at about 300 feet, rising to a few thousand feet approximately 60 miles from the coast. The bomb was released at about 30–40 miles from land, when the parent aircraft immediately lost height and disappeared. Generally, radar stations had no difficulty in plotting the aircraft when it was gaining height for the launching, but it was often difficult to get a continuous picture of the activity when it was flying at a few hundred feet only.[2]

In many cases, stations were actually able to plot the "split"[3] when the bomb was launched from the parent aircraft. Typical operational records state :—

> *September 1944. H.Q. No. 75 Wing.*—"The first 'pick-a-back' was plotted on the night of 20/21 September. Picked up at 60 miles off the Norfolk coast and plotted incoming, stations being able to determine quite easily the launching point."
>
> *September 1944. Dunwich C.H.L. Station.*—" The enemy has started to launch attacks from *Heinkel* and *Junkers* aircraft. Last attack from ground-based sites seen 6 September. The carrier aircraft usually come in to 50 miles of the coast, but on one occasion came in to within 20 miles when the weather was too bad for fighter patrols."

Both Dunwich and Bawdsey Radar Stations stated that they were sometimes able to see the "split" as the bomb was launched. Activity continued throughout the autumn and winter, but never on the same scale which had marked the enemy's initial onslaught. Bawdsey noted they saw two hundred and ten tracks in November, a large percentage of which were shot down by the guns. Dunwich saw one hundred and fifty tracks in the same month, generally on dark nights. On the evening of 6 November they tracked nine "Divers" and stated " Watnall Filter Room (No. 12 Group) congratulated us on producing the best picture, and the guns gave their blessing by writing all nine of them off."

These tactics continued until 14 January 1945, this date marking the end of the air-launched flying bomb offensive, which had continued on a small scale and with numerous pauses from the late summer of 1944. One outstanding

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[1] No. 75 Wing, O.R.B. [2] Air Ministry File C.M.S. 202, Encl. 41A.

[3] The parent aircraft, with bomb attached, first appeared on the cathode ray tube as one echo, or response ; as the bomb was launched the echo appeared to " split " or divide into two responses side by side, one of which—that from the parent aircraft—generally faded at once as the machine lost height. The echo from the flying bomb remained on the face of the tube and was plotted in the usual way.

raid occurred in the early hours of 24 December, when the enemy appeared to direct bombs at the Manchester district. Between 0444 and 0632 hours on this day thirty "Divers" crossed the coast between Flamborough Head and Skegness, at heights of between 1,000 and 3,000 feet, and flew west over the Midlands. The missiles crashed over a wide area between Hull and Manchester. Twenty-one enemy aircraft were plotted during the burst of activity, from 30 miles east of Flamborough Head to 30 miles south-east of Spurn Head.[1] One *Heinkel 111* was destroyed by fighters controlled by Orby G.C.I. Station. All stations in the area as far north as Goldsborough C.H.L. Station plotted the activity, and every flying bomb track was plotted by the radar stations.

Phase Three

A six-weeks interval with no activity followed the cessation of attacks on the 14 January 1945, but on the night of 2/3 March, the enemy resumed his attacks against this country, although the scale was not nearly so intensive as in previous phases. The flying bombs in this third wave of activity were all land-launched from bases near the Hook of Holland and were well tracked and plotted by the east coast radar stations. The heaviest attack occurred on 28/29 March, this being the enemy's last fling, as no further flying bombs were directed against this country after that date. Good pick-up ranges during this month came from Walton C.H.L. Station which saw a " Diver " first at 92 miles, and from North Foreland C.H.L. Station which reported " Diver " 126 at a distance of 104 miles. One hundred and twenty-three flying bombs were reported during the month, ninety-two of which were destroyed.[2]

The percentage of successes achieved by our defences—day and night fighters, A.A. batteries, balloons and so on—during the month of March was seventy-five, although the proportion was higher on some individual occasions. For instance, the Type 55[3] equipment at Great Bromley plotted eighteen flying bombs on 29 March, all of which were shot down. Canewdon C.H. Station reported that the average number of successful interceptions made on " Diver " tracks plotted by them was five out of six ; whilst Walton C.H.L. Station reported that during the last enemy salvo on 29 March they plotted twenty-two " Divers," seventeen of which were destroyed by A.A. guns, the remainder crashing either in the sea or immediately on crossing the coast.

Analysis of " Diver " Tracks against the United Kingdom

The following figures give an indication of the weight of the flying bomb attacks against the United Kingdom. It will be seen that the first phase, from June to September, was by far the heaviest, and the chief reason probably for the gradual reduction in intensity of the attacks was the fact that the Allies on the Continent were advancing so rapidly, capturing the launching sites as they progressed. Altogether, German Intelligence reports

[1] Headquarters, Fighter Command O.R.B., December 1944, Appendix " K."

[2] A.A. destroyed 87½, fighters 4, miscellaneous ½. Headquarters, Fighter Command O.R.B., April 1945, Appendix " O."

[3] Type 55 was a Coast Defence No. 1 Mark 6++ (Tower) station. A ten-centimetre equipment for surface watching/very-low-flying aircraft detection, with the aerial system mounted on a cantilever of one of the C.H. towers.

reveal that 10,526[1] flying bombs were launched against England.[2] Of these, British defences reported 7,437, of which 5,648 crossed the coast, 2,388 to the London area. Defences accounted for 3,959 bombs.[3]

Defensive action against the flying bomb was at first carried out mainly by fighter aircraft, flying both by day and by night, and they worked gallantly and well, particularly during the first few weeks when flying bombs were coming over in great numbers. Later, the anti-aircraft batteries played an increasingly important part, and their percentage of " kills " rapidly rose, until eventually they were responsible for the majority of flying bombs destroyed.[4] The percentage destroyed rose from 33 per cent. in the week 15–21 June to 50 per cent. in the week 9–15 July, almost entirely due to the efforts of fighter aircraft. In this period the percentage successes of the fighter squadrons were doubled from 20 per cent. to 40 per cent. The best day for the defences was 27/28 August, as the following figures show.

Flying bombs reported	97
Flying bombs destroyed	87
A.A. batteries	62
Fighters	19
Balloons	2
Guns plus balloons	4
	87

Only four of these flying bombs succeeded in reaching the London area.

Although the casualty figures[5] were heavy, they would have been far heavier had the defences not succeeded in destroying so many flying bombs either over the sea, or over land before they could reach thickly populated areas. Radar tracking proved very valuable by providing information which enabled the defences to reduce the heavy toll taken by this new enemy terror device against the civilian population. With an average pick-up range of 55 miles from the radar stations, fighter aircraft only had about six minutes warning in which to intercept a " Diver " before it crossed the coast. In the case of the Straits of Dover this period was only about three minutes. It was essential, therefore, that the most full and accurate information should be provided, and

[1] Figures from German sources show that, of the total of 10,526 flying bombs, 1,287 were air-launched between 7/8 July 1944 and 10 November 1944. No records are available to cover the period 10 November to 14 January 1945, when bombs ceased to be launched from piloted aircraft.

[2] Air Warfare Analysis Section Reports, A.H.B./IIB/47/3 and 4.

[3] These were allocated between the various defences as follows :—

	First Phase. (13 June–5 Sept. 1944)	*Second and Third Phases.* (15 Sept. 1944–29 Mar. 1945)
Day and Night Fighters	1,773	75½
Anti-aircraft batteries	1,459	407½
Balloons	231	—
Naval Gunners	—	13
	3,463	496

[4] A.D.G.B. Series, Vol. 7, " Flying Bomb and Rocket Campaigns."

[5] Casualties from flying bombs : 6,184 persons killed, 18,000 seriously injured, 24,000 minor injuries. From the combined effect of rockets and flying bombs 12,000 houses were totally destroyed in London.

passed from the Home Chain stations with the minimum of delay. The number of successful interceptions undertaken by fighter aircraft is a tribute to the speedy way in which the radar stations tracked the flying bombs.

Tracking of Flying Bombs by the Radar Stations

A meeting of the " Crossbow " Inter-Departmental Radiolocation Committee was held on the 20 June 1944, when it was agreed that radar tracking and early warning performance had, after the first attack, been satisfactory. Stations had been able to discriminate between flying bombs and ordinary aircraft, providing that the aircraft did not fly tracks resembling " Diver " tracks, and that the stations were not saturated by the presence of large numbers of friendly aircraft. The " Diver " tracks were characterised by their straightness, although there was evidence that the bomb's mechanism provided for one pre-set turn.[1]

Pick-up ranges of the radar stations had been adequate for the launching areas in Holland but were inadequate for bombs launched from around Dieppe. C.H. station ranges had been between 40–50 miles for projectiles between 2,000–4,000 feet, and 15–20 miles for bombs at 1,000 feet. C.H.L. station ranges to that date had been 37 miles at 4,000 feet and 18 miles at 100 feet. Centimetre wavelength radar stations had given an upper pick-up limit of 46 miles and a lower limit of 18 miles. Identification had been made by stations having either Plan Position Indicator displays, height-finding or I.F.F. (Identification Friend or Foe) facilities by the range of pick-up, straightness of track, lack of I.F.F. response, flying height, and characteristic change of signal amplitude with range. A combination of these factors made identification almost certain.

The committee recommended that in view of the urgent desirability of obtaining accurate firing-point location on sites in the Dieppe area, Headquarters, Allied Expeditionary Air Forces, should procure and install an M.E.W. (Microwave Early Warning) equipment on high ground near Beachy Head. It was further recommended that a sub-panel should investigate and recommend to Headquarters, Air Defence of Great Britain,[2] on the most expeditious way of getting good radar location of firing points, particularly in the Dieppe area.

Pick-up Ranges and Heights of " Divers "

Records obtained from the radar stations showed that representative ranges obtained by them on the pick-up of " Divers " were as follows :—[3]

Type of Station.	*Site Height.*	*Distance in Miles.*			
		Max.	*Average.*	*Min.*	
1. C.H.	—	55	40	—	
2. C.H.L. ..	—	70	44	28	
16. Fighter-Direction.	500 feet	79	52	31	Used chiefly for controlled interception.
	200 feet	54	39	24	
11. C.H.L. Standby	500 feet	50	35	22	
50 to 56 High-power Centimetre.	500 feet	75	45	28	

[1] Air Ministry File C.M.S. 202, Part I, Encl. 11A.

[2] In November 1943 Fighter Command was re-formed as a Unit under Allied Expeditionary Air Force, and was known as Air Defence of Great Britain. On 15 October 1944 it reverted to its old title, and came again under the direct control of Air Ministry.

[3] Air Ministry File C.M.S. 205, Encl. 8A.

The heights of flying bombs ranged between 1,000 and 7,000 feet in the following proportions :—

Over 5,000 feet	1 per cent.
Over 4,000 feet	3 per cent.
Over 3,000 feet	15 per cent.
Over 2,000 feet	50 per cent.
1,000 feet and under	31 per cent.

Speeds were fairly constant for individual Divers, but on tracks in general varied between 230 and 430 miles per hour.

Use and Performance of M.E.W. (Microwave Early Warning) Equipment

To assist in obtaining all possible data about flying bombs, and in particular about their launching points, an American radar equipment AN/CPS-1, known as M.E.W.—Microwave Early Warning—was borrowed from the United States Army Air Force then operating in the United Kingdom. This was set up at Fairlight, and became operational on 29 June 1944. Fairlight was chosen in preference to Beachy Head, as recommended by the " Crossbow " Committee, as it appeared to be in the best position for seeing " Divers " launched from the French coast. 800 tracks had been seen by this C.H.L. station from the first attack in June until the end of the month, the highest in one day being 148.[1]

The M.E.W. set had previously been used by the U.S.A.A.F. for control purposes at Start Point in Devon, whence it was moved to Fairlight, complete with its American crew. This crew continued to operate the equipment throughout the time it was used for the analysis of " Diver " attacks and their interception. The M.E.W. was a high-powered centimetre set capable of giving long-range facilities and high discrimination, enabling it to be used simultaneously for interception and normal raid reporting purposes.[2] A report made by the Air Officer Commanding-in-Chief, Air Defence of Great Britain, to the Under Secretary of State for Air on 6 July 1944 stated that when dealing with flying bombs the M.E.W. proved superior in performance to any other radar equipment on the south coast in the following respects :—[3]

(*a*) Superior range: estimated approximately at 15 per cent. in excess of other equipments. (The maximum pick-up range was 80 miles with an average of 50–55 miles.)

(*b*) Noticeable superiority in continuity of tracking.

(*c*) High track-handling capacity.

(*d*) Mobility: which would enable the set to be moved at reasonably short notice should a change of enemy tactics render this necessary.

Drawbacks of the equipment were that no height-finding facilities were incorporated in the set, and the highly accurate estimation of speeds was not possible. However, a Type 13 (Centimetre Height) set was installed at Fairlight to provide heights, for use in conjunction with the M.E.W.

The original purpose of the M.E.W. at Fairlight was to provide a specialist station for the analysis of " Diver " tracks, and in particular to locate enemy firing points. An Analysis Section was set up using the M.E.W., co-ordinating and correlating all unfiltered information relative to radar tracks from the

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[1] Fairlight A.M.E. Station, O.R.B., June 1944.
[2] Air Ministry File C.M.S. 202, Encls. 36A and 151A.
[3] Air Ministry File C.M.S. 205, Part II, Encl. 8A.

C.H.L. stations, at Fairlight, Beachy Head and other neighbouring stations, and producing filtered tracks of greater accuracy than those normally submitted straight from Filter Room.[1] Both photographic and written records of tracks were sent from all interested stations to Fairlight, and the filtered information was normally available in 30 hours. Very valuable work was done by this Analysis Section which came under the control of Operational Research Section at Headquarters, Air Defence of Great Britain, during the heavy bombing attacks of July and August, but with the over-running of enemy territory in the Pas de Calais area the necessity of such a branch became less, and it was finally disbanded on 7 September 1944. Special " Diver " recording on all south coast radar stations ceased on the same day. The branch of Operational Research at Headquarters, Air Defence of Great Britain dealing with " Diver " tracks continued, of course, with its work until all " Diver " attacks ceased.

Microwave Early Warning used for Controlled Interception

Authority was given by Air Ministry, following a recommendation made at Inter-departmental Radio Location Committee held, under the Chairmanship of Sir Robert Watson Watt, on the 1 July 1944, for the M.E.W. station to be used for control and raid reporting purposes in addition to co-ordination of " Diver " information. It was felt at that time that such would not interfere with the station's primary role of analysis. In consequence the station was linked to the Combined Directional Plotting table at Fairlight C.H.L. station, and did excellent work both on normal reporting and on controlled interception. From 4 August 1944 the role of the M.E.W. changed, and from thence it was used primarily as an interception station, with analysis as its secondary function. The value of this equipment for controlled interception is shown by the fact that by the end of July fighter aircraft directed by Controllers at the M.E.W. destroyed fifty-six flying bombs, and by the time the M.E.W. was finally moved the score had risen to 142.

At the end of August the M.E.W. was formally handed back to the Ninth United States Army Air Force, who needed it urgently for use on the Continent. The set had originally been lent for a matter of weeks only, but owing to the whole-hearted co-operation of the American authorities, and their appreciation of the valuable part played by their equipment in the anti-" Diver " operations, it had continued for two months on loan to the Royal Air Force, in spite of the Americans' urgent need of it elsewhere.[2]

Type 26—(British M.E.W.)

To take the place of the M.E.W. equipment, when it was moved to the aid of Allied forces on the Continent, a British version known as A.M.E.S. Type 26 was assembled and installed at Fairlight on 26 August. The equipment was made from a Type 20 set formerly at Sandwich, which was dismantled in June and modified into a Type 26 by means of M.E.W. transmitter and aerial system flown from the U.S.A.[3] The Type 26 had a performance comparable with that of the M.E.W., with facilities for four displays for controlled interception and four for normal reporting, plus a console Type 10 (Skiatron), which gave a general picture of the situation. Working in conjunction with the Type 26 was a Type 24 set, a long range centimetre height-finding apparatus using modified A.M.E.S., Type 20, Mark 1 turning gear and

[1] Air Ministry File C.M.S. 205, Part II, Encl. 34A.
[2] Fairlight A.M.E. Station, O.R.B., June/July 1944.
[3] No. 75 Wing, O.R.B.

aerial frame, with a large cheese aerial.[1] A further Type 26 was also made from a redundant Type 20 set at Wartling, plus component M.E.W. parts from the U.S.A. This was intended to be installed at St. Margaret's Bay, Dover, but work was abandoned when it was obvious it would not be complete in time to be of real value, in view of the Allies' rapid advance in France. With the capture of launching points in the Pas de Calais area the need for the Type 26 at Fairlight decreased, but an urgent requirement arose in September for a similar set to be sited on the East Coast. The second phase of the enemy's flying bomb activity had now started, characterised by the launching of flying bombs from piloted aircraft over the North Sea. The Type 26 was accordingly moved to Greyfriars and became operational on 29 November 1944. It was used for controlled interception, and worked in conjunction with a Type 24 height-finding equipment. Information from these sets was passed direct to the C.H.L. station at Dunwich, where it was combined with the C.H., C.H.L. and C.H.E.L. information and displayed for "Diver" interception and for telling to Nos. 11 and 12 Fighter Groups.[2] The results were good, ranges of up to 78 miles being recorded.

Other Measures adopted for Tracking Flying Bombs[3]

Photographic Equipment

As an aid in the location of firing points special photographic equipment was installed at Beachy Head, and Fairlight, by 25 July 1944 and later at Hythe for making photographic records of Plan Position Indicator displays every few seconds when there was flying bomb activity. By the subsequent examination of these photographs additional information concerning the early tracks of flying bombs was obtained, such information being difficult to obtain visually under normal operating conditions, owing to the weakness of the signal at long range, and the large number of tracks involved.

A.M.E.S., Type 13, Mark III

Height-finding sets A.M.E.S., Types 13, Mark III were installed at Beachy Head and Fairlight C.H.L. stations by 14 July 1944, and at Swingate C.H. and Foreness C.H.L. stations by 9 August 1944. These provided heights on tracks to within 500 feet at ranges of up to 60 miles, and were of considerable assistance for identification and controlled interceptions. The sets worked on a centimetre wavelength and were mobile, the vehicle containing a power-turned vertical cheese aerial, demountable, and a mobile operations room. The sets from Beachy Head and Fairlight were later transferred to the East Coast and installed at Hopton and Happisburgh, to counter the pilot-launched flying bombs which were so numerous during the autumn and winter of 1944.

Off-Centre Plan Position Indicator Displays

In order to assist site location and obtain the fullest advantage from displays, off-centre P.P.I. tubes were fitted to some C.H.L. and high-power centimetre stations between North Foreland and the Wash. By this means longer ranges could be read directly from the P.P.I. instead of from the linear range time base. Such P.P.I.s were fitted at the C.H.L. stations of Bawdsey, Hopton, Dunwich, and North Foreland, and the C.H.E.L. stations at Dunkirk, Thorpeness, Bawdsey, North Foreland, Benacre, Hopton, Trimingham and Winterton.

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[1] Air Ministry File C.M.S. 205. [2] Air Ministry File C.M.S. 202, Encl. 153A.
[3] Air Ministry Files C.M.S. 205, Encls. 8A and 12A, C.M.S. 636.

Increased Transmitter Power

The power of the transmitters was increased at the C.H.L. stations of Hopton, Dunwich, Bawdsey, Walton, Whitstable and North Foreland.

Propeller Modulation

A device was designed by Telecommunications Research Establishment on high priority and installed at Beachy Head and Hythe, which enabled a distinction to be made between aircraft with a normal airscrew and a jet or rocket-propelled aircraft. This equipment had particular applications in dealing with flying bombs launched from aircraft, since from its use it was possible to discriminate between the launching aircraft and the flying bomb shortly after its release. The original Mark 1 equipment proved moderately satisfactory at Beachy Head, but the improved Mark 11 equipment at Hythe gave more satisfactory performance.

Other Devices

Other means of aiding flying bomb tracking and interception included the installation of a Console, Type 8, at Fairlight on the 20 July, to facilitate interceptions. This presented Plan Position information from two separate channels, ensuring continuous tracking without fades, and it was designed to provide the simplest possible presentations of the relative positions of target and intercepting aircraft. A Type 57 equipment (High power Naval type 277 ten-centimetre mobile set) was also installed in November at Walton-on-Naze, to improve inshore cover for " Divers." It was hoped that this would track flying bombs after they were lost by the C.H.L. station, with a consequent higher level of track continuity. The set was finally taken off the air in April 1945, when the " Diver " activity was over, and transferred to Whitstable for surface watching.

Two " Red Queen " convoys also operated, one at Hopton and the other at Greyfriars. These equipments were designed to detect enemy aircraft by interrogating the Type 25 *Fuge* (German I.F.F.), which was installed on all long-range controlled enemy aircraft, and was used for aiding the identification of parent aircraft carrying flying bombs for release over the North Sea. Furthermore, in an attempt to detect flying bombs at sea at a range greater than that possible by ground radar stations, a frigate—H.M.S. *Caicos*—was fitted with Naval Type 277 10-cm. equipment early in December. It was intended originally to patrol between the minefield belt and the convoy route about 20–25 miles off the East Anglian coast. However, weather conditions at that time prevented intercepting aircraft from flying, and with the decrease in enemy flying bomb activity it was decided that the maintenance of this frigate was not absolutely essential. It was therefore withdrawn from operations.

Defensive Measures against the Flying Bomb

Four main defensive measures were used against the enemy to combat flying bombs. These were :—

(*a*) Bombing of the launching sites, depots and supply routes.
(*b*) Interception of fighter aircraft.
(*c*) Use of the anti-aircraft coastal barrage.
(*d*) The provision of a balloon barrage.

Of these, the first three were very largely dependent for efficient operation on accurate information provided by radar methods.

Value of Radar Information in Locating Firing-Points

A report made by the "Crossbow" Inter-departmental Radio Committee[1] on 15 August 1944 stated that in the early stages of "Diver" attack radar tracking proved of invaluable assistance to Photographic Reconnaissance Unit aircraft in the location of sites, and had on occasion been wholly responsible for locating a number of sites.[2] This important function of radar only diminished with the discovery of all sites in the Pas de Calais area. Radar tracking had also given valuable information on the "Diver" fire plan on which had been based the allocation of bombing priorities as to sites; on correlation of activity with the weather, day and time of launching; on the relative accuracy of individual firing points ranged on London; and it had provided a valuable check with intelligence information on the location of firing points.

Controlled Interception of "Divers"

The G.C.I. (Ground Controlled Interception) stations were used for the controlled interception of flying bombs with a considerable degree of success. Since, however, it was necessary to shoot down the missiles before they crossed the coast, interceptions were also conducted from C.H.L., 10-centimetre, and Type 16 (Fighter Direction) stations, in addition to the M.E.W. station at Fairlight and the Type 26 station at Greyfriars.[3] At the beginning of the attacks, Beachy Head radar station was used very successfully as a Forward Control point, its value only lessening as attacks in this area ceased with the move of activity north-eastward. Hopton C.H.L. station was later established as another Forward Control point, again considerable success being achieved. Fighter aircraft were directly controlled from the stations by experienced Controllers, whilst at the same time an A.A. liaison officer on the spot passed up-to-the-minute information to the parent Gun Operations Room. The following outlines some of the various combinations of radar sets used for controlled operations at representative radar stations :—[4]

(*a*) *Beachy Head C.H.L.*
- Type 51 (High-power 10 centimetre).
- Type 13 (Height finding).
- Type 16 (Fighter-Direction).
- Type 24 (Long-distance height finding).

(*b*) *Fairlight C.H.L.*
- Type 52 (High power 10 centimetre).
- Type 13.
- M.E.W. or Type 26.

(*c*) *Hythe*
- Type 16.
- Type 24.

Radar Information Passed to the Guns

Excellent work was done by Anti-Aircraft Command in shooting down "Divers," their aim and accuracy reaching a very high standard as the attacks from the enemy progressed. The A.A. batteries used their own radar sets,

[1] The name was changed from "'Crossbow' Inter-Departmental Radiolocation Committee" to "'Crossbow' Inter-Departmental Radio Committee" on 1 August 1944, when the terms of reference of the Committee were extended.

[2] Air Ministry File C.M.S. 202, Encl. 120A.

[3] Air Ministry File C.M.S. 203, Encl. 47A.

[4] *See* Appendix No. 50 for details of various types of radar equipments.

S.C.R. 584—a modified American gun-laying equipment—which did excellent work in enabling them successfully to intercept and shoot down so many flying bombs. This was an automatic-following radar equipment tied to the gun predictors, and doubtless full information will be given in the Army account of their defences against the flying bomb. However, the Home Chain played a vital part too by giving the batteries preliminary warning at long range of enemy activity. Without these preliminary warnings, the A.A. defences would have been handicapped. Very close liaison was maintained between A.A. Command and Fighter Command, and all relevant information was immediately passed to the guns, both from Filter Room and from the radar stations themselves. The latter gave immediate warning to guns in the vicinity of any tracks which appeared within their coverage. The long-range warning given by the Royal Air Force radar chain to the Army A.A. batteries enabled the latter to be absolutely on the alert when the flying bomb came within range of their own radar system and of the guns.

Reporting of " Diver " Tracks

All types of radar stations in the area facing the enemy's launching points were able to see " Diver " tracks, with varying success according to their normal limitations of range or height-finding. C.H., C.H.L., C.H.E.L. and also the more specialised stations such as the Types 11, 16, 26 and the M.E.W. all played their part in providing home defences with an accurate picture of the enemy's activities. Flying bomb tracks were reported by stations to Filter Room, in the usual way, except that " Diver " was shouted down the line immediately such a track appeared on the tube, and this was repeated in a very loud voice by the plotter in Filter Room, and again by the filter officer. Priority was given to " Diver " tracks over all normal aircraft tracks, and very close co-operation was maintained between Filter Room and the stations.

Little difficulty was experienced by the Home Chain in the detection and reporting of flying bombs, except in the following circumstances :—[1]

(*a*) When the reporting system became saturated by friendly aircraft during massed raids ;

(*b*) When the display at centimetre stations was affected by fixed echoes from sea clutter, storms, raincloud or abnormal weather conditions ;

(*c*) When enemy jamming was present ;

(*d*) When there was mis-identification in Filter Room due to the activity of friendly aircraft. When this latter difficulty was appreciated, special personnel were allocated to Filter Room and the Movement Liaison Section's information and the radar information was better correlated.

Value of Information Provided by the Home Chain against the Flying Bomb

At the end of the first stage of flying bomb activity, a message dated 6 September 1944 was sent by the Air Council to the Air Officer Commanding, Air Defence of Great Britain, for circulation to all ranks, in which it was stated : " The Air Council convey to you their warm congratulations on the manner in which the defences against the flying bomb have operated since the launching of the enemy's campaign against London and southern England.

[1] Air Ministry File C.M.S. 202, Encl. 41A.

The Council watched with admiration the steady mounting rate of destruction inflicted on flying bombs. They are aware that this result could only have been achieved by the most careful planning and by an imaginative deployment of the defences to meet each phase of the attack as it developed. These measures, coupled with the devotion to duty of all concerned in the operation of the fighters, and the manning of the A.A. guns, balloon and air raid reporting organisation, largely crippled the enemy's effort and achieved what can only be described as a notable victory."[1]

This congratulatory message was sent six months before the flying bomb attacks ceased, yet it remained as true in March 1945 as the day on which it was written. In spite of the fact that casualties were heavy and considerable damage to property was caused, yet more than half the flying bombs which were reported by the defences as being launched against the United Kingdom were destroyed. The enemy's original plans had been to bombard southern England, and London in particular, with a far heavier concentration of bombs than were in actual fact fired. The defence of this country really began long before the first flying bomb reached England, when the German experimental station at Peenemunde was bombed. This was the enemy's secret research station on the Baltic, where continual research and development into V-weapons had been undertaken. The Royal Air Force's heavy raid of 17/18 August 1943, carried out by 580 heavy bombers was, despite the grievous loss of 41 aircraft, a most successful sortie and proved a great setback to the enemy. Not only were his material losses heavy—more than half the buildings of the experimental establishment were severely damaged or destroyed—but many of his most important scientists and research workers were killed in the raid.[2]

This attack was followed by continuous bombing, both by Bomber and Fighter Commands, of the enemy launching-points—located by reconnaissance or from information supplied by Intelligence sources—supply routes, communications and ammunition depôts. The attacks on launching sites were intensified when the enemy at last began his onslaught, and it was then that radar proved so valuable, with the more precise information it afforded on the launching point locations.

[1] Headquarters, A.D.G.B. O.R.B., September 1944.
[2] A.H.B./IIH4/2/3, " Long-range Weapon History," D. of Ops. S.O., 1944.

CHAPTER 27

RADAR IN RAID REPORTING AGAINST "V"-WEAPONS—THE LONG-RANGE ROCKET ("BIG BEN" OPERATIONS)

How the Home Chain dealt with the V1, the first of the enemy's new terror weapons to be used against the United Kingdom, has already been described. The preparations which had been made in anticipation of its use proved adequate, and the performance of the flying bomb in practice was in many respects so similar to that of piloted aircraft that its detection and subsequent tracking on the radar screen were relatively simple matters. The rocket, however, presented greater difficulties, as exact details of its nature were unavailable, and there were no reliable records to show its behaviour in flight. Plans therefore had to be made largely on theoretical surmise, and a full scheme of counter-measures could not be introduced until further information was available on the effect of the rocket in operation. One thing was clear—that the speed of a rocket-propelled missile and the course it took would present the Home Chain with a problem utterly unlike anything that it had previously encountered.

From the summer of 1943, radar stations were maintaining continuous watch for signs of rocket activity, using the equipment then available, whilst modifications to the C.H. (Chain Home) stations were pressed ahead with all speed. On 25 January 1944 the code-word " Big Ben " was introduced as the term referring specifically to the V2 rocket, and all operations connected with it. " Crossbow " was the code-word for V-weapons in general.[1]

The maximum range of the rocket was approximately 230 miles ; the majority of the rockets reaching London from sites in Holland were launched at distances of between 150 and 200 miles. When it is recalled that the average time taken for the rocket to reach its destination was five or six minutes, and that in this time its flight lay in a curve, the highest point of which frequently reached 50 miles above the earth's surface, it will be realised at what an immense speed the missile travelled. The rocket achieved its maximum velocity on its downward path when terminal speeds of up to 3,000 miles per hour were attained. The speed of the rocket was such that two sounds were heard by persons in an area anything up to ten miles from the spot where the rocket fell. The first sound was that of the actual impact with the ground as the rocket's warhead exploded and the next sound, following almost immediately, was that of the rocket *as it travelled*—the noise being the rush of displaced air caused by the weapon's bow wave during its flight, which lasted for several seconds after the sound of the explosion had ceased. Hence no aural indication could be given of the rocket's arrival until it had, in fact, arrived. It is obvious then that the task of the Home Chain in tracking this entirely new form of weapon was a very formidable one.

Short Summary of the Rocket Attacks against the United Kingdom[2] September 1944 to March 1945

The first incident occurred at 1843 hours on the 8 September 1944, when a missile fell at Chiswick. No radar warning was given at the time, but post-incident examination of the photographic records at Bawdsey Radar Station,

[1] Air Ministry File C.M.S. 99/2, " Big Ben—Use of by Enemy against United Kingdom," Encl. 60A.

[2] Headquarters, A.D.G.B., O.R.B., September 1944, Appendix " BB," and Air Ministry File C.M.S. 636.

showed a range of 133 miles, and subsequent sound-ranging plots proved the firing point to have been near Rotterdam. A second rocket, which fell at the same time, landed at Pain Wood, 3½ miles north of Epping. No radar indication was present, but later investigations showed the firing point to have been in the Amsterdam district.

Thirty-six incidents were recorded up to the 30 September 1944. Of these, radar ranges were given on twenty-four, enabling firing-point data to be obtained by means of range cuts by the special "Big Ben" Scientific Watch maintained by Operational Research Section at Headquarters, Fighter Command. Radar warning to Filter Room was given in eight of these incidents, the period varying from three minutes to six minutes. In three cases radar was unable to see any response, owing to the masses of friendly aircraft which cluttered up the cathode ray tubes.

The whole question of warning is dealt with later in this chapter, but it is thought advisable to point out here that warning to which reference is made in these paragraphs refers to the time a rocket response appeared on the cathode ray tube of the C.H. station, and was reported to Filter Room, until the time the actual incident occurred. It does not refer to a general or public warning.

The attacks increased in intensity during October, when 94 incidents were confirmed. Of these, firing-point ranges were obtained on 83. During the latter part of the month, however, radar performance improved and 49 out of 50 incidents were recorded by the cameras. Warning to Filter Room prior to the incident was given by the C.H. stations in 65 out of the 95 incidents. At the beginning of the month the average warning was four and three-quarter minutes, but later this was increased to five and a half minutes. No radar information at all was available in 11 incidents, but again a gradual improvement in performance was noted, as in the latter part of October only one incident was missed.

The principal areas affected in October were Norwich (with 19 rockets in the neighbourhood), Greater London (27) and Essex (24), with scattered incidents in Kent, Suffolk, Cambridgeshire, Hertfordshire and Buckinghamshire. It was noteworthy that the attacks at first were largely centred round Norwich, but later the enemy appeared to change his tactics, and rockets began to fall more and more frequently in the London area. The foregoing figures for October 1944 are of recorded and confirmed incidents only. In addition, more than 248 warnings were issued during the month, by the C.H. stations, which were not followed by a rocket. It is probable that some rockets fell on the continent, in the sea, or burst in the air, and that only a proportion were false alarms.

Rocket attacks continued throughout the winter, gaining in intensity and also in accuracy. During March 1945, 223 rockets were recorded, located as follows :—

Greater London	112
Essex	82
In the sea	12
Kent	10
Herts	4
Surrey	2
Norfolk	1

It will be noted that the enemy had succeeded in getting much more frequently to the target area which was now London only and to the area north of the Thames Estuary, and that his ranges had obviously been considerably corrected.

The last rocket fell at Orpington at 1654 hours on 27 March 1945. No records are available from enemy sources of the number of rockets directed against the United Kingdom, but the total number reported by home defences was 1,115. Of these, 517 landed on London, and 58 fell in the sea. The total fatalities were 2,754, with a further 6,523 persons seriously injured and more than 15,000 slightly injured.[1]

Rocket Attacks on the Continent

The foregoing refers only to rockets which were aimed at, and reached, southern England. It must be remembered, however, that many of the enemy's attacks were launched directly at Allied key-points on the Continent, Antwerp in particular being extremely heavily bombarded both by rockets and flying bombs. The C.H. stations in England were able to plot, both visually and photographically, many rockets aimed at Continental targets as well as those destined for England, and full records were kept of these, as the location of such sites was, of course, equally as important as locating those directed against the United Kingdom.

Cathode Ray Direction-Finding and Cathode Ray Height-Finding Equipment

Mention has already been made of the installation of C.R.D.F. equipment on the south coast of England in 1943, to meet the anticipated attack on this country by rocket projectiles.[2] By the end of October 1943, when most of this equipment was either installed or in process of installation, information was received from Intelligence sources which indicated that a signal-to-noise ratio of only 2 : 1 could now be expected on the rocket echo on the cathode ray tube, instead of $3\frac{1}{2}$: 1 as had been forecast in August 1943. This information, together with the fact that the range of the rocket was now found to be about 200 miles, necessitated a complete review of the cover provided by the existing radar warning equipment.[3] The Research Establishments were therefore requested to make further recommendations, particularly in respect of the detection of rockets at greater ranges. The design of radar equipment for this purpose presented some difficulty, as two main requirements had to be met ; one to provide early warning, and the other to provide firing-point location ; and one type of equipment could not adequately fulfil both these requirements now that greater ranges were believed to be involved.

Early in March 1944 it was decided that the provision of an adequate radar warning system should take priority over the firing-point location. Recommendations were made for the use of a Mobile Radar Unit working on a higher frequency, to be sited in a hollow in order to provide cut-off from normal aircraft responses, and to throw the main area of illumination upwards. This equipment was known as C.R.H.F. (Cathode Ray Height Finding) or A.M.E.S. Type 9 Mark III, and it was hoped it would also afford protection from enemy jamming. The ordinary C.H. station range of detection upwards was about 50,000 feet. It was anticipated that the range of the new equipment would

[1] Air Warfare Analysis Section Reports.
[2] *See* Chapter 16.
[3] Air Ministry File C.M.S. 636.

go up to 100,000 feet. It consisted of a modified C.R.D.F. (Cathode Ray Direction Finding) equipment, the display containing two time-traces with normal deflection. Comparison of the echo amplitude on the two traces formed the method of detection of the rocket. This equipment was sited at Martin Mill, near Swingate, and became operational on 8 August 1944.[1] A similar equipment was sited at Snap Hill, near Pevensey, and this came on the air on 30 August.

A.M.E.S. Type 9 Mark IV

As a long-term policy to replace the mobile stations at Martin Mill and Snap Hill, four high-looking mobile radio units, improved models of the C.R.H.F. and known as A.M.E.S. Type 9 Mark IV, were planned. Sites were found at Pevensey, Rye, Swingate and Canewdon and the target date for completion of installation was 1 October 1944.[2]

" Big Ben " Watch

The " Crossbow " (" Big Ben ") watch, which had first come into operation in July 1943, went into abeyance on 5 March 1944, when Intelligence information stated that the rocket danger was not imminent. All equipment and personnel were, however, kept ready to go into action at very short notice. Full watch was resumed at all stations concerned on 13 June 1944, the operating commitment being identical with that which obtained previously.[3] In addition " Big Ben " watch was opened at Ramsgate on 8 August, using a mobile C.R.D.F. set, and at Bawdsey by 31 July.[4]

However, the advance of the Allied Armies on the Continent, and the capture of the Cherbourg Peninsula, made it apparent that the south-western part of the C.R.D.F. Chain would be rendered redundant, and so on 9 July watch was discontinued by Branscombe, Ringstead and Southbourne, the equipment being withdrawn for fitting at Bawdsey C.H. station and two mobile radio units in Kent.[5] St. Lawrence and Ventnor ceased " Big Ben " watch on 9 August, Poling and Pevensey to the eastward on 6 September, and Rye and Dymchurch on 9 September. The two C.R.H.F. equipments at Snap Hill and Martin Mill were similarly closed down on 10 September but were transferred for use on the Continent. All other special equipment, unless removed for use elsewhere, assumed a standby reporting function to the main operational channels on the stations. At the same time Air Ministry issued instructions that all work on the A.M.E.S. Type 9 Mark IV installations was to cease from 31 August, as it was apparent no further threat existed from the Cherbourg/Dieppe area which it had been intended to cover.[6] Equipment thus released was again made available for employment with the Allied Expeditionary Air Forces.

In the meantime, special watch began on stations further east. High Street became operational, using short wave final equipment and " Oswald,"[7] on 10 September and Great Bromley (R.F.8 receiver and " Oswald ") on

[1] Air Ministry File C.M.S. 203, Encl. 83A. [2] *Ibid.*
[3] Headquarters, No. 60 Group, O.R.B., March 1944.
[4] Air Ministry File C.M.S. 203, Encl. 35A.
[5] *Ibid.*, Encl. 7A, the O.R.B.s of the A.M.E. Stations mentioned, and No. 75 Wing File 75W/155/1/Org. [6] *Ibid.*, Encl. 93A.
[7] Display Unit Type 53, a special electrical high speed tracker, with photographic attachment which automatically recorded photographs of the cathode ray tube on a continuous film. (Details given in Chapter 16.)

13 September. " Big Ben " watch also opened at Bawdsey C.H.L. Station from 10 September, the aerial array being kept stationary on a fixed bearing, but limitations of range were so great that the station saw nothing of the rocket incidents which occurred, and consequently special watch was abandoned there on 19 September.

Thus in September, when the enemy launched his first rocket attack, the special " Big Ben " watches were in operation at the C.H. stations of Swingate, Ramsgate, High Street, Great Bromley and Bawdsey. All these stations were equipped by 19 November with megawatt transmitters for maximum power output.[1] The " Big Ben " equipment and operational staff were transferred from Ramsgate to Dunkirk on 24 October, the latter station becoming operational on 28 October, after a period of seven months on a care and maintenance basis. Further cover was also obtained at Bawdsey by the installation of a mobile C.R.D.F. set (Bawdsey III), the results from which compared very favourably with those obtained on the main C.R.D.F. channel. Watch on the latter was, however, closed in November 1944, when the " Oswald " console was withdrawn in order to equip a mobile Type 9 Mark V equipment which was being sent to north-west Europe. " Big Ben " watch was also opened at Stoke Holy Cross C.H. Station on 20 October, but closed in mid-November when the " Oswald " console was withdrawn for use in a mobile Type 9 Mark V set destined for the Continent.[2] The Type 12 Stations, to which reference has been made in a previous chapter, proved of no avail against rockets and in consequence Highdown Hill and Hythe were closed in December 1944, and the remaining stations soon afterwards.

It was recommended by the " Crossbow " Committee that from 21 February 1945 all United Kingdom stations keeping rocket watch should cease to assist in locating firing points of rockets launched against Antwerp, save on special demand from S.H.A.E.F.[3] Great Bromley therefore ceased reporting incidents on the Continent from 22 February and concentrated only on rockets directed against this country ; High Street similarly concentrated only on " homers " from 14 March.[4]

With the cessation of rocket attacks the need for " Big Ben " watch ceased, and so by agreement with Fighter Command the visual watch on " Oswald " with its concentrated continuous eye-straining observation, was discontinued on 13 April, though the camera was still kept in operation. All " Crossbow " defences and radar stations on the Continent were closed down on 18 April. The Chiefs of Staff at a meeting held on 2 May 1945, recommended the closing down of all " Crossbow " formations with effect from 4 May. " Big Ben " watch therefore ceased at the Army G.L. sets and the C.H. stations on 5 May 1945, and the special section maintained at Headquarters, Fighter Command, for determining the location of rocket firing points was disbanded.[5]

Use of Army Gun Laying Mark II Equipments against the Rocket

In addition to the cover provided by the " Big Ben " watches on the C.H. stations, further aid in the rocket detecting system was provided by the Army, who used G.L. Mark II equipments, modified for high-looking. Arrangements were made for the deployment of twelve of these sets, 20 to 30 miles apart, to

[1] No. 75 Wing O.R.B.
[2] Air Ministry Files C.M.S. 636, Encls. 101A and 141A, C.M.S. 99/1, Encl. 138A.
[3] Supreme Headquarters, Allied Expeditionary Force.
[4] Air Ministry File C.M.S. 718, Encl. 23A. [5] *Ibid.*, Encls. 50A and 44A.

cover the coast from North Foreland to Portsmouth. It was expected that the sets would only detect the rocket as it crossed the coast, and would therefore give shorter warning time than the C.H. stations, but the problem of rocket defence was so urgent that it was felt all available information should be utilised to the full. By 22 September 1944 eight sets were operational—at Wrentham (1), Aldeburgh (1), Felixstowe (2), Foreness (2) and Deal (2). Three G.L. sets and the two equipments A.M.E.S. Type 9 Mark II rendered redundant at Martin Mill and Snap Hill were also sent to the Continent, with No. 105 Mobile Air Reporting Unit, to give additional warning in view of the longer ranges obtained as the enemy rocket launching sites further north came into use.[1]

To meet increasing commitments on the Continent, the Chiefs of Staff approved on 11 November 1944, the transfer to S.H.A.E.F. of nine Gun Laying sets, on condition that replacements were made in this country. The sets were accordingly transferred overseas on 22 November.[2] It was later decided, however, that a total of eight G.L. sets, instead of the previous twelve, would meet all operational requirements for rocket watching in the United Kingdom. Two more sets, in addition to the three which had remained operational throughout, were in action by 13 December. By 12 January 1945 nine G.L. sets were functioning, some having been re-sited to meet changing conditions. The sets were now deployed at Aldeburgh (3), Wrentham (2), Felixstowe (1) and Foreness (3).

" Crossbow " Continental Organisation

A meeting was held at Headquarters, A.D.G.B., on 11 September 1944, to consider the provision of a Continental warning and rocket site locating organisation.[3] It was explained that, owing to doubts as to the ability of the organisation in the United Kingdom to detect the flight of rockets launched from territory then still remaining in German hands, it was advisable to set up an advanced organisation on the Continent. No. 21 Army Group had been requested to release a Survey Regiment for " Big Ben " Sound Recording and Flash Spotting duties overseas, and the War Office undertook responsibility for providing the necessary communications from Flash Spotting and Sound Ranging Units to Survey Regiment Headquarters on the Continent, and from thence to 11th Survey Regiment Headquarters at Canterbury. No. 21 Army Group were also requested to release three Gun Laying sets for early warning purposes. A further meeting held on 17 October at Versailles decided that additional radar facilities were required to give warning on rocket attacks to Antwerp and Brussels. This was followed by a series of meetings at Versailles in late October 1944, when representatives of Fighter Command discussed further plans of the organisation with members of the staff at Supreme Headquarters, Allied Expeditionary Forces.

Air Ministry decided to install two specially modified Type 9 sets overseas for early warning purposes, and the C.R.H.F. sets rendered redundant at Martin Mill and Snap Hill were re-deployed for this purpose.[4] No. 365 Wireless Unit and an 80 Wing Radio counter-measures detachment were also installed on the Continent ; the latter two units were not, however, solely concerned with " Big Ben " detection and radio jamming, but had also other commitments.

[1] Air Ministry File C.M.S. 636, Encl. 55A.
[2] *Ibid.*, Encls. 167A, 191A.
[3] *Ibid.*, Encl. 27A.
[4] Air Ministry File C.M.S. 204, Encl. 17A.

The three Army G.L. sets, two A.M.E.S. Type 9, Mark III, and No. 80 Wing detachments were formed into No. 105 Mobile Air Reporting Unit. This formation was under the operational control of Fighter Command and had direct communication with No. 11 Group Filter Room.[1] No. 11 Survey Regiment (for Flash Spotting and Ranging) was not under the operational control of No. 105 M.A.R.U. but was very closely linked to it.

Two of the G.L. sets were operational by early October in Bruges; the first Type 9 equipment became operational in Holland on 9 October. Four further A.M.E.S. Type 9 sets, of an improved type, Mark V, were in action overseas by 12 January 1945.[2] These mobile equipments were completed by the " Oswald " console from Stoke Holy Cross, which had been removed in November 1944, and one removed at the same time from Bawdsey III. Two sets were sited in Holland, three in Belgium, and one in Luxemburg. They proved extremely useful and played a major part in the location of V2 launching sites.

In October 1944 it became apparent that a major threat existed to the port of Antwerp from long-range rockets directed at it by the enemy, and Supreme Headquarters, Allied Expeditionary Force, asked the Chiefs of Staff to hand over their rocket watching organisation on the Continent to S.H.A.E.F. control. They also requested that a team of officers from Fighter Command should be lent to advise on the detailed organisation and handling of information within the new Continental " Crossbow " organisation which was to be developed. The Chiefs of Staff granted this request, and with the formation of a special " Crossbow " Wing under No. 85 Group of the Second Tactical Air Force, the Home Chain ceased to have any further control of the radar stations deployed on the Continent for V-weapon observation. Close liaison was maintained, however, and the successes achieved by the Continental organisation have already been described.[3]

Radio Countermeasures against Rockets

The full story of the part played by the organisation employing radio countermeasures against the enemy is told elsewhere in this history, with an account of the special measures taken by it against rocket attacks.[4] However, brief mention is made here of the link between the Radio Countermeasures section and the Home Chain. Special aircraft were maintained by No. 80 Wing of No. 100 Group, to maintain a listening and visual watch in the air for any signs of rocket activity—such as the spotting of trails or flashes. An organisation under the control of No. 80 Wing was set up at Eastbourne in August 1944 to exploit countermeasures against rockets and to investigate the possibilities of interfering with the radio control mechanism which was contained in some types of rocket.[5]

The following measures were taken: Eastbourne and H.Q., No. 80 Wing were informed immediately a long-range rocket was detected by radar means; Eastbourne in turn informed Filter Room and all " Big Ben " stations immediately information was available that the launching of a rocket seemed probable. For this purpose special alarm buzzers were fitted at Eastbourne, H.Q., No. 80 Wing, No. 11 Group Filter Room and at all C.H. and Army G.L. stations maintaining the " Big Ben " watch.

[1] Air Ministry File C.M.S. 636, Encl. 106A. [2] *Ibid.*, Encls. 89A, 141A.
[3] In Chapter 25. [4] *See* Volume VII. [5] Air Ministry File C.M.S. 203, Encl. 98A.

Performance of the Home Chain Radar Stations against the Long Range Rocket

At a meeting of the " Crossbow " Inter-Departmental Radio Committee held on 5 January 1945—nearly four months after the start of the rocket attacks—a report was presented by the Operational Research Section of Fighter Command.[1] An analysis of the films of the last 168 incidents recorded showed that it had been possible in 155 cases to estimate firing points within a rectangle of 2 by 5 to 10 kilometres. Failure to obtain adequate radar information in the other thirteen cases had been mainly due to the presence of aircraft masking the response. No precise information was available on the approximation of the centres of these rectangles to actual firing points, but the areas had in all cases been found to coincide with areas that were known from visual and intelligence sources to contain rocket firing sites. In only one of the 168 incidents had no radar information been available.

Performance of the " Oswald " console had varied for different stations on the chain, the non-performance figure for the worst station over the 168 incidents being as high as eight, and for the best as low as one. Reading errors of 2–3 miles were experienced with the films from the C.H. stations, but this had not markedly affected the results obtained as, on the great majority of occasions, there had been readable data from a sufficient number of stations to permit location of the launching areas. Estimated launching areas had been worked out on the average within 2–3 hours of the incidents, the delay being dependent on the number of incidents reported.

Radar Information used in the Determination of Rocket Firing Points

The chief value of the Home Chain's information on rocket tracks was in enabling firing points to be located. When these had been worked out, bomber and fighter aircraft carried out sorties over enemy territory and attacked the areas where launching sites were believed to be situated. Owing to the determination and vigour with which these attacks were pressed home, a large number of launching points were rendered useless, and many potential threats to citizens and property in England removed. Not only were the actual firing points attacked, but the supply lines in the area were also repeatedly bombed, so preventing the enemy from rushing up reinforcements. The many lulls in rocket activity which occurred were probably often due to the fact that the enemy had used all available ammunition and had to wait till further supplies could reach him.

A special " Big Ben " scientific branch was set up at Headquarters, Fighter Command, forming part of the Operations Research Section. Its main job was to co-ordinate all relevant data on rockets supplied by the Home Chain and, in particular, to calculate probable launching areas. All relevant records kept by the stations were forwarded without delay to the scientists in this branch. The C.H. station radar trace was continuously photographed upon a travelling film, the negatives being sent daily to O.R.S., together with details obtained by visual means. When a rocket was detected from photographs, the slant ranges at specific times were obtained and converted to ground ranges; from the ground ranges of two or more stations range cuts were made, giving " fixes " at specific moments of time. Using this data, the known point of

[1] Air Ministry File C.M.S. 636, Encl. 193A.

impact, the standard trajectory curves, O.R.S. were able to obtain an approximate firing-point. Very great care was taken to ensure the accuracy of all recorded times. Constant time checks were issued from Filter Room to all stations concerned and synchronisation of all clocks and watches with Greenwich Mean Time was thus maintained.

Determination of Trajectories

The great height which the rocket attained—in excess of 50 miles—in an extremely short period of time meant that the C.H. stations were only able to record the beginning of the trajectory, for a matter of seconds only. The greater part of the rocket's flight was completely beyond their scope.[1] The information thus available from the C.H. stations on the early part of the trajectory could not be completely accurate, and was dependent on a knowledge of presumed trajectories. Heights could not be measured, and were estimated by O.R.S. by means of vertical polar diagrams. The information obtained from the Army Gun Laying sets, however, was more accurate, as it concerned the latter part of the rocket's trajectory only until its point of impact.

The question of trajectory investigation was discussed on 16 March 1945 at a meeting of the "Crossbow" Radio Committee. It was stated then that an expanded time-base had been installed at the C.H. Station, Great Bromley, which promised a range accuracy from the station of $\pm$ 2 miles. This was a considerable improvement on the $\pm$ 5-mile range accuracy achieved by the other C.H. stations. The maximum accuracy obtained from the "Oswald" films had been $\pm$ 1 mile. Allowing for unavoidable reading errors, it was improbable that a visual accuracy better than $\pm$ 2 miles could have been attained. A second station was fitted that same day with the expanded time base, enabling cross-cuts to be obtained for firing point location. An inaccuracy of $\pm$ 2 miles in range could result, when determining firing points, in an inaccuracy in line determination of plus or minus ten miles or more; too large an error of uncertainty to permit discrimination between firing points.

The meeting concluded that it would not be possible to improve on the accuracy of $\pm$ 2 miles without a re-design of the "Oswald" apparatus. The Committee agreed that maximum accuracy in firing point location attainable with improved C.H. station equipment was still not sufficiently high for any discriminatory warning system to be based on this information. It was decided, too, that in view of the current continuing improvement in the accuracy of the enemy's fire, no recommendation could be made calling for major improvements in the C.H. stations for warning purposes. This decision was doubtless coloured by knowledge of the Allies' victorious tactics on the Continent, and was justified by the fact that all rocket-firing sites were in Allied hands within two weeks after the meeting, when the rocket menace finally ceased.

Difficulties of Giving Adequate Warning of Rocket Attacks

The greatest difficulty facing the defences of this country at the outbreak of the rocket attacks was that of providing an adequate and reliable warning system, both to the active defences and to the general public. Radar had proved of inestimable value throughout the war in giving an adequate warning of attack; the flying bomb had provided no special difficulties in this way and warning of imminent attack was given just as in the case of piloted enemy

[1] Air Ministry File C.M.S. 718, Encls. 4A and 23A.

aircraft. Now the case was altered. The flight of the rocket was so fast that only a matter of a few minutes elapsed between its launching and arrival in this country and it was almost impossible to tell its direction, no continuous track being possible, as in the case of " Divers " and ordinary aircraft. Only a very small portion of the rocket's trajectory could be plotted by radar, owing to the immense heights which the missile attained. Localised warnings were therefore practically an impossibility. In addition, many false alarms were given by the defence system, and had these been passed on to the public a loss of faith in the warning system would have been inevitable.

The question of adequate public warning was never fully solved in spite of all the strenuous efforts made to obtain a fair system, and although by March 1945 it was thought possible to give fairly safe warning of attacks, though at very short notice, the rockets themselves ceased before any such system could become operative. Warnings were, of course, given whenever possible by the radar stations themselves to Filter Room and associated defences, but no general system of siren alerts were passed on to the public. At first, the public were not even told that the country had been assailed by rockets. On 9 September 1944—the day after the first attack was launched—the War Cabinet met, and whilst they agreed that confidential information should be given to the Press, an absolute ban on publication was imposed.[1] The reason then, of course, was that the Cabinet did not want the enemy to realise how successful his attempts were, and every effort was made to prevent such information from reaching him. The position was reviewed by the Cabinet again on 11 September, when the silence ban was again confirmed.

A report from the Director of Radar to the Chiefs of Staff, dated 16 September 1944, on radar performance, stated that in general, as was expected, the radar stations in the United Kingdom could not be relied upon to give early warning although they provided useful data which would assist in locating the areas from which the rockets were being fired.[2] Gradually the public realised what was happening, and were informed that rockets had been aimed against this country, but very stringent precautions were still taken to prevent the enemy getting full details of attacks and very little appeared in the Press. Only those who lived in the affected areas had any knowledge of the weight of the attacks.

The Director of Radar, in a minute to the Director of Operations, on 25 November 1944 gave the following summary of the position regarding public warning :—

(*a*) Radar warning did not meet reasonable warning requirements under conditions then obtaining.

(*b*) Using G.L. and C.H. sources of information, a maximum of only two minutes warning, and in many cases only 90 seconds warning, could be given. In these circumstances at least 50 per cent—every other warning—would be false alarms, and some rockets (approximately one in six) would arrive unheralded.

(*c*) Using C.H. information alone, five minutes warning might be given, but in this case 90 per cent. of the warnings would be false.

(*d*) C.H. performance might be improved with experience but any such improvement might well be offset by an improvement in the maximum range of the rocket.

[1] Air Ministry File C.M.S. 636, Encl. 8A. [2] *Ibid.*, Encl. 40A.

It was pointed out that any warning given by the C.H. or G.L. stations might refer to the launching of a rocket which ultimately :—

(*a*) Arrived in this country,
(*b*) landed on a Continental target, or
(*c*) was destined for either of these targets, but either fell grossly short or burst in the air.

It was impossible to tell when a rocket was first spotted, what its destination would be, hence the seemingly disproportionate number of false alarms.[1] Radar records, Intelligence reports, and reports from aircraft patrolling on jamming and listening watches, all agreed in concluding that a very large number of rockets which were fired, and seen by the radar screens, were not reaching this country.

A comparison of the performance of the two types of station in use—the C.H. and G.L.—made at a meeting of the "Crossbow" Committee on 19 September 1944, showed that the C.H. gave more satisfactory identification on rocket incidents, and with the help of "Oswald" films gave valuable information on the early part of the trajectory. As only a small percentage of rockets fired then reached London, it was thought more desirable to employ in any warning system the G.L. equipment, as this saw only those rockets which actually crossed the English coast. A period of trial warning carried out between the watching stations and Filter Room from 28 October until 7 November gave the following results :—[2]

G.L. sets ..	Warnings given	75
	Warnings followed by a rocket in London area	29 (36 per cent.)
	No incidents without a warning.	
	Percentage of false alarms therefore	64 per cent.
G.L. and C.H. combined information.	Warnings given	37
	Warnings followed by rocket ..	24 (64·8 per cent.)
	Five rockets without warning.	
	Percentage of false alarms therefore	35·2 per cent.

It was thought that the more accurate the rocket became, the more reliable would the warning be.

As the rocket attacks continued, the number seen by the radar stations increased, and it was a rare occurrence for an incident to take place without a prior radar report. A report, dated 4 January 1945, stated that Rocket No. 427, which fell at 1215 hours on 2 January on South London, was unusual in that it was completely missed by all radar stations, although no obvious explanation could be offered.[3] This was the first complete miss in the last 250 incidents. In spite of this, however, it was still found impossible to give reliable warning of longer than 90 seconds.

Warning to London Passenger Transport Board

The matter had been discussed between the Royal Air Force and the Ministry of Home Security, and at a meeting of the Lord President's Committee, held on 22 December 1944, it was agreed that the necessary work for the institution

[1] Air Ministry File C.M.S. 636, Encls. 193A and 53A. [2] *Ibid.*, Encl. 132A.
[3] Headquarters, No. 60 Group, O.R.B.

of a proper radar warning system should proceed. The operation of the warning however was to be deferred pending the receipt of a report by the Paymaster-General and representatives of the Admiralty, Air Ministry and Ministry of Home Security, to decide whether, if a rocket fell in the river near an underground railway tube, the explosion would breach the tube.[1] On the 2 January 1945 the War Cabinet agreed that the warning system should be brought into use, but to officials of the London Passenger Transport Board only, and not to the public. A telephone line was accordingly installed linking No. 11 Group Filter Room and the L.P.T.B. Control Room at Leicester Square, London. On receipt of warning, the L.P.T.B. immediately closed the flood gates on the underwater tubes, to avoid any risk of flooding. The system came into use on 8 January 1945. Six warnings were given on that day, all followed by incidents ; no false alarms were given and no rockets fell without warning.

Summary of Warning System

A report published by the Operational Research Section on 23 March 1945 gave a summary of the warning system. It remarked that the mechanism of the system had been operating for some months, though it had only been used for direct warning, apart from the defences, from 8 January. The information was received from the five coastal C.H. stations maintaining " Big Ben " watch, four or five of which invariably observed the projectile immediately after launching, and from the G.L. sets at Aldeburgh, Southwold and Walmer.[2] The G.L. sets first saw the rocket when it approached or crossed a line joining North Foreland with Orfordness.

As soon as the operator at the C.H. station saw an echo showing rocket characteristics she immediately warned the plotter in No. 11 Group Filter Room manning the normal plotting line from the station. The plotter operated a switch which lit a lamp in front of an N.C.O. in the Filter Room, who was manning a head-and-breast telephone headset connected to a common circuit linked with all the G.L. sets in parallel. On receipt of a C.H. warning, the N.C.O. warned the G.L. sets to stand by. Immediately any G.L. set saw a " Big Ben " echo a warning was passed to the Filter Room Controller, via the N.C.O., and the Controller operated the warning switch. If through unserviceability, interference, or aircraft saturation three or more of the five C.H. stations were reported as unlikely to detect a rocket echo, the warning was issued from Filter Room as soon as any G.L. set reported a rocket response. At no other time was a warning issued on a G.L. detection that was not preceded by a C.H. warning. This procedure (excluding prior C.H. warning) had only been necessary in a negligibly small proportion of cases—namely, in under two per cent. of incidents in the Greater London area.

A summary by Operational Research Section, dated 10 March 1945, made ten weeks after the warning system became operative, concluded :—[3]

(*a*) Throughout the time the warning system had been in operation the fraction of incidents in the London area, not preceded by warning, was under 3 per cent., and in the past five weeks only two failures were recorded in one hundred and forty-six incidents.

[1] Air Ministry File C.M.S. 636, Encls. 174A, 180B, 198A.
[2] O.R.S. Report No. 660, Air Ministry File C.M.S. 718, Encl. 36B.
[3] Air Ministry File C.M.S. 718, Encl. 36A.

(*b*) Discrimination against incidents which were going to fall outside the London area was low, partly through reduction in the cases of gross errors in aim. Over the whole period 79 per cent. of all these incidents were preceded by warnings, and in the second part of the period reviewed, 87 per cent.

(*c*) The number of wholly spurious warnings was low—3½ per cent. The proportion of warnings defined as "false"—in that the rocket observed fell outside the exact boundaries of the Greater London area, or Civil Defence Area—was controlled almost entirely by the proportion of the fall of shot in that period lying outside the boundary. In other words, assuming London to be the sole target the more perfect the enemy's aim, the nearer did the warning system come to 100 per cent. efficiency.

(*d*) The average length of warning was just under two minutes for rockets falling in London, about 12 per cent. falling below 1½ minutes and 64 per cent. over two minutes.

(*e*) It was impossible by any simple process to reduce the proportion of "false" warnings without reducing the warning available and substantially increasing the number of failures in the London area.

(*f*) An increase of the warning time to 4 or 4½ minutes would be possible by the use of C.H. stations only, but the proportion of false warnings would increase from 45 per cent. to 62 per cent.

The Allies' main defences against the long-range rockets were by methods unconnected with radar. The bombing raid on Peenemunde in August 1943 was the first definite attack against the enemy's new weapon—an attack made nearly a year before the first rocket was fired.[1] This raid, and further raids on the same target carried out in July 1944, coupled with heavy bombardment of storage depôts and factories making essential parts and components for the rockets, undoubtedly seriously upset the enemy's plans and delayed his introduction of the weapon. When it finally came into use, Allied troops were already on the Continent, and we were enabled to take countermeasures which would have been impossible had the attacks been launched, as expected, in 1943. The final defeat of the rocket menace was due partly to these earlier raids, and to later attacks on storage depôts, communications and firing points, and in the last instance to the capture of the actual launching areas by the Allies as they advanced on the Continent.

Radar proved very valuable as a means of locating firing points and launching sites, and often provided information unobtainable from other sources. It must be admitted, however, that it did not achieve its secondary purpose of giving adequate early warning to the general public in the United Kingdom. The reasons for this have already been discussed—the great speed of the weapon, the trajectory it took, and the difficulty, if not impossibility, of estimating direction and probable point of impact. Radar was originally devised and developed as a means of detecting aircraft. The Home Chain was established and maintained for this purpose, and successfully fulfilled this function. The speed and general characteristics of the flying bombs were much like those of piloted aircraft, and in consequence their tracking was well within the scope of the radar equipment. The case was vastly different with the V2. Every

[1] This is described in the preceding chapter.

effort was made by all concerned to make full use of the radar equipment available, in an attempt to track the rocket, and the best possible results in the circumstances were obtained by those responsible for the operation and maintenance of the rocket watch. The fact, however, remains that the satisfactory tracking of rockets was a matter far beyond the scope of the normal radar system, and one requiring very special study and development. Any future countermeasures against rockets will require specialised investigation and development, unrestricted by considerations of other requirements for air defence.

CHAPTER 28

GENERAL ACTIVITIES OF THE HOME CHAIN FROM JANUARY 1944 UNTIL THE CESSATION OF HOSTILITIES WITH GERMANY, MAY 1945

The period from the beginning of 1944 to the cessation of hostilities with Germany in May 1945 was one of great variety from the point of view of the Home Chain. During this last fourteen months of the war the radar early warning organisation had not only to face the normal problems of tracking hostile aircraft approaching Britain's shores, but in this period also the enemy tried to use his V-weapons—pilotless aircraft and rocket projectiles. To simplify the narrative, the story of the V-weapons in relation to the Home Chain has been written elsewhere :[1] the purpose of this chapter is therefore to round-off the war history of the radar chain by an account of its general defensive activities against enemy aircraft and surface raiders, together with some consideration of its assistance to the Allied aerial offensive in the closing stages of the war.

1944 was characterised by a renewal by the enemy of aerial attacks against the United Kingdom. At first these consisted of heavy bombing raids directed against our main cities and ports, in particular, against London, and were accompanied by smaller raids carried out by intruder forces. Activity by friendly aircraft which had already reached vast proportions in the previous year was still on a rising scale and many sorties by bomber and fighter aircraft kept the Home Chain constantly busy. Increased activity around the coast, both by enemy surface craft and by that of the Allies, gave heavy responsibility to the surface watching stations, particularly in the maritime operations associated with the Allied liberation of North West Europe. The climax of the period was, of course, Operation " Neptune " and the intense activity undertaken by all branches and interests in the radar raid reporting system in making preparations for the operations in North West Europe was more than repaid by the efficient way in which the Home Chain played its part in the events leading up to and succeeding D-day—6 June 1944.

Installation programmes of the C.H. and C.H.L. stations had been complete for some time ; the centimetre programme was now carried to completion. Centimetre equipment had passed its period of probation and proved of the greatest value in the detection both of aircraft and surface vessels, and had become perhaps the most valuable part of the Home Chain's defences. The demands for equipment and personnel made upon the Home Chain proved a constant drain on its resources. Replacements had to be provided for overseas units in all theatres of war, for operations such as " Apostle " (the planned Allied invasion of Norway in 1945), and especially for air forces in North West Europe. The demand for trained personnel to be provided by the Home Chain could not be balanced by the employment of new technicians, mechanics, operators and administrative personnel, although the training schools and the training sections within the Home Chain framework did their utmost. Experienced personnel were utilised mainly in the south and south-east areas of England, where work was heaviest, whereas stations in the quieter areas carried on with very limited numbers, and largely with partly-trained personnel.

[1] *See* Chapter 26, " Radar in Raid Reporting against V-weapons—The Flying Bomb. ' Diver ' Operations " and Chapter 27, " Radar in Raid Reporting against V-weapons—The Long Range Rocket. ' Big Ben ' Operations."

Strenuous hours of duty had to be worked to make the best use of the meagre manpower available, and it is to the credit of the radar personnel that in spite of the acute shortage of men and women experienced by all stations, operations were not allowed to suffer and a high standard of proficiency was expected, and obtained.

Equipment was in equally short supply, and in order to economise as much as possible in manpower and material, a considerable policy of retrenchment had to be carried out during 1944–1945. Every station and each piece of equipment not performing an essential function was closed down, personnel and technical gear being transferred to areas where the need was greater. The advances made in the Home Chain technical equipment since the beginning of the war, however, were so considerable that many of the functions of the older stations were now taken over by newer and more up-to-date equipment, with the result that despite the closing of many stations, the coverage which the Home Chain afforded around our coasts was still adequate to meet all requirements and contingencies.

Hostile Activity against the United Kingdom, January 1944–May 1945

During the first six months of 1944 the enemy resumed his night raids on the United Kingdom, on a heavier scale than for many months past. The attacks on London, in particular, were the heaviest since May 1941. No bombs were dropped by day, and daytime activity by the enemy was confined almost entirely to reconnaissance flights, in attempts to check the extent and location of the preparations for operations in North West Europe. After June 1944 the night raids ceased completely until March of the following year.[1] Although night bombing ended in the summer of 1944, the enemy continued to attack this country both by day and by night, and for the first time used his new weapons—the pilotless aircraft (or V1) and the long range rocket (or V2)—the detection of which confronted the radar stations with yet another task.

During the first half of 1944, 2,928 enemy aircraft flew overland on 77 nights and 3,177½ tons of bombs were dropped on land (about 39 per cent. of the total bomb load being incendiaries). London was at first the target for heavy attacks, but in March ports and coastal areas began to be attacked, and these, with shipping concentrations, absorbed practically all the enemy's main effort during April and May. This bombing was of course a deliberate policy of the enemy, having as its object the smashing of stores and supplies gathered together by the Allies in readiness for their assault on the Continent, and the destruction of the ports and harbour installations from which the Allied forces were expected to sail. Considerable damage was caused, but the advance warning of attacks given by the radar chain enabled defences to be on the alert, and the results must have caused the enemy great disappointment. Certainly he failed in his primary object of preventing or delaying the Allied offensive, and the operations against the enemy in North West Europe took place according to plan.

Hull and Bristol were raided in March, and again in April. Attacks in this month were also made on Portsmouth and Plymouth, whilst in May Bristol, Portsmouth, Weymouth, Torquay and Falmouth were the objectives.[2] Apart

[1] Air Warfare Analysis Section Report BC/35.

[2] Hull raided 19/20 March (90 enemy aircraft), 20/21 April (40 enemy aircraft). Bristol raided 27/28 March (110 enemy aircraft), 23/24 April (50 enemy aircraft), and 14/15 May (80 enemy aircraft). Portsmouth raided 25/26 April (35 enemy aircraft). Weymouth 27/28 May (15 enemy aircraft). Torquay raided 28/29 May (10 enemy aircraft); and Falmouth raided 29/30 May (12 enemy aircraft).

from London, Portsmouth and Gosport received the heaviest tonnage of bombs (36 tons), followed by Weymouth ($17\frac{1}{2}$ tons), Gravesend ($12\frac{1}{2}$ tons) and Southend ($11\frac{1}{2}$ tons). All these raids were made by ten or more aircraft at a time. Thirty-six other towns in the United Kingdom were bombed, apart from isolated instances and intruder attacks on airfields and Royal Air Force stations. In these cases, less than ten aircraft attacked at any one time, although some towns experienced several raids.

The "Little Blitz" on London

London was the enemy's main target during 1944, one-third of the total bombs dropped by the Germans in that year falling in the Greater London area. The attacks between January and April became known as the "Little Blitz," to distinguish them from the heavy night raids on the capital made in 1940–41 and popularly referred to as "The Blitz." Fourteen heavy raids were made on the city between 21/22 January and 18/19 April 1944. Two hundred and ten aircraft operated during the first raid, and on each of the other occasions more than one hundred aircraft were employed. Numerous other raids were also made by the Germans, with smaller formations of aircraft. These raids were intended by the enemy to be retaliations against the ever-increasing attacks made by the Allied forces against German towns. The great difference between the heavy tonnage of bombs dropped by the Allies and the relatively small and ineffectual raids of the enemy made his efforts at reprisals appear ludicrous.

Measures adopted by the enemy to elude radar ground search observation and to hinder the defences showed rather more variety than usual. The major attacks were concentrated in time, and attempts at careful routeing to the target appear to have been made ; while at the same time night fighter airfields and their associated dummy flare paths were attacked on a moderate scale.

Enemy Attempts to Elude Radar Cover

Three main measures were adopted by the enemy in attempts to escape detection by radar. These were :

(*a*) the employment of "Intruder" aircraft, flying with a mass of returning friendly bombers ;

(*b*) the use of "Window," and

(*c*) an intensification of his previous methods of jamming English radar frequencies.

Apart from the main bombing raids against specific targets made by the enemy between January and June 1944, intruder tactics were also adopted. These latter raids were made generally by single aircraft, after flying in under cover of friendly returning bomber forces to escape radar detection, and they were generally directed against airfields. The enemy's objects were either to weaken our defences or to provide a secondary target for enemy aircraft unable to get to London. Practically all the intruder attacks until March 1944 were directed against Fighter Command stations, or their associated dummy flare paths ; during April, in addition to the bombing of airfields, a large number of machine-gun attacks were made either against airfields or against friendly aircraft about to land.

Such tactics made detection very difficult for the radar reporting system. Although adequate public warning was given in practically every case when large-scale attacks were made by enemy forces, it was not always possible in the case of single raiders.[1] When they flew in amid a mass of returning bombers on a parallel course and at a similar height, it was difficult, if not impossible, to identify the track as hostile. It should be noted, however, that the problem was one of identification rather than of detection in many cases—the aircraft was often seen and reported by radar methods, but might not be given a hostile identification at Filter Room. If mass or "macroscopic" plotting was in progress, it was not possible for the radar stations to plot individual tracks through the confusion of echoes on the tube unless special characteristics were shown by the track. True, hostile responses did not give an I.F.F. (Identification Friend or Foe) signal, but although Allied bomber aircraft were all fitted with Mark III I.F.F. in 1944, some pilots did not switch it in on the return journey, so the lack of I.F.F. response was no criterion that a track was hostile.

When the intruder flew in at very low level (thirty-four attacks under 1,000 feet were made between November 1943 and May 1944) detection was more difficult for the Radar Chain, as the aircraft would be below the coverage of the C.H. stations, and sometimes below that of the C.H.L. stations too, except at close range. The centimetre stations of the Home Chain were designed for this purpose, and were able to plot very low-flying aircraft. Warning in the case of aircraft at such heights was, unfortunately, necessarily short. A drawback was that probably only one station would see the intruder, whereas in the case of aircraft at greater heights, several stations might plot the track, thus providing confirmation that a hostile was approaching. The intruder attacks ceased in June 1944, with the advent of the flying bomb, and attacks did not recur until the spring of 1945.

Resumption of Enemy Intruder Activity in March 1945

In the month of March 1945, there began the final phase of the German Air Force's intruder activity—inspired, no doubt, by the loss of his V-weapon sites on the Continent. During this month, a total of one hundred and ten enemy aircraft (of which only seven were destroyed) made landfall on four nights, the main effort being confined to the night of 3/4 March, when eighty enemy aircraft were estimated to be operating overland.[2] Generally, the aircraft made landfall under cover of returning Bomber Command aircraft. The main targets attacked were again Allied airfields, built-up areas, and road or rail transport. Bombing was not heavy (18·09 tons of high explosive being dropped during the month, no incendiaries were used), and the majority of the attacks were made with machine-guns and cannon fire. The chief targets for attack were the bomber airfields of Yorkshire and Lincolnshire.

Headquarters, No. 73 (Signals) Wing, which controlled all radar stations on the east coast of England, from the Scottish boarder to mid-Suffolk reported in their Operations Record Book that on the night of 3/4 March 70+ aircraft had crossed the coast between the G.C.I. station at Northstead, in Northumberland, and about half-way down the Suffolk coast.[3] Good tracks were maintained by all radar stations from Bamburgh to Benacre, but difficulties were experienced at first in identifying the aircraft as hostile. Many of the raiders crossed the Lincolnshire coast with the main stream of British bombers returning from a raid on Norway.

[1] Air Warfare Analysis Section Report BC/G/12, June 1944.
[2] Air Warfare Analysis Section Report BC/36. [3] No. 73 Wing, O.R.B., March 1945.

When many bombers were returning at approximately the same time on the same course, the cathode ray tubes of the stations were filled with a large number of responses, often overlapping and crossing one another, and it was not easy to pick out and follow separate tracks. On the C.H. stations, the Mark III I.F.F. trace was superimposed on the face of the tube, parallel to and slightly above the normal time-base. Echoes from aircraft were deflected downwards, whilst those from the I.F.F. equipment went in the opposite direction. When only one aircraft was within the radar coverage it was simple to keep track of it, as the echo from the aircraft and the I.F.F. blip appeared at the same range and moved along the face of the tube at the same rate, the only distinction being that the aircraft response remained constant, whilst the I.F.F. blip appeared for a very short space of time, recurring at intervals of approximately 2½ seconds. When scores of aircraft reponses appeared on the tube, however, as often happened when friendly bombers were returning from a raid, the majority accompanied by I.F.F. blips, then the clutter on the tube made it very difficult for the operator to associate each aircraft with its I.F.F. response. Too great concentration could not be given to individual responses by the radar operators owing to the necessity of keeping track continuity by plotting regularly on each echo in turn. It sometimes happened, therefore, that an operator could not immediately state whether an aircraft was showing I.F.F. or not, and consequently there might be considerable delay before Filter Room definitely identified a track as hostile. Occasionally, too, I.F.F. might have been wrongly reported as associated with a certain track, which might later have proved to be hostile. In conditions of great activity, the problem of identification was therefore a difficult one from the point of view of both the radar station and the Filter Room.

Use of "Window" by the Enemy

The heavy raids on London on the night 21/22 January were accompanied by heavy "Window" infection. The first raid occurred between 2040 and 2233 hours, when ninety-four long-range bombers and six fighter-bomber aircraft came overland, approximately twenty of which penetrated the Greater London area.[1] The average height of the raiders was 15,000 feet but actual heights varied between 4,000 and 32,000 feet. Ten raiders were destroyed. The second phase of the attack took place between 0415 and 0555 hours; one hundred and four bomber and six fighter-bomber aircraft participated, flying at similar heights to the previous raid, and six of the raiders were destroyed. "Window" was dropped on both occasions, and proved a great hindrance to the reporting stations of the radar chain, confusing the picture of the activity presented on the cathode ray tube face and rendering difficult the accurate estimation of numbers. During the earlier raid only the C.H.L. stations appeared to be affected, and consequently Filter Room information was provided chiefly by the C.H. stations. Most of the C.H.L. stations within plotting range of the raiders were affected in varying degrees, and in some the cathode ray tube was at times saturated, plotting becoming extremely difficult and sometimes even impossible. The C.H. stations, however, were affected during the second phase and their efficiency was reduced. One or two Type 11 stations were affected, but centimetre equipment was not, and where an enemy aircraft was flying low enough to come within centimetre coverage, plotting was accurate and very useful.

[1] Air Warfare Analysis Section Report BC/35 and Signals Wing's O.R.B.s.

" Window " continued to accompany practically every enemy raid directed against this country from January to June 1944, and was particularly heavy in the violent attacks on London between January and March. Though the C.H. stations were affected, they were, on the whole, able to plot satisfactorily and with increasing accuracy as the operators became used to the manifestations of " Window." Trained and experienced operators could usually manage well during heavy infection, and as time went on their estimation of numbers—one of the chief functions of such stations and the one most easily confused by " Window "—regained its accuracy. One minor advantage of " Window " was that at least it helped to identify enemy activity. The C.H.L. stations on the south and south-east coasts were, however, much hampered by this counter-measure, and in many cases were almost completely saturated during raids and consequently were unable to plot.[1]

Enemy Jamming of Radar Stations 1944–1945

" Window " was not the only difficulty with which the radar stations had to contend during the enemy bombing attacks in the Spring and early Summer of 1944. The enemy again resorted to jamming, both from ground stations and from aircraft, and directed his efforts against both C.H. and C.H.L./G.C.I. frequencies. On the night of 21/22 January, Dunkirk, Swingate, Dymchurch and Pevensey C.H. stations reported interference, as did the C.H.L. stations at Fairlight, Truleigh Hill and Swingate.[2] The two latter were at times unable to plot through the jamming, but on the whole, stations were able to deal effectively with it. On this occasion the enemy employed F.M.C.W. (Frequency Modulated Continuous Wave).

Jamming from ground stations continued to accompany the enemy's big raids on London during February and March, and to some extent persisted till the end of the night offensive in June. F.M.C.W. was the method generally employed, against both C.H. and C.H.L. frequencies; the C.H.L. stations in addition were much troubled with " railings " which at times rendered the stations almost non-operational.[3]

Most of the radar stations affected by ground jamming were those in the south-east of England, but later, stations in the south-west were jammed, both from the ground and from the air, when the enemy directed his attention away from London towards targets in Devon and Cornwall. The stations on the east and north-east coasts were heavily jammed on a few occasions in June 1944, radar station operations being seriously affected at times when the enemy made intruder attacks on Royal Air Force airfields on the east coast.

Airborne Jamming

A new device was employed by the enemy against this country for the first time on 15 May 1944, during a raid on the south-west of England. This raid took place between 0120 and 0315 hours, and nineteen stations—C.H.L. and G.C.I.—reported jamming at changing bearings, indicating that the jammers were airborne. Beer Head and Worth Matravers were unable to operate most of the time and several other stations reported that they were seriously affected.

[1] No. 75 Wing, O.R.B., February 1944.
[2] No. 60 Group and No. 75 Wing, O.R.B., January 1944.
[3] " Railings " jamming is described in Chapter 14.
[4] Air Ministry File C.S. 20273, " Jamming Analysis on the Home Chain."

The remainder were able to operate almost normally, though the jamming would occasionally become intensified. Coincident with the airborne jamming, the enemy jamming stations around Cap Gris Nez and Boulogne were switched on, beginning ten minutes after the first sign of airborne jamming and continuing during most of the raid. " Window " was also used by the enemy during this raid. Stations from the east coast round to those in the south-west had been warned in February 1944 that airborne jamming in the near future was a probability. They were therefore able to recognise it immediately it presented itself, and were enabled to take all appropriate steps. At least twenty-five transmitters appeared to be operating simultaneously and the frequency band 134·5 to 237·2 megacycles per second was almost completely jammed.[1] One enemy aircraft shot down during the raid by a night fighter aircraft controlled by Hope Cove G.C.I. was found to be equipped with jamming apparatus.

Airborne jamming was experienced the following night, 15/16 May, and was caused in part by an aircraft which made landfall west of Portland, flying west along the coast.[2] The interference took the form of " railings " and modulated continuous wave, and was comparable with land-based jamming when aimed directly at a radar station. The limits of frequency sweep were between about 15 and 25 megacycles per second and the interference blotted out the lower end of the I.F.F. band. The radar stations, when they were beamed in its direction, were reduced in efficiency by about 70 per cent. The number of jammers and their effectiveness was much less than on the first raid. Seven stations reported interference, but none suffered any marked restriction of operational efficiency.[3] Some suspected airborne jamming of C.H.L. stations was also experienced on the east and north-east coasts in June 1944, when intruder attacks were made by the enemy on airfields in Norfolk and Suffolk. After this month the radar stations were free from trouble, the enemy having diverted his attention to the launching of his new V-weapons, the " flying bomb " and the rocket.

No new methods of countering jamming were introduced on the Home Chain during this period. A report made by the Anti-Jamming Panel of the Radar Board in March 1944 stated that it had been appreciated for some time that little reliance could be placed on anti-jamming devices, particularly when noise jamming on a large scale was encountered.[4] In accordance with this, therefore, frequency spreading within the existing wavebands had been adopted. Equipments operating on alternative wavelengths with variable frequency properties were in operation and being further introduced into the Service. The C.H. Chain operated on spot frequencies spread between 22·7 and 29·7 megacycles per second and had a certain number of " Buried Reserve " equipments at the more important south and east coast stations, which operated on spot frequencies in the 40–50 megacycles per second band. When jamming on the main equipments rendered radar observation almost impossible, it was often found that good results could be obtained by using the reserve equipment. C.H.L. stations at that time were operated on frequencies of either 193 or 200 megacycles per second, and although further frequency spreading was possible technically, it had not been attempted owing to the difficulties of mutual interference with the many other forms of search radar used by the Allies at that time.

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[1] No. 60 Group, O.R.B., February 1944. [2] Air Ministry File C.S. 20273, Encl. 20A.
[3] *Ibid.*, Encl. 22A. [4] Air Ministry File C.30392, Encl. 86A.

Enemy Action against Home Chain Radar Stations, 1944

The Home Chain radar stations themselves received attention from the enemy during 1944. Swingate (C.H. and C.H.L.) was shelled across the Strait of Dover by the big batteries near Calais. The shells which hit the radar station were probably aimed at the British long-range gun battery nearby and not directly at Swingate, but the proximity of the two sites meant that the radar unit was well within the danger zone. In spite of the constant threat of danger the work of the station proceeded normally. The first direct attack on the station took place at 2255 hours on 29 January 1944, following a shell warning at 2145 hours. Twenty airwomen were in a shelter when the shell exploded nearby and unfortunately two of their number were so badly injured that they died in hospital. Nine others were injured.[1] The next shelling attack was on 23 February, when one airwoman was injured. The C.H.L. compound was hit and an operations building belonging to No. 11 Group was demolished. Damage otherwise was slight and operations were not affected. St. Margaret's C.H.E.L. station was hit by a shell during the same bombardment and was off the air for 33 minutes, but no serious damage was done. The radar station at Swingate was again shelled on 20 March and also on the 21st, and again in September—on the 1st, 3rd and 5th. Fortunately no further casualties were sustained, and the damage was not heavy.

Easington C.H.L. station was attacked on 20 April by a hostile aircraft which flew in low with a number of other raiders operating in the Humber area; incendiaries and a few high explosive bombs were dropped in the neighbourhood, but damage was not severe. Bawdsey (C.H., C.H.L. and C.H.E.L.) sustained mild blast from a raider on 22 June. Minor damage was done to Headquarters of No. 75 Wing at Keston by several near-miss flying bombs in June, and on 24 July another flying bomb slightly injured four persons and caused considerable damage to billets. Wing Headquarters were then moved to new premises at Broadstairs. Dymchurch C.H. station sustained slight damage from a flying bomb on 20 August, and Winterton was slightly damaged by another in September. Several other stations, especially those in "flying bomb alley," had narrow escapes when missiles fell in their vicinity, but the Home Chain was fortunate to escape severe damage, and the enemy did not succeed in putting any of the stations out of action for any appreciable time.

Friendly Aircraft Activity Plotted by the Home Chain, 1944–1945

By far the greater part of the Home Chain's activity in 1944–1945 lay in the tracking of friendly aircraft. The more spectacular work of the Chain lay, perhaps, from the east coast of England around to the south-west coast, where hostile aircraft, flying bombs, rockets, Allied bomber and fighter sweeps were all plotted on the radar screens. None the less exacting, however, was the work done by stations all around the coast, which plotted carefully and faithfully on trainer, transatlantic and Coastal Command aircraft, as well as on the aircraft guarding convoys and coastal shipping. Friendly activity was on a constantly increasing scale in all areas in 1944, preparing for the climax on 6 June—the long-awaited D-day.

The heavy, round-the-clock bombing raids carried out by the United States Army Air Forces and by Bomber Command kept the radar stations constantly busy. Fighter Command, too, maintained an intensive series of

[1] Headquarters, No. 60 Group, and Signals Wings O.R.B.s.

daylight sweeps over the Channel and East Coast, "softening-up" for D-day, by bombing and machine-gunning enemy road and rail communications, troop concentrations, the launching sites and storage depots of V-weapons. The cathode-ray tubes of some of the radar stations around the south-east corner of England were rarely free from concentrations of echoes, and only when the weather was bad was some respite obtained by the operational crews.[1] Bomber aircraft went out over the coast in waves, both by day and by night. All types of radar station on the east coast frequently saw raids of one thousand or even two thousand plus aircraft. The cathode ray tubes were saturated with echoes, the responses from returning bombers often mingling with those from aircraft still on the outward journey. The south-eastern stations were more concerned with fighter offensive sweeps and with bombers on their way home, and numbers again were high—for instance, Swingate C.H. station reported two thousand plus fighters flying to northern France on 21 January 1944, and St. Lawrence I.C.H. station reported that on 24 July, between 1200 and 1300 hours, more than two thousand aircraft were plotted outwards, fading beyond Caen.

It will be appreciated that skill of a high order was required from radar operators during periods of maximum activity, in order that all tracks might, as far as possible, be plotted and Filter Room given a comprehensive picture of the activity. This was particularly the case when formations were incoming and outgoing at the same time, and great concentration was required in order to keep continuity of tracking. During such activity the closest co-operation was required between all members of the watch in the radar Operations block, and between the staff at Filter Room.

The vast numbers of aircraft operating during 1944 made it of vital importance that stations should keep watch for "stragglers" and damaged aircraft, and the plotting of aircraft in distress was always the first duty of the crews. Radar stations were in many cases directly responsible for reporting, either by seeing "broad" I.F.F. (which meant S O S), or by noticing peculiarities in the track, that aircraft were in trouble. Such reports set the rescue organisation in motion, often thereby resulting in saving the lives of aircrews. Co-operation with the Air-Sea Rescue authorities was very close, and the results were frequently gratifying.

Air-Sea Rescue and Plotting of "S O S" Tracks

An example of the way in which Air-Sea Rescues were aided by radar is shown by the events of 16 March 1944. The G.C.I. set, controlled by Beachy Head and aided by information from the Type 51 (high-power 10-centimetre surface-watching set) on the same station, gave information and directions which enabled a Walrus aircraft at 1430 hours to rescue a fighter pilot in a dinghy inside the Somme estuary, half a mile from the French shore.[2] The Walrus aircraft was shelled, but took off safely with the pilot, who was alive and unhurt. The same afternoon another section of Walrus aircraft was directed to an area where reconnaissance aircraft had reported seeing "a number of 'bodies' in the drink." Ten men were seen in the sea. Two Walrus aircraft directed from Beachy Head picked up some of the survivors but could not take all as they were fully loaded; a third Walrus aircraft was sent out to

[1] Headquarters, No. 60 Group, and Signals Wings O.R.B.s.
[2] No. 75 Wing O.R.B., March 1944.

pick up the remainder and all got safely back to land. Later in the day a further five American airmen were similarly rescued from the sea and brought safely home.

The careful plotting of S O S tracks brought its own reward to the operators when the aircraft were able to land safely. Here are some comments by Operational Research Section at No. 12 Group, Watnall.[1] " *16 January 1944*—Stoke Holy Cross C.H. station excelled themselves in the plotting of six S O S tracks. *23 January*.—An S O S track was tracked excellently by Hopton. Bomber 272 was coming in on one engine. It ditched over Lowestoft and the crew were picked up about one mile from last pinpoint." " *2 May*.—Once again radar plays its part in the rescue of the crews of aircraft in distress. Happisburgh (C.H.L.) brought a damaged Fortress through an outgoing massed raid. The aircraft made a forced landing and the crew were quite safe."

Fighter Director Stations

Although Home Chain stations reported to Filter Rooms all movements of Allied aircraft flying within their coverage, they were not the only radar installations tracking friendly aircraft. The year 1943 had seen the growth of special G.C.I. stations whose functions were to control Allied aircraft taking part in offensive sweeps against the enemy. Previously, all movements of friendly aircraft, apart from single interceptions of enemy aircraft flying over the United Kingdom, had been directed from Operations Rooms, but now this function devolved in part on the special radar stations. The first Fighter Direction Station—A.M.E.S. Type 16—became operational on 31 December 1942, and was so successful that by the summer of 1943 each Fighter Sector in No. 11 Group had its own Fighter Direction Station controlling offensive movements of Allied fighter aircraft.[2]

A.M.E.S., Type 21, Mark I

In this connection a new equipment, which had been developed during 1943, came into operational use early in 1944 on certain of the more important G.C.I. stations, and was used both for Fighter Direction and for interception of hostile aircraft flying over the United Kingdom. This equipment was known as A.M.E.S., Type 21, Mark I, and employed a centimetre wavelength, designed primarily for the detection of low-flying aircraft. Centimetre wavelengths were now used by the G.C.I. stations for the first time although they had been increasingly in use by certain Home Chain stations for the detection of low-flying aircraft and shipping for some time past. Details of the equipment and sites at which it was installed are appended to this volume.[3] The Type 21 programme was given very high priority, the first equipment being installed in January 1944. An additional reason for rushing the programme through was that centimetre equipment was unaffected by " window," which was widely used by the enemy during his renewed attacks on the United Kingdom in the first six months of 1944.

[1] A.H.B./IIE/197, " No. 73 Wing in Action."

[2] A.M.E.S. Type 16 controlled the following operations :—

" Rhubarbs "—Fighter attacks on enemy installations.
" Roadsteads "—Destruction of enemy shipping.
" Rodeos "—Free-lance fighter sweeps to destroy airborne enemy aircraft.
" Ramrods "—Fighter defence of bomber formation.
" Circuses "—Combined " Ramrod " and " Rodeo " operations.

[3] *See* Appendix 51, " A.M.E.S. Type 21." Full details of Type 21 work in connection with Fighter Control are given in Volume V of this narrative.

The Type 21 stations, as they were G.C.I. installations, were directly controlled by Air Defence of Great Britain and did not form part of the Home Chain early warning system. However, because of the new technique required by centimetre equipment, and of the fact that it had been in use for some time with very satisfactory results on C.H.E.L. stations, it was decided that selected W.A.A.F. officer supervisors from Home Chain stations equipped with such apparatus should work directly with A.D.G.B. in supervising operations on the new equipment. At first only a few were attached experimentally to the G.C.I. stations, but in May 1944, Headquarters, A.D.G.B. reported to No. 60 Group that the experiment had been an unqualified success.[1] In consequence, further supervisors were withdrawn from the Home Chain and transferred to all G.C.I. stations using Type 21 equipment. Certain selected radar operators were also posted to these stations, to give members of the normal G.C.I. crews the benefit of their experience.

Use of Searchlights as Homing Beacons by the Radar Stations

A very valuable factor for aiding friendly aircraft in distress was the installation on many radar stations of searchlights for use as visual beacons. The first stations to be so equipped were fitted in August 1943, and during the next few months the installation programme went rapidly ahead; by mid-winter 1943/1944 most of the northern stations were equipped. The great majority of stations with searchlights were those on the northern coasts of Great Britain and Northern Ireland, and in particular on islands, such as the Hebrides and Shetlands, and on the north-east and north-west Scottish coasts. Not every Home Chain station in these areas was equipped, but searchlights were installed at all stations right on the coast in lonely or exposed spots.[2] On these northern sites the risk of attack by hostile aircraft was relatively slight but heavy traffic was experienced from friendly aircraft, expecially those of Coastal Command, on Transatlantic flights, or bombers flying over enemy positions in Norway, or to and from Iceland.

The searchlights were sited on high ground near the operational and technical buildings, and were manned when necessity arose, by members of the operational crews. The area round the searchlight was marked out with compass points, with a painted line in the direction of the nearest airfield, so that when the light was exposed it pointed directly towards the airfield. Orders to expose the searchlight were given by Flying Control at Group Headquarters, via the appropriate Filter Room. Crews from the various Chain stations vied with one another in seeing which could most quickly get the searchlight operational. This was often done in a matter of a few minutes, even in a gale at dead of night, but operators realised that every minute wasted might mean the difference between life and death to an aircraft's crew.

Frequently, lost or crippled aircraft would be tracked towards the coast on the cathode ray tube, and then guided overland to safety by the same radar crew which had been reporting its progress for many miles. Searchlights were a great help to aircrews and were often the only means of guiding back to safety a hopelessly lost aircraft. During the winter months, in particular, when aircraft were in navigational difficulties owing to the heavy gales which swept around the northern coasts, the searchlights proved their value, and gave further proof of the way in which the radar chain was able to be of service to Allied aircraft.

[1] Headquarters, No. 60 Group O.R.B., May 1944. [2] No. 70 Wing, O.R.B., 1943/44.

The example which follows is typical of many entries made in their records by stations using searchlights. Lisnaskea (N. Ireland) reported in their official log that at 2310 hours on 7 February 1945, a request was received from Filter Room at Headquarters, R.A.F. in Northern Ireland, to keep a look-out for an overdue Civil aircraft. The response was picked up on the cathode ray tube at 2335 hours, and the track showed that the aircraft was probably in difficulties. The duty mechanic and one operator therefore stood by in case the order to expose the searchlight was received. At 2340 the expected order was given by Filter Room, and 45 seconds later the searchlight was ready for exposure. At 2345 hours instructions were received to expose the light on St. Angele airfield. This was done, and the Civil aircraft landed safely, with its instruments and oxygen apparatus frozen. The pilot stated that he had been completely lost and " thought he was finished till he saw the searchlights."[1]

Completion of Centimetre Installation Programme

Although the greater part of the centimetre equipment programme for the detection of very low-flying aircraft and shipping was complete, or in progress, by the end of 1943, a certain amount still remained to be done before the installation schedule could be said to be finished. Before commenting on the equipment erected during the period 1944–1945 it will be found helpful to consider changes in nomenclature which came about at the end of 1943, to keep pace with the vastly increasing number of radar equipments using centimetric wavelengths.

Nomenclature of Centimetre Air and Surface Watching Stations

The rapid development of centimetric ground radar during 1943, and the fact that the Army, Navy and Royal Air Force were all concerned in its growth and application, led to considerable confusion in nomenclature. The first centimetre equipments were devised by the Navy, and consequently had Naval type numbers—for instance, N.T. 271 or N.T. 277 for 10-centimetre sets. The original Coast Defence stations were Army, and referred to as C.D. No. 1, Marks I–IV, and these references were at first retained when the Royal Air Force took over the stations for maintenance and later operational purposes, and when the combined Triple Service stations first came into use.

Royal Air Force radar stations, on the other hand, had always been referred to by the letters A.M.E.S. (Air Ministry Experimental Station), followed by a number. For instance, the first radar stations, the C.H. (Chain Home) floodlight equipments, were A.M.E.S. No. 1, and the next development, the beam stations for detecting low-flying aircraft, or C.H.L. (Chain Home Low), were A.M.E.S. No. 2. Not only was it confusing to have three types of reference for one station and its equipment, but the rapid improvements and modifications which were constantly being made led to an increasing number of " Marks " for each reference number, even followed by other symbols. As an example, C.D. No. 1 Mark VI** (Tower) was a ten-centimetre high power set mounted on a C.H. transmitter tower cantilever, and which eventually became A.M.E.S. Type 55. Accordingly, on 7 December 1943, Air Ministry issued a revised list of type numbers, which clarified the position.[2] These type numbers were agreed by the Admiralty, with the proviso that the Navy was free to use Naval names in purely Naval correspondence. Nos. 30–39 all denoted low-power

[1] No. 70 Wing, O.R.B., February 1945.

[2] Air Ministry File C.S. 19935, Encl. 18A.

centimetre equipments, the earlier models, A.M.E.S. Nos. 40–49 were of medium power, and A.M.E.S. Nos. 50–59 were the high-powered sets. A list of these revised type numbers is appended to this volume,[1] with the centimetre stations in use at the beginning of 1944. The centimetre stations of the Home Chain at this time had five functions—air watching (A), surface watching (S), dual role and air and surface detection (D). In addition, certain equipments had air watching as a primary, and surface watching as a secondary function, and other equipments were used in the reverse role.

New Centimetre Stations opened in 1944–1945

Numerous other centimetre equipments came into use during 1944, to complete the Home Chain's installation programme.[2] The Type 55 installations at Drone Hill and Danby Beacon, work on which had been suspended late in in 1943,[3] were finally cancelled in February 1944, as after a full review of the circumstances had been undertaken, it was considered that better results and greater economy would be obtained from the high-powered A.M.E.S. Type 52 equipments which were installed at Lamberton Moor and Goldsborough.[4] The Type 55 equipment at Dunkirk became operational in February 1944, and a little later that at Great Bromley came into use. A similar installation was made at West Beckham in March 1945 ; this restored to the North Norfolk coast the cover for surface craft and low-flying aircraft which had been given formerly by the Type 54 installation at Bard Hill. The tower of this equipment had been destroyed in the early morning of 15 January 1945, when a Lancaster bomber, returning from operations, crashed into it ; all save one of the aircraft crew were killed, but no casualties were sustained by radar personnel.[5]

In many cases completely new centimetre equipments were installed ; in others, modifications were carried out, converting existing equipment to a more up-to-date type, so giving better performance. Many of the mobile units were moved from station to station, as necessitated by operational requirements, or when the installation of static equipment rendered the original mobile outfits redundant. Just as the centimetre programme appeared to be consolidated, however, the necessity for saving manpower and equipment for overseas theatres of war meant that certain installations had to be closed down—particularly in quieter areas where the risk of enemy aircraft was slight. In some cases too, the installation of high power equipment, giving consequent wider and more reliable cover, duplicated the coverage given by the medium and low power sets and in the latter case the equipments were removed or relegated to serving in a stand-by capacity.

Surface Vessel Cover

1944 was an extremely busy year for the Home Chain as far as the plotting of surface craft was concerned. The Home Chain itself had changed almost beyond recognition from the early days of the War. Originally its chief function

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[1] *See* Appendix No. 52, " Centimetre Stations of the Home Chain at 1 January 1944," and Appendix No. 50, " Nomenclature of Ground Radar Stations."

[2] *Types* 13 were installed at Appledore, Hythe and Dimlington ; *Types* 41 at Start Point, The Needles, Dunderhole Point, Ventnor, The Verne, Kingswear, Truleigh Hill, Dimlington and Bembridge ; *Types* 52 at St. Margaret's Bay, Kingswear, Fairlight, Bolt Tail, Jacka, Kete, Ventnor, Lamberton Moor and Goldsborough ; *Types* 56 at Penolver and Cresswell, replacing two Type 57 sets ; *Types* 57 at Kingswear, Penybryn, Lamberton Moor, Goldsborough and Prestatyn.

[3] This was discussed in Chapter 15.

[4] Air Ministry File C.S. 12138, Part 1, Encls. 87A, 88A.

[5] Bard Hill A.M.E. Station, O.R.B., January 1945.

had been to give warning of hostile aircraft approaching the shores of Great Britain. This function it of course retained, but more and more of its activities were devoted in 1943 and 1944 to the plotting of Allied aircraft, and as the bombing offensive against the enemy increased in intensity, so did this part of the radar chain's task. During 1943, however, a third function of the Home Chain was becoming of ever growing importance—the plotting of surface craft—and 1944 saw it reach a climax. The increasing importance of the Chain's surface-watching function was occasioned by two causes—firstly, the growing need for sea cover to counter the continual U-boat and E-boat menace threatening shipping convoys. Secondly, the developments in centimetre technique became more and more widespread and its value in detecting surface craft of all kinds, as well as very low-flying aircraft, became rapidly apparent.[1]

By the end of 1943 radar cover for surface craft had been provided round the whole coastline of Great Britain and Northern Ireland, and at the beginning of 1944 this cover consisted of eighty-nine equipments. Of these, eight had dual-purpose Air-Surface functions, thirty swept continuously for surface craft and low-flying aircraft, thirty-six equipments were for surface detection only, and fifteen were standby sets for the same purpose.[2] All big Naval bases were covered, particularly those in danger areas, such as Portsmouth, The Nore and Harwich. The early months of 1944 saw the extension of this coverage, with the use of newer and more powerful apparatus, giving greater range and clearer definition, thus greatly assisting the Naval authorities in their task of identification.

The centimetre installation parties of the Home Chain were probably the busiest of all the technicians during this period, as their work was expanding all the time, whereas the programme for the C.H. and C.H.L. stations had been completed for some time. The only major modifications in this period to the older stations were to those C.H. stations engaged in " Big Ben " watch for the long range rocket.[3] The centimetre experts worked with a will, sharing with all other branches of the radar chain the objective of reaching 100 per cent. efficiency before D-day.

Surface Vessel Activity

Unlike the aircraft-watching stations, where activity was generally confined to districts susceptible to enemy attack or over which Allied fighter and bomber aircraft flew on offensive sorties, the detection of surface craft was a constant source of activity in all parts of the country. Stations which were in a comparatively quiet area as far as aerial activity was concerned were amongst the busiest when it was a question of watching shipping. This applied particularly to channels on the west coast of England and Wales, N. Scotland and N. Ireland. Bad weather generally gave the C.H. and C.H.L. stations a brief respite, but it was in such circumstances that the surface watching stations were of great value—particularly those on the northern shores of Britain where winter gales were at their worst.

In the early part of 1944, much attention was devoted to the tracking of E-boats, particularly along the eastern coast of England. Activity of all kinds increased during May, reaching a climax in June with the maritime operations

[1] *See* Appendix No. 8, " The Development of the Magnetron Valve."
[2] Radio Board, Paper 702, 28 January 1944.
[3] *See* Chapter 27, " Radar in Raid Reporting against V-weapons. The Long Range Rocket—' Big Ben ' Operations."

associated with D-day, and thereafter activity was constant along the south and south-east coasts. E-boats continued their sorties right up to the end of the war, and constant vigil had to be maintained to give warning of their approach. An illustration of this is afforded by the events of 31 January 1944, when the Types 31 and 51 radar equipments at Beachy Head saw a complete picture of an E-boat attack, three to five miles south of the headland.[1] A convoy of some twenty ships, three sweepers, a front and rear escort of two motor launches were being plotted westwards. At 0123 hours the convoy was south of the station when three unidentified sets of shipping were observed at 43,000 yards, bearing 142° ; 49,000 yards on the same bearing ; and 49,000 yards at bearing 137°. Two vessels were seen in each group, proceeding north at 24 knots. Information was supplied by Beachy Head to the Naval Plotting Room every two minutes. The Type 31 equipment plotted the convoy and the other radar set the unidentified vessels, and, later, the movements of escorts. Useful advance warning was given to the convoy. The last E-boats were plotted to ranges of 55,000 yards after the skirmish. P.P.I. plotting came into its own during this operation, and enabled good continuity to be obtained on the fast-moving vessels.

The tasks of the surface-watching stations were many and varied. Not only was radar responsible for the safe passage of convoys against air and sea attack, but it was very valuable in guarding "stragglers" from minefields, from collisions, or from natural hazards such as bad weather, rocks, or the Goodwin sands ; it helped to fix the position of minefields sown by the enemy ; it gave evidence of raids by enemy E-boats, and it worked in very close liaison with the Air/Sea rescue authorities. On several occasions, by plotting wreckage or rubber dinghies, radar was instrumental in saving the lives of aircraft crews who had crashed into the sea.

An appreciation of the work done by surface-watching stations of the Home Chain was provided by the Naval Commander-in-Chief, The Nore, in his report for January 1944, which stated[2] " . . . it is now a *sine qua non* that the various authorities and Services involved in Naval Operations along a coast adjacent to the enemy, require the continuous assistance of Shore Radar. On 18 January Hopton detected two merchant vessels straggling from a convoy in fog, and standing into danger. Two motor gunboats from Yarmouth conned on to these vessels in order to give navigational assistance, and discovered that one was a United States ship of 7,000 tons laden with explosives, and straggling with a defective compass in mined waters. Had this happened in the Humber area during a maintenance or breakdown period of the radar station the consequences might have been disastrous." The other vessel, incidentally, was a merchantman which had lost her convoy in the fog.

Economies in the Radar Chain

By the end of 1943 the need for economies in the Home Radar Chain had become apparent.. The constant drain on resources of man-power and equipment to meet all radar commitments overseas meant that the Home Chain could not be maintained at full strength, either as regards personnel or radar installations. The need for radar personnel for overseas was still growing ; not only were they needed for ground radar, many mechanics from No. 60 Group were being transferred to airborne radar, now well into its stride. Plans being made for the

[1] Headquarters, No. 60 Group, and Beachy Head A.M.E. Station O.R.B.s.
[2] A.H.B./IIE/197, " No. 73 Wing in Action," p. 4.

Allied liberation of Europe depended too on adequate supplies of men and radar equipment being ready to follow up the forces as they landed on the Continent. Although training was proceeding as rapidly as possible and although manufacturers were doing everything they could to supply equipment, it became obvious that stringent economies would have to be effected in the home stations themselves. Fortunately, the course of hostilities was such that imminent threat to the British Isles by invading troops seemed very remote, and therefore cover could be relaxed somewhat in those areas furthest from enemy-occupied territory. Surface cover needed to be maintained in strength, but it was felt that air cover could be relaxed in a few selected instances.

Closing of the Air-Watching Stations

A review of the position was made by Fighter Command in November, 1943, in which it was stated that the Command agreed in principle that in order to effect economies in the radar chain certain stations should either be reduced in personnel or closed down when circumstances required such action.[1] The radar cover in the United Kingdom, it was stated, had been built up to provide complete cover and peak traffic handling capacity, and there was no doubt that considerable reduction could be effected, and yet sufficient radar cover be left to satisfy the requirements then existing in areas which were unlikely to be concerned with operational flying. A review was therefore made of Home Chain stations, which were placed in five categories :—

Category A. A full watch, capable of Combined Directional Plotting and full raid handling capacity with, in the case of the C.H. stations, full use of the console and tracker.

Category B. A watch capable of maximum traffic handling capacity without Combined Directional Plotting, and with no console or tracker at the C.H. stations.

Category C. A reduced watch and reduced traffic handling capacity.

Category D. Sufficient personnel to provide radar cover over part of the twenty-four hours only.

Category E. Reduction to a care and maintenance basis.

Category F. Station to be dismantled.

Stations in Category D were selected on the basis that although sufficient air warning cover was provided without resort to their coverage, they would probably be necessary during certain periods to ensure accurate tracking of transatlantic aircraft.

Fighter Command therefore recommended that certain stations,[2] none of which had a surface-watching function, should be reduced to Categories D, E and F. The Radar Board at their ninety-first meeting on 4 January 1944, agreed that four of these stations should be treated as redundant, and Air Ministry were asked to implement.[3] Of the C.H. stations, two which had

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[1] Headquarters, Fighter Command, O.R.B., November 1944, Appendix FC/S.30385/Ops.2(*b*).

[2] To be reduced to Category D : Broadbay (C.H.), Borve Castle (C.H.B.), and the C.H.L. Stations Ben Hough, Greian Head and Kilchiarin.

To be reduced to Category E : Barra Poll (C.H.B.), the C.H. Stations at Loth, Dalby, Wylfa, Scarlett, Castell/Mawr, Greystones and Kilkeel ; and the C.H.L. Stations at Navidale, Prestatyn, South Stack, Ballymartin and Roddan's Port.

To be reduced to Category F : Habost (C.H.B.) ; the C.H. Stations at Bride, Newtown Butler and Kilkenneth ; the C.H.L. Stations at Oxwich, The Law, Westburn, Point of Stoer, Rodel Park, Carsaig, Cromarty, Formby, St. Bees, Blackhead, The Needles, Kendrom.

[3] Blackhead, The Needles, Kendrom and Rodel Park.—Radar Board Paper 728, 1 March 1944.

given good service and had formed part of the original twenty-station chain closed down during this period—Dunkirk, which went on to care and maintenance on 23 March and Ottercops Moss which was closed in July. Dunkirk was later reopened on 28 October as one of the five C.H. stations engaged in tracking the long-range rocket, but did not then form part of the ordinary reporting system.

G.C.I. Stations Reporting to Filter Rooms

The pressing need for economy in equipment and manpower which manifested itself early in 1944 and the consequent closing-down of certain Home Chain C.H. stations, meant that full C.H. information would not be available in such areas. As a result, it was arranged between Headquarters, Air Defence of Great Britain, and No. 60 Group that certain G.C.I. stations would, in addition to their normal interception duties, take over a reporting role and become part of the full raid reporting system.[1] Normally, G.C.I. stations in areas remote from enemy attack had little to do, and were only fully operational during infrequent hostile raids, or for practice and trial purposes. The risk of enemy action, though lessened, was still a factor which had to be considered and so the stations could not be disbanded. By using G.C.I. stations for reporting purposes, their equipments and crews were utilised to fullest advantage and the Home Chain was assured of adequate cover in all areas.

The G.C.I. stations were entirely under the control of A.D.G.B., and their only connection with No. 60 Group was for purposes of technical installation and maintenance. The additional crews needed for a full twenty-four-hour watch system were, however, now supplied by No. 60 Group from operators and mechanics on the strength of the Home Chain. In February 1945 the authority for the reporting sections was transferred to No. 60 Group, and the reporting crews were established from No. 60 Group stations as lodger units on the G.C.I. sites.[2]

The necessary communication facilities were provided early in 1944 to enable the selected G.C.I. stations to be fully linked to their respective Filter Rooms. The first Home Chain operators to be used for G.C.I. reporting were trained by the Signals Wings of No. 60 Group in the spring of 1944 and took over reporting duties at Ballywoodan (Northern Ireland), Seaton Snook (Durham), Northstead (Northumberland) and Trewan Sands (Anglesey) in May 1944.

Ripperston (West Wales) came into the reporting chain soon afterwards, when the C.H. station at Folly went over to a care and maintenance basis. Other G.C.I. stations which gradually took over a reporting function were Ballinderry (N. Ireland), Hope Cove (Devon), Orby (Lincolnshire) and Patrington (Yorkshire). The experiment proved successful, as considerable savings in manpower and equipment were effected with little, if any, loss of operational cover and efficiency.

Reorganisation of Radar Stations in No. 60 Group

With the dual object of consolidating economies already made and making available personnel for a special Signals Wing in No. 60 Group, the existing Signals Wings were reorganised in May 1944.[3] As a result, No. 72 Wing was disbanded and its stations transferred to No. 70 Wing, which now comprised

[1] Headquarters, No. 60 Group, O.R.B.
[2] No. 73 Wing, O.R.B., February 1945.
[3] No. 60 Group File 60G/534/1/Org.—Organisation Circular 108/44, 27 April 1944.

all stations in Scotland and Northern Ireland. The stations in No. 77 Wing, which was also disbanded, were transferred to No. 73 Wing, whose new territory included the northern part of England, the Isle of Man and North Wales. No. 75 Wing boundaries ran from Suffolk to the Isle of Wight, whilst the remainder of the Home Chain—the south and south-west coasts of England and South Wales—came under the control of No. 78 Wing. No. 70 Wing (with Headquarters at Inverness) reported operationally to Royal Air Force in Northern Ireland and to No. 13 Group of Fighter Command; No. 73 Wing (Malton, Yorks, later Boston Spa) to Numbers 9 and 12 Groups; No. 75 Wing (Keston, Kent, and later Broadstairs) and No. 78 Wing (Ashburton, Devon) to Numbers 11 and 10 Fighter Groups respectively. No. 72 Wing was re-formed on 15 May 1944 with temporary Headquarters at No. 60 Group, Leighton Buzzard, and its members went with the Allied Invasion forces on to the Continent for Radar Navigational Aid work, maintaining the ground stations and equipment for "Gee" and "Oboe."

The radar stations concerned at the time of this reorganisation totalled 208. Of these, six were Naval stations operated by the Admiralty, though maintained technically by No. 60 Group, and thirty-three were G.C.I. (Ground Controlled Interception) stations, also maintained technically by No. 60 Group, but administered and operationally controlled from Sector stations of Fighter Command. A further twenty stations (comprising eight G.C.I., one C.H.B., four C.H.L. and seven C.H.) were already on a care and maintenance basis. Sixteen stations were part of the Radar Navigational Air Stations (ground stations for "Gee" and "Oboe") which were administered by No. 60 Group, and in many cases housed on the same sites as C.H. stations, but which were operated under Bomber Command and were not part of the reporting system.

The reporting chain proper thus consisted of forty-eight C.H. stations, three C.H.B. stations, six Type 12 stations[1] and the remainder were C.H.L. and C.H.E.L. stations. The majority of the C.H.L. stations had centimetre equipments associated with them, and it will be remembered that one station might comprise three or even four types of equipment. The ordinary C.H.L., 200 megacycles per second frequency (1½ metre wavelength) stations worked in conjunction with 3,000 megacycles per second frequency (10-centimetre) sets for the detection of very low-flying aircraft and shipping. The latter equipments were both mobile and static, though the higher-powered permanent installations were replacing the earlier mobile sets as rapidly as possible, particularly on the east and south-east coasts.

Economies effected as a result of Re-organisation

This re-organisation resulted in considerable economies both in personnel and equipment. The Home Chain could not, however, be left static even after the re-orientation of the Wings, and the whole question of radar cover was kept constantly under review. Air Ministry stated on 3 June 1944, that considerable economies had already been effected in personnel in the air reporting chain by closing down twenty-four radar stations, the personnel released having, in the main, provided crews for manning the mobile radar sets needed for operation "Overlord."[2] The statement continued that in view of the commitments which would arise at a later stage of Continental operations, to provide air

[1] Mobile stations adapted for floodlit technique, kept in reserve in case the C.H. stations were rendered useless by enemy jamming. Maintained on a "Care and Maintenance" basis, crews to be provided when necessary from neighbouring C.H.L. stations. *See* Chapter 16 of this volume.

[2] Air Ministry File C.S. 13501, Encl. 46A.

and surface cover, further stations would have to be established and a programme was projected for a total of fifty sets, for which radar personnel numbering 900 would be required. The shortage of personnel was such that new stations could only be set up at the expense of closing down existing stations, and manning would therefore have to be undertaken from the home radar chain. It was therefore essential that economies in the United Kingdom reporting facilities be put into effect at the earliest possible opportunity, particularly in areas where the risk of air attack had been greatly reduced.

Preparations made for Radar Cover by the Home Chain in Operation "Neptune"

Plans and preparations for the landings and the associated maritime efforts —Operation "Neptune"—had been made for many months past and all Home Commands of the Royal Air Force had their specific part to play, either in the preparations for the event, or in the operation itself. Amongst the responsibilities of Air Defence of Great Britain towards the Allied Expeditionary Air Forces was that of providing radar cover from the United Kingdom for the aircraft and shipping involved in Operation "Neptune" until the mobile Fighter Director Posts and Fighter Director Ships became operational on the other side of the Channel.

Responsibility for seeing that radar was able to play the part allotted to it devolved largely upon No. 60 Group and its constituent formations. The date of the assault was not, of course, made known in advance to the radar stations, though they realised the attempt would be made in the summer of 1944. Every effort was therefore made to have the Home Chain at concert pitch well beforehand and stations were, in fact, absolutely ready early in May 1944.

Although all stations reached a high standard of efficiency, it was on the stations in No. 75 Wing (High Street to Ventnor) and 78 Wing (S.W. England and S. Wales) that the main task of preparation fell, and in particular all those individual stations from south of the Thames Estuary around to Devon and Cornwall. Not only had the stations to be ready to plot efficiently the anticipated heavy traffic and to be safeguarded against coming off the air, but they had to be prepared for the possibility of heavy reprisals from the enemy. This was a contingency which, fortunately, never arose.

Preparations made included the collection of adequate reserves of such stores as technical spares, fuels, ammunition, reserve rations, medical supplies, clothing, cleaning material, and anti-gas and anti-fire equipment. In some cases extra stocks were maintained at all stations, in others at selected stations only, where they could be easily re-issued to neighbouring units should the need arise.[1] No. 75 Wing was divided into nine areas, and kits of spare parts were held at a control point in each area. Not only were major and minor spares held, but even reserve mobile C.H.L./G.C.I. and centimetre equipments, and mobile power supplies. In order to decentralise control in the event of sudden emergency, the Wing was also divided into four zones with a continuity officer in each. The latter was responsible for reporting fully on any and every aspect of the position in his zone at any given moment to the Chief Continuity Officer at Wing Headquarters. Here an up-to-the-minute picture of the technical and operational situation was always available. Adequate defence precautions were taken at all stations in both Wings, and guards were reinforced to meet any possibility of enemy attack.

[1] Nos. 75 and 78 Wings, O.R.B.s, May/June 1944.

Technical and Operational Preparations

Commanding officers, technical and supervisory officers, were all fully briefed from the technical and operational point of view, and they in turn passed on all relevant instructions and information to their crews. Finally, just before the great day dawned, Wing technical personnel were dispersed to all the stations where activity was likely to be greatest, so that they would be at hand should any unforeseen event arise. The operational crews were maintained at full strength, partly at the expense of stations in the quieter areas which found themselves very short of trained and experienced personnel. The operators had been getting plenty of experience with the increased activity on the south coast which was a necessary prelude to D-day, both as regards the plotting of surface craft, and of the many bomber and fighter sweeps which were so common a feature in the early summer of 1944. W.A.A.F. radar operators dealing with centimetre equipment for surface watching had been attached to their nearest Naval Plotting Rooms for a few days' experience, and had been there whilst several large-scale exercises were plotted. The experience gained proved very useful during the heavy activity of D-day and led to increased co-operation with the Naval and Royal Air Force authorities.

The Home Chain and D-Day Activity

The initial phase of Allied operations in north-west Europe provided the south coast radar stations of the Home Chain with probably the busiest period of concentrated activity in their history. The activity was so intense that all types of station—those providing cover for high-flying and low-flying aircraft, and for shipping—were able to see part at least of the liberation forces, and their combined information resulted in a very clear picture being presented to Filter Room and the Naval Plotting Room. The activity was not confined to D-day alone, although it reached its peak on the night of 5/6 June, the few days preceding and immediately following it were almost as important from an operational point of view.

The Operations Log for No. 78 Wing recorded that the month of June was operationally the busiest on record in the Wing, traffic in both surface craft and aircraft having been exceptionally heavy. Prior to the commencement of the Allied landings in Normandy, and subsequently, heavy mass raids had been competently handled by the southern stations which had plotted almost continuously all raids proceeding to and from the Cherbourg peninsula, the activity only decreasing in density or ceasing during periods of inclement weather.[1] The same story was told by the stations in No. 75 Wing, which reported that although many sorties were plotted by them, which distracted enemy attention from the main crossing, there was little aircraft cover for the landing itself.

Many stations recorded that their cathode ray tubes were often saturated from the ground ray outwards, and others reported that the clutter on the tube was so concentrated that area raids outgoing and incoming appeared to replace each other without there being noticeable changes in numbers, or in the four corners of the areas being plotted. The aerial activity plotted was of all kinds—fighter and coastal screens and "umbrellas," bombers, gliders, fighters patrolling over shipping concentrations, aircraft circling over the landing beaches, as well as bomber formations over Northern France attacking V-weapon sites, storage depots and other military targets.

[1] Nos. 75 and 78 Wings, O.R.B., June 1944.

Maritime Operations on D-day

The surface-watching stations of the Home Chain were also abnormally busy with the vast shipping traffic associated with the Allies' crossing of the Channel. Dunderhole Point, to give one example, reporting constant activity for the five days preceding the assault, over one thousand one hundred and thirteen vessels passing through their area in that time, reaching a climax on 4 June when six hundred vessels were plotted proceeding south. A typical report from a south coast centimetre station stated that considerable assistance was rendered to the Naval Operations Room by radar information in the period leading up to the invasion, during it, and afterwards. Checks were kept on all convoys coming in from the west, many hundreds of ships being plotted along the convoy routes and to the assembly area south of the Isle of Wight and St. Alban's Head. Destroyer patrols were also constantly plotted, and a close watch kept for evidence of E-boat activity.

Ventnor's Operations Log makes interesting reading, as the Isle of Wight was right in the middle of the assembly area at the start of the assault. It reads : " The commanding position of Ventnor in the invasion of the continent by the Allied Forces is reflected in the intensity of the operational activity by all types of equipment during the month. In an operation of such magnitude, it is only possible to give a general picture, since enemy reaction was negligible, being limited to minor surface vessel operations and isolated sorties over the battle area. Up to the night of 5 June the softening process on the French coast was intensified, whilst the Type 53, C.H.L. and Type 41 at Bembridge saw a great deal of shipping, congregating in and around Portsmouth and Southampton approaches. The air umbrella raised on 5/6 June took both C.H. and C.H.L. almost to saturation—the latter resorting to area plotting with up to five hundred aircraft as a rule. Throughout the evening the concentration of shipping from Spithead and The Solent steadily increased until the Type 53 was area-plotting 1,600 plus in a vast diamond formation, with extremities in Spithead and Seine Bay. Throughout 6 June this number increased to over two thousand with the strength of the air umbrella sustained. Thereafter, till the end of the month, the maritime 'shuttle' service, and its air cover was maintained at high density with only slight weather interruptions."

Co-operation with Filter Rooms and Naval Plotting Rooms

In spite of the intense activity, the radar stations were able to give Filter Room a very comprehensive picture of the aerial and seaborne operations and the officer in charge of No. 11 Group Filter Room wrote the next day that throughout the night the radar stations performed exceptionally well.[1] It was possible for individual tracks to be plotted, but macroscopic methods proved effective and area raids were constantly plotted. Here Combined Directional Plotting proved of great assistance, as the C.H. and C.H.L. stations, with their associated C.H.E.L. equipment, were able to sort out much of the information before it reached Filter Room and the plots and ancillary information which were told required little further filtering.

A disappointment to many of the stations at long range from the centre of operations which were yet able to see a good deal of the activity, was that they were not allowed to pass plots on the responses on their tubes. The reason, of course, was that sufficient information of greater accuracy was provided by

[1] Headquarters, No. 60 Group O.R.B., June 1944.

the radar stations at closer range. Restricted plotting was also adopted by Filter Room, whereby stations only plotted in a certain area, thus eliminating duplication of information and unnecessary clutter on the telephone lines and Filter Room table.

A very satisfactory feature of the operations at this period was that, with the exception of a solitary airborne incident in the far west, the night passed with no jamming by the enemy of our radar installations. This was concrete proof of the success of the active countermeasures undertaken in the previous weeks by aircraft of Bomber and Fighter Commands in their raids on German jamming installations along enemy-occupied coasts. The result, during the operations in June, was that practically a perfect picture of the activity was presented at all times on the Operations Tables and Maps of the various Services—a fact which must have simplified considerably the task of those senior officers responsible for co-ordinating the whole operation. It is very pleasing to note, from records made at the time, that nearly all radar stations referred to the excellent co-operation shown between their personnel, and the staffs at Filter Room, and the Naval Plotting Rooms. The team spirit which was shown on this occasion did much to render the difficult tasks of both the radar crews and the plotting crews less arduous.

Tributes to Radar Plotting of D-day Activity

Tribute was paid to the work of the Home Chain on 7 June 1944 by the Director-General of Signals at Air Ministry, who stated in a letter to the Air Officer Commanding No. 60 Group : " I would like to let you know how much the very good work that 60 Group had done in the last few months has contributed to the initial success in the cross-channel operations." He concluded by stating " We have many headaches still ahead of us . . . but I am sure it must be gratifying to you and all the personnel in the Group to know that the hard work they have put in in the last few months had already paid such a high dividend."[1]

The monthly technical letter of No. 60 Group for June 1944 states that " the admirable serviceability record of all 60 Group stations immediately before and during the crucial days following the 6 June is the best possible evidence of the successful maintenance efforts of Wing quarterly overhaul parties and station technical officers and radar mechanics. Additionally, the last moment ' crash ' Mark III installation programme on Nos. 75 and 78 Wing C.H., G.C.I., and C.D. stations, and the speed with which No. 75 Wing succeeded in installing Bembridge, Type 41, and Ventnor, Type 52, stations in time for D-day had not passed unnoticed. Lastly, it is appreciated by the Allied Expeditionary Air Force that the very hard work carried out by the No. 60 Group detachment at Chigwell is contributing largely to the successful results being achieved by the No. 85 Group, Type 25, G.C.I. stations now operating in Normandy. These convoys, which were actually landed in France during the first few hours of the operation, were accompanied by a small No. 60 Group commissioning party and, despite a considerable enemy opposition entailing casualties to both personnel and equipment, they were operational and carrying out interceptions in a remarkable short space of time."

[1] No. 60 Group File 60G/S.700/Rad.—No. 60 Group Monthly Technical letter dated 1 July 1944.

The Home Chain and Operation "Apostle"

Radar had a further overseas commitment early in 1945, when No. 60 Group provided and trained officers and crews taken from the Home Chain for the radar element of Operation "Apostle 1." The object of the latter was the occupation of Norway by an Allied force consisting of Naval, Army and Air Force contingents. The specific objects of the Royal Air Force component were :—[1]

(a) to establish airfields and support local or military operations when necessary ;

(b) to assist in the disarmament of German armed forces in Norway ; and

(c) to assist in the provision of communications.

Royal Air Force responsibility was vested in No. 88 Group, but No. 60 Group were ordered on 1 April 1945 to provide the radar element of the Signals Section.[2] Their responsibility entailed the provision of a radar technical officer and staff for Headquarters, a field servicing unit, and the formation of the following units, all of which were later transferred to No. 88 Group :—[3]

Unit No. 14072, a Type 14 mobile unit set up six miles north of Stavanger Sola airfield.

Unit No. 6478, an A.M.E.S., Type 6, Mark III, light warning set designed to be installed on the Island of Flekkero, for the provision of early warning for Kirstianland airfield.

Radar Unit No. 6477, a similar unit to the foregoing, for covering Oslo airfield.

These three radar units were formed and assembled at Cardington by 18 April 1945 and then passed out of No. 60 Group jurisdiction. In addition, No. 60 Group provided Radar Unit No. 15063, a Type 15 mobile G.C.I. equipment set up as one entity with No. 14072 Unit, for reporting movements of low-flying aircraft and surface vessels to Flying Control at Stavanger Sola airfield and Naval Operations Rooms if required. A further Type 15 equipment was also provided—Radar Unit No. 15064—to give control facilities and air warning for the protection of the Stavanger area. The success of the Allied campaign in north-west Europe led to the capitulation of the enemy forces at the beginning of May 1945 ; this included his occupying forces in Norway and Denmark. Consequently some of the "Apostle" force went to Norway to take over from the Germans. Although the radar equipment was included, it was not required for operational purposes before the end of hostilities.

Attempts by the Enemy to Plot on Home Chain C.H. Station Responses—"Heidelberg"

An Intelligence report issued in November 1944 revealed that the enemy had made attempts to use the radiations from Home Chain C.H. stations to plot Allied aircraft when the "Mandrel Screen"[4] rendered their own radar sets

[1] A.H.B./IIE/165, No. 88 Group Headquarters Signals Instruction for Operation "Apostle."

[2] Headquarters, No. 60 Group, O.R.B., April 1944.

[3] A.H.B./IIE/165, No. 88 Group Headquarters Signals Instruction for Operation "Apostle," paras. 133 and 140.

[4] "Mandrel" was an airborne jamming device carried in certain Allied aircraft, which had a very confusing effect on German ground radar equipment. A "Mandrel Screen" was usually put up to mask a heavy offensive bomber raid by the Allies, and was also used on other nights when no bombing was planned, as a "spoof" for the enemy. When the "Mandrel Screen" was operating, it was difficult for German radar sets within range to get a true bearing on raiding aircraft, or to assess numbers.

inoperative. Information available showed that the German device—to which the name " Heidelberg " was given by the Allies—had a receiving apparatus, but no transmitter. Plots were obtained by locking on to the ground ray of a C.H. station in the United Kingdom, allowing the British station to provide the transmission and then observing the echoes from aircraft.[1] Maximum range was stated by a prisoner-of-war to be about 450 kilometres, and range accuracy about $\pm$ 10 kilometres.

The reading on an enemy range tube gave the difference between (*a*) the distance of the C.H. station from the German Wassermann radar equipment, and (*b*) the length of the path—C.H. station to aircraft to Wassermann. Since (*a*) was fixed and known, this determined (*b*) and the aircraft consequently lay on an ellipse whose foci were the two radar stations. The position of the aircraft on the ellipse was obtained by taking a bearing. The potential value to the enemy was considerable. For the past few months the Germans had had difficulty in deploying their night fighters due to lack of early warning—the result of the " Mandrel Screen " employed by the Allies, and the radio silence which was maintained by their bomber forces.

Technical Investigation on the Continent

The Telecommunications Research Establishment was asked to investigate technical methods of modifying equipment at the C.H. stations so that the enemy would not be able to pick up their transmissions. Preliminary investigations were made, but it was decided that further research was first of all necessary, to decide how much of the English transmissions could actually be picked up by the enemy. Accordingly, two scientific officers (the Home Chain Pulse Analysis party) were despatched to the Continent in January 1945 for this purpose.[2] It had already been reported from the Type 7000 station at Axel that ground rays from English C.H stations had been picked up, using a half-wave dipole aerial mounted on a 75-foot tower and a standard " Gee " receiver. This finding was confirmed by the T.R.E. party in a report from Knocke in Belgium dated 6 February 1945.[3] They stated that their investigations had shown it was possible to receive saturation signals from English C.H. stations, by locking to the triggered time-base, and it was also possible to name echoes and to measure path differences with the lock. This applied to either jittering or steady pulses.

A meeting held at Air Ministry on 2 March 1945, after discussing countermeasures, decided that ground jamming in the United Kingdom was out of the question, as ten times the transmission power available would be required, ground jamming on the Continent would jam Home stations, and airborne jamming would be difficult as it was likely to become a long-term project.[4] The use of " jitter " could be easily overcome by the enemy—and probably already had been, judging by his apparently renewed interest in " Heidelberg."

Intelligence reports in February 1945 revealed that a new " chimney " tower with " Heidelberg " array had been erected on the Island of Romo, off the Danish coast.[5] In a statement by the Director-General of Signals to the Deputy Chief of Air Staff, dated 4 March 1945, this information was passed on, and also the fact that three at least of these equipments were known. It was

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[1] Air Ministry File C.M.S. 717, " Heidelberg—Countermeasures on C.H. Stations."
[2] *Ibid.*, Encl. 2A. [3] *Ibid.*, Encl. 30A. [4] *Ibid.*, Encl. 37A.
[5] *Ibid.*, Encls. 35A and 36A.

thought that the " Heidelberg " threat should now be taken seriously. The report continued that the obvious first course was to examine the technical methods by which our ground transmissions could be made useless to the enemy. Detailed examination so far had revealed that none of the possible methods would have more than a temporary effect, and would in any case take time to implement. Investigations were continuing, but the Deputy Chief of Air Staff was informed that two other possible steps could be taken. These were (*a*) the physical destruction from the air of the German installations, and (*b*) switching off transmission at C.H. and M.R.U.[1] stations. With regard to the first method, it was stated that considerable effort would be required to carry out such an operation successfully, and there was a possibility that not all the enemy stations might be located.

Disadvantages of Losing C.H. Cover

The report continued by stating that if the C.H. and M.R.U. stations were " off the air " during the period the " Mandrel Screen " was operating (and this might cover a nightly period of up to five hours), the Home Chain would be denied certain advantages. These were—

(*a*) The early warning of very high-flying aircraft;
(*b*) The advance warning ($4\frac{1}{2}$ minutes) of long-range rocket detection from the five C.H. stations engaged in " Big Ben " rocket watch;
(*c*) The collection of information assisting in the location of rocket firing points.
(*d*) Broad I.F.F., shown as a sign of distress, would be missed as it could be seen at greater range by the C.H. stations.

With regard to the first point, the danger of attack on this country at this time, by very high-flying aircraft, was regarded as negligible. The effect of shutting down the C.H. transmissions, as far as the rocket watch was concerned, would be that reliance would have to be placed solely on Army gun-laying stations for early warning of approaching rockets. The time of warning would probably remain the same, but warning would be less reliable and the number of false alarms would increase.

The C.H. and M.R.U. stations which would be involved if transmission were cut, were all C.H. stations from Land's End eastwards to Scapa Flow, and all M.R.U. equipments on the Continent. It was also thought that the enemy might be using our " Gee " transmissions similarly, but no definite evidence was available on this point.

Recommendations for Counteracting " Heidelberg " by Non-technical Means

The Director-General of Signals suggested that at that time there was insufficient evidence to confirm that the operational value of " Heidelberg " to the enemy justified switching off Home Chain stations, but proposed that policy should be decided immediately for application later, should this become necessary. He recommended that preparations should be made to switch off C.H. transmission, if and when necessary; that agreement should be given for stations to put this procedure into effect when required; that consideration should be given to attacking " Heidelberg " stations when located; that Intelligence sources be asked to confirm that a close watch was being kept on

[1] Mobile Radar Units—mobile equipment with the same functions as the C.H. stations. Used at home as stand-by equipment for C.H. stations, and extensively overseas where permanent C.H. installations were impossible.

the development and operational value of " Heidelberg," and that any indication of its successful use be reported at once to Air Ministry. The Deputy Chief of Air Staff convened a meeting on the 10 March 1945 to discuss the whole matter, when it was decided that the Ministry of Home Security, S.H.A.E.F. and Fighter Command should express views on the cessation of transmissions from the C.H. stations at home and M.R.U.s on the Continent.[1] In the meantime, plans were to be drawn up for the immediate switching-off of C.H. and M.R.U. transmissions if necessary, and neutralising action of the German stations was to be considered. A code-word—" Baffler "—was selected to initiate action for closing down of C.H. transmitters.

The whole problem received a great deal of thought at very high level, and much technical research work was carried out by T.R.E. and No. 60 Group technicians. Although plenty of radar cover was available without the C.H. stations, provided by the C.H.L., C.H.E.L. and G.C.I. equipments, yet the special services which have been previously enumerated could not be obtained from any other type of station. Weighing against this was the fact that if the enemy made extensive use of " Heidelberg " and so got ample warning of approaching Allied aircraft, our bomber losses were likely to be very much increased. After the problem had been thoroughly considered and discussed from all angles, it was eventually decided that the more important factor was the saving of our bomber aircraft and crews. However, before definite instructions were issued for the closing down of the C.H. and M.R.U. stations at specific times, the military situation changed very rapidly within a few weeks, greatly in the Allies' favour. In consequence, it was decided on 19 April 1945 that no further action be taken in the matter.[2] Scientists continued with their researches, however, with a view to discovering technical measures which could be devised or adapted to combat this activity of the enemy.

Final Contraction of Home Chain Cover

The policy of gradual closing-down of Home Chain stations was implemented throughout 1944, and a further shrinkage took place during the latter part of the year. This chiefly applied to the northern and western coasts ; no relaxation was possible before the end of hostilities on the eastern and south-eastern coasts, where the radar stations were busily engaged in plotting the V-weapons. Surface-watching equipment could not be readily released except in cases where duplicate cover was available. The final war-time contraction of the air-watching stations took place in the spring of 1945, when eighteen further stations were placed in care and maintenance, following an Air Staff decision in March 1945 to relinquish all radar cover for air defences on the west coast, between Cape Wrath and St. David's Head.[3]

When stations were taken off actual operations they were placed in one of the three following categories :—

Care and Maintenance, Stage I.—The station or channel was maintained in such a state of readiness that it could, if necessary, return to operations at fourteen days' notice.

Care and Maintenance, Stage II (Caretaking).—The station or channel was maintained at such a level that it could return to operations at six months' notice.

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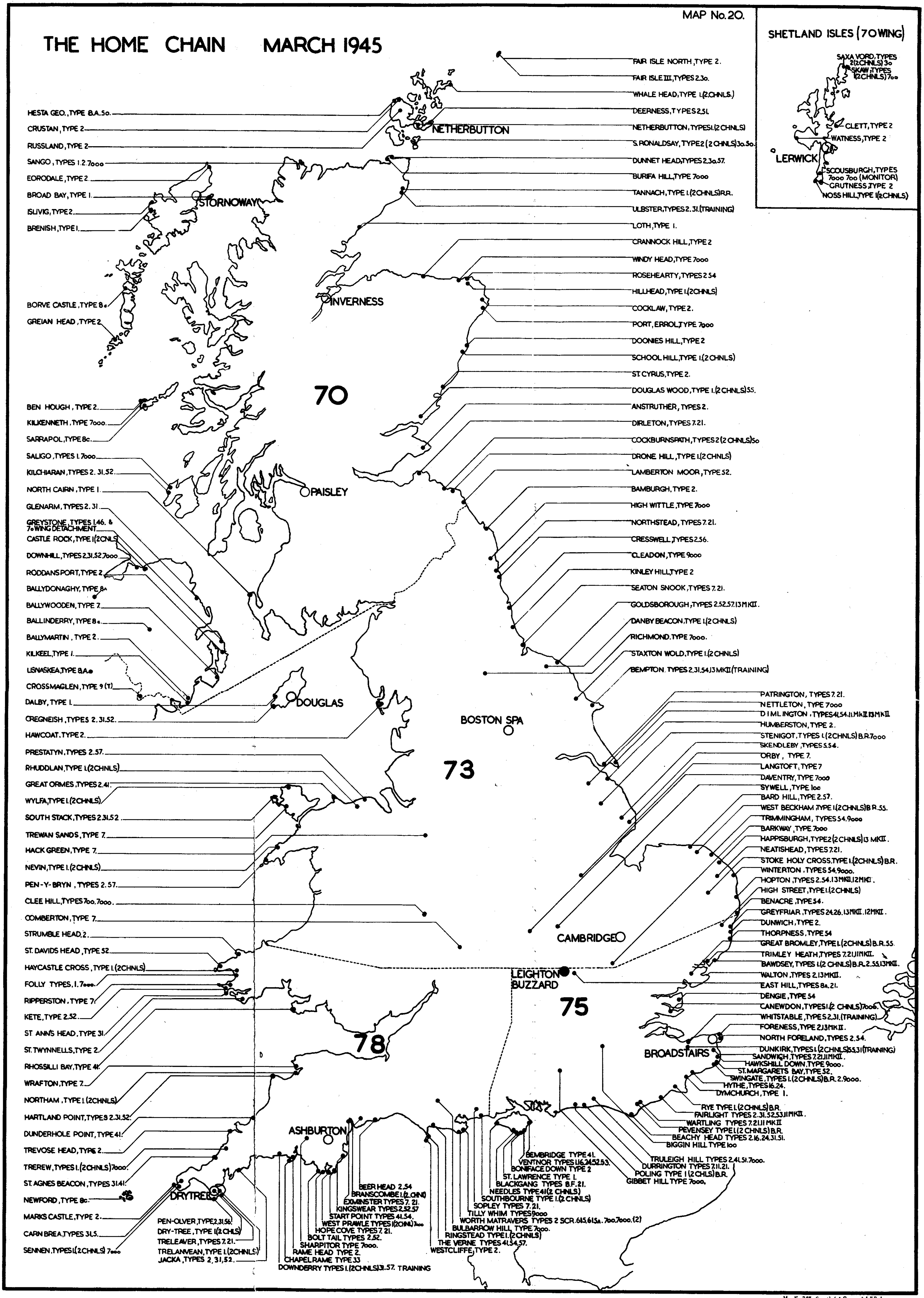
[1] Air Ministry File C.M.S. 717, Encls. 54A, 57A. [2] *Ibid.*, Encl. 80A.
[3] Radar Board Paper 944, 29 March 1945.



Map No. 207 Compiled & Drawn at A.H.B. 1.

Care and Maintenance, Stage III (Pending Dismantling).—The station or channel would never be required to return to operations, and it was in this category only for the period between cessation of operations and its handing-over to Air Ministry for the dismantling of towers and buildings.

The majority of stations closing down during this period were placed first in Category I and later Category II. A few stations, however, whose function had become redundant as a result of improved coverage at neighbouring sites and which were remote from the possibility of enemy attack, were regarded as "dead" and closed completely. A map of the Home Chain as it was at March 1945 is appended to this volume,[1] together with a list of Wing boundaries and stations in care and maintenance at that date.[2] A list of ground stations still in existence when all hostilities had ceased is also given.[3]

Closing Down of Surface-watching Stations

A special meeting of the Radar Board, which included representatives from all three Services, was held on 18 August 1944, when the whole question of surface cover by radar stations was considered with a view to effecting economies.[4] As a result of this meeting, the Board recommended the closing down of the surface-watching apparatus at certain stations, with a review in a month's time of several others, and the Admiralty and Air Ministry were invited to supplement accordingly. The only purely naval equipment concerned was the Type 30 station at Gwespyr, and orders for this to be closed down were issued by the Admiralty on 14 October 1944.[5] Further instructions were issued by Air Ministry from time to time following recommendations made by the Radar Board, and a list of stations and equipments affected is appended.[6]

Further small economies were made in the surface cover chain during the remainder of 1944, and until the end of the war in Europe, but generally surface cover was maintained at a high level until well after the cessation of hostilities, as not until then could the U-boat menace be said to have ceased. The final decision with regard to the closing down of surface cover rested with the Admiralty, as their interests were most closely concerned. The Radar Board, at its 109th meeting in May 1945, stated that in view of Air Ministry's anticipated commitments for providing radar cover in theatres of war in Europe, and consequent difficulties regarding radar personnel and equipment, the Admiralty should be invited to review Home Chain requirements for surface cover with the object of reducing the number of operational stations; shortages of personnel and equipment being such that new stations could only be set up at the expense of closing old ones.[7] The Radar Board consequently invited Air Ministry to state the position in detail to the Admiralty with a view to further economies being effected in the Home Chain surface cover plan.

The need for economy was urgent, both as regards equipment and the manpower essential for its efficient operation and maintenance. Not only had the radar element of the Allied activity in Europe to be supplied mainly from Home Chain sources, but the campaign in South-East Asia Command

[1] Map No. 20, "Map of the Home Chain as at March 1945."
[2] Appendix No. 53, "The Home Chain, March 1945."
[3] Appendix No. 54, "Ground Stations Operational in October 1945."
[4] Radar Board, Minutes of Meeting, August 1944.
[5] Air Ministry File S.C. 23319, Encls. 11A, 18A.
[6] Appendix No. 55, "Final Contraction of Home Chain Cover."
[7] Radar Board, Minutes of Meeting, 23 May 1945.

was working up to its climax, and the additional radar units necessary to the success of the war in the Far East could only be provided at the expense of operations at home. It is a tribute to the efficiency of the Home Chain, and to the co-operation of the Royal Air Force and the Royal Navy, that such economies were effected without detriment to the defences of Great Britain.

Thus concludes the narrative of the Home Chain, which began in February 1935 and ended ten years later, in May 1945, when the cessation of hostilities in Europe meant that for the first time since August 1939 the 24-hour radar watch maintained around the coasts of Britain could be relaxed without danger.

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In the short space of ten years a project which had seemed little more than a scientists' dream became, by the vision and tenacity of purpose of a few far-seeing men, one of the outstanding scientific achievements of the age. Although radar was eventually used by all three Services and by the other Allied nations, the Home Chain stations of the Royal Air Force were the first units to employ radar as a defence against the enemy. The first test came in August 1940, when the stations round the south-east coast of England received their baptism of fire, and gave warning of enemy raids which enabled Fighter Command, during the ensuing three months, to make the fullest use of the resources available to them. There can be little doubt that the part played by radar in the Battle of Britain fully justified the faith which had been placed in it by its pioneers in the years immediately preceding the War. The time, labour, and money spent in the erection of the early A.M.E.S. stations, the development of associated communications systems, and the training of a great army of personnel for the operation and maintenance of the Home Chain all drew rich dividends.

Although knowledge of radar was still in a very elementary stage at the outbreak of war, the need for this new scientific weapon was so great that development and production had in many cases to proceed side by side. This meant that as our scientific and technical knowledge rapidly increased and operational requirements became more apparent, some equipments were obsolescent before they came off the production line, and constant modifications and improvements had to be made to equipments already in service. The effect of these two factors—the urgent need for defence and the rapid developments in ground radar made during the War, led to a total of approximately two hundred and fifty ground radar stations being erected in the United Kingdom, many of them multiple stations containing two or even more types of equipment. This policy was dictated by circumstance, but although results on the whole were satisfactory it was very expensive in both equipment and personnel.

Experience overseas with the Type 70 Station[1] clearly demonstrated that a " master radar station " technique was possible ; providing complete cover up to 30,000 feet and over 100 miles on a single aircraft. Relatively few stations of this type, embodying all the latest technical devices and improvements, supplemented by a small number of coastal centimetric stations for specialist purposes and for surface craft cover, and backed by a sound air movements liaison organisation, could in all probability economically provide

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[1] *See* Chapter 25 for details.

the combined radar early warning and control facilities required, both out to sea and inland. It may well be that the necessity for the Royal Observer Corps will, in part at least, cease or that its activities will become an integral part of the new organisation. A master-station, such as the one visualised, with cover overland as well as over the sea, would also have the very great advantage of ensuring continuity of tracking and would eliminate the confusion of tracks and identities which, under the old system, often existed when aircraft were passing from radar cover into the area of operations of the Royal Observer Corps, or vice versa. Against these advantages of a centralised master-control system must be put the danger of having too many eggs in one basket, and the consequent need to have a duplication of the system for adequate security.

The war ended without really satisfactory countermeasures to "Heidelberg" electronic jamming and "Window"; handicaps which could render key sectors of any future long range early-warning radar system almost useless in the event of a wholly defensive phase of war, and one—"Heidelberg"—which could turn our early warning radar against our own air striking force, in the absence of suitable countermeasures. We should not, therefore, be carried away into self-complacency by the success of the long-range radar defences in the United Kingdom during the latter half of the war, but be ever mindful of the almost overwhelming advantages they enjoyed.

APPENDIX No. 1

MEMORANDUM BY MR. R. A. WATSON WATT 27 FEBRUARY 1935

Detection and Location of Aircraft by Radio Methods

It appears unsafe to base any method for the detection or location of enemy aircraft on any of the primary radiations from the craft. Lamps and radio senders will not be used on a scale permitting detection. Sound from engine propeller and structure is steadily being reduced, and is in any case subject to extreme vagaries in propagation which, while still permitting detection, may prevent location. Electro-magnetic radiation from ignition systems is readily screened to very low values. Infra-red radiation from engine is so heavily and variably absorbed in a water-laden atmosphere as to make it an unreliable indicator.

Of the secondary radiations, excited by " illuminating " the craft by ground installations emitting light, heat, sound or radio-waves, the first two are excluded by atmospheric absorption (especially in cloudy conditions). The use of sound waves above the audible limit has some attractions, but the low-power rating of emitters and the low velocity of propagation—a small multiple of the speed of the craft—are against it. It appears, in sum, that the only moderately promising method of detection and location is that of secondary " wireless " radiation.

The most attractive scheme is that of setting up zones of short-wave radio " illumination " through which the approaching craft must fly. The most desirable form of this scheme will be discussed in more detail.

Let it be assumed that the typical night-bomber is a metal-winged craft, well bonded throughout, with a span of the order of 25 metres. The wing structure is, to a first approximation, a linear oscillator with a fundamental resonant wave-length of 50 metres and a low ohmic resistance. Suppose a ground emitting station be set up with a simple horizontal half-wave linear oscillator perpendicular to the line of approach of the craft and 18 metres above ground. Then a craft flying at a height of 6 km. and at 6 km. horizontal distance would be acted on by a resultant field of about 14 millivolts per metre, which would produce in the wing an oscillatory current of about $1\frac{1}{2}$ milliamperes per ampere in sending aerial. The re-radiated or " reflected " field returned to the vicinity of the sending aerial would be about 20 microvolts per metre per ampere in sending aerial.

It is at present common practice to put 15 amperes into the sending aerial, giving a received field, from the re-radiating craft, of the order of a tenth of a millivolt per metre after generous allowance for losses. This value can in effect be more than doubled in the pulse technique without overload in the transmitter. If, further, the method proved so reliable that general " illumination " could be abandoned and a thick sheet of " illumination " at a convenient inclination could be relied on, this field could be increased at least tenfold by the provision of a suitable beam array, of practicable dimensions and cost, at the ground station. It will be observed that this last improvement is obtained at some sacrifice of easy watch, as an indication is obtained only while the craft is " illuminated," in the one case the illumination is weak flood lighting of a very large area, in the other it is strong searchlight illumination in an inclined sheet of small thickness.

It is not wholly fantastic to suggest that the span of the machine could be measured to aid identification, by a rapid sweep of the emitted radio-frequency, but without emphasis on this possibility it will be noted that the simpler scheme will lose in efficiency as the emitted frequency fails to fit the resonant frequency of the wing structure.

The resonance curve of the wing and fuselage structures will be very flat; this militates against easy span-measurement but in favour of easy distance-measurement; without change of radio frequency to fit the craft, a variation of two or three to one in span will not much affect sensitivity. This also reduces sensitivity to changes in aspect of the craft as in strong cross-winds. On balance, however, it may be concluded that reflected fields of the order of a millivolt per metre are readily attainable at 10 km., rising by the use of an alternative height to the order of 10 millivolts per metre as the craft passes overhead at heights under 20,000 feet. These fields are about ten thousand times the minimum required for commercial radio communication, so that very large factors of safety indeed are in hand for ranges of the order of 10 miles at flying heights of about 20,000 feet.

If now the sender emits its energy in very brief pulses, equally spaced in time, as in the present technique of echo-sounding of the ionosphere, the distance between craft and sender may be measured directly by observation on a cathode ray oscillograph directly calibrated with a linear distance scale, the whole technique already being worked out for ionospheric work at Radio Research Station. In the examples already taken the reflected ray would return after 56 microseconds for 6 km. horizontal distance and after 40 microseconds from overhead. I believe these times to be quite manageable within the technique, though they involve a very considerable shortening of the pulse durations now used (about 200μ sec.), or an artifice, which we can certainly provide, for reading the time of return even when the reflected pulse is superposed on the primary timing pulse which has arrived at the receiver by a very short ground path. If we are not interested in distances over 300 km., or if other instrumental and propagational limitations prevent us from utilising the method up to such distances, then we can send a thousand pulses per second, and obtain, by superposition of the successive images on a synchronised time base, a very easily visible sustained image permitting close measurement and even showing the advance of the craft. Some compromise pulse-frequency between 50 and 1,000 would be selected after experimental trials.

It will be clear that the installation of three such receivers for time-delay measurement alone would enable the equations of position to be solved, by means which could be made partially or wholly automatic, for height and plan projection. The provision of a line of senders over a long front is not prohibitively difficult, since the polar diagrams are such as to permit substantial spacings and the echo-patterns are readily sorted out. Finally, the provision of two parallel lines, roughly perpendicular to expected line of approach, would give still more accurate positional data enabling speed and course to be measured with some precision. There are two main objections to the use of the radio-frequencies discussed, to which the whole metal structure of the craft is nearly resonant. The technical one is that echoes from the ionosphere will appear on the received picture and will have to be discounted in observation. This is no more than a mere inconvenience, in view of our existing knowledge of what to expect, and even this inconvenience is mitigated by the value of the ionospheric echoes as indicators that the gear is in good order. The time scale can be made very open for the first hundred kilometres—and it is not unreasonable to expect that the technique can be developed to operate on craft up to that distance—and the first ionospheric echoes can be crowded into a stand-still period at the end of the time-base. But it is impossible to avoid the ionospheric echoes from, say, $(nk + x)$ km. being read as from x km., where k is the distance corresponding to the recurrence frequency of the time-base and $n = 1, 2, 3$ —, except by the exercise of intelligence and experience of ionospheric reflection, or by additional instrumental artifices.

The second objection is one of policy. The ionospheric reflection makes it certain that these special emissions will be audible in foreign countries, and alike on grounds of secrecy and of mitigating interference with communications this is undesirable. The interference problem can, presumably, be dealt with through the normal machinery, with due regard to the importance of the objective. The secrecy problem might be best solved by an offer from Air Ministry to Department of Scientific and Industrial Research of facilities for ionospheric investigation and other work for the Radio Research Board at a conveniently flat and isolated site at Orfordness, suitably distant from Slough for special experiments.

It is felt that none of these objections should be allowed to delay the attack which depends on the use of the wave-lengths, around 50 metres, on which we have adequate experience and adequate radiated power. But as soon as possible the technique should be developed to cover the wave-lengths under 10 metres, which are not normally reflected from the ionosphere, and which would thus mitigate the interference problem and would help to maintain secrecy after the " camouflage " already suggested was beginning to wear thin.

The power which can at present be radiated on these shorter wavelengths is about half that attainable in the 50-metre range, and the receivers are probably somewhat less sensitive, so that some sacrifice of sensitivity would at first result. The main reason for preferring the 50-metre wavelength, however, is connected with means for location by reflected pulse signals, other than by the measurement of time-delay as already outlined.

The cathode ray direction-finder, developed at Slough for visual direction-finding on extremely brief signals, has already been used on 50 metres, but not yet on 10 metres. It is almost certain that instruments of this type, working on 50 metres, could be used at the ends of a suitable base-line, the indications being " piped " to a central control room in which the advance of the craft could be indicated continuously by the movement, on a map, of the point of intersection of two lines of light representing the directly indicated bearings at the two stations.

This technique can doubtless be extended to 10-metre working, but substantial development work is yet required. Closely related experiments down to 15 metres have, however, revealed no acute difficulties.

It may, further, be desirable to supplement or supplant the time-delay measurements by adding to the cathode ray direction-finding measurements another cathode ray technique also worked out (exclusively, as was the direction-finder) at Radio Research Station, Slough. This enables the angle of elevation of descending radio waves to be measured with an accuracy of about half a degree, an accuracy which can almost certainly be improved on demand ; the work already in hand has not required higher accuracy. This technique has already been used on wavelengths between 60 metres and 10 metres.

The manner in which the three methods may best be combined for the most rapid deduction of the most convenient positional co-ordinates from these direct and continuous indications of the distance, angular azimuth and angular elevation of the craft, can only be determined by trial and development.

I am, however, convinced that the work can only be brought to a successful issue by the utilisation of the wide range of cathode ray technique in which Radio Research Station, Slough, has specialised for many years, and in which its experience is unique.

If the foreseen difficulties of the pulse method prove unexpectedly great, or if some major difficulty has not been foreseen, there remain two practicable though less attractive processes. In one the sender would emit continuous-wave signals, and no echo would be detected save from a moving reflector, such as the craft. The rate of approach could be measured from the interference pattern on the cathode ray screen, the plan position could be plotted from cathode ray direction-finders into which were injected suitably phased e.m.fs. to suppress the images due to the direct rays and those reflected from fixed objects.

In the other process the frequency of the sender would be varied over a known range, as in Appleton's frequency-change method of ionospheric sounding. Here the interpretation of the pattern from a moving reflector would appear likely to be slower than is permitted by the practical problem of locating—and intercepting—high-speed enemy craft, and the method is not proposed for consideration until some flaw has been found in the quite unexpectedly favourable indications for the pulse method.

There will also be, for consideration, the problem whether the interval between detection and engagement may not be best reduced to a minimum by having interceptor craft fitted with a keyed resonating array so that they are readily located by the same methods as those used on the enemy bombers, but discriminated and identified by the intermissions in their " reflected " field. The interception operation can then be controlled by radio instructions to the interceptors closing them into the positions indicated for the bombers.

We have already disclosed, in patents and publications, means for making the oscillographs " follow-up," and these may be relevant to further developments of the present scheme, as for distant repeating, etc.

(C27392)

EXTRACTS FROM THE FIRST INTERIM REPORT OF THE COMMITTEE FOR THE SCIENTIFIC SURVEY OF AIR DEFENCE, 16 MAY 1935

Detection and Location of Aircraft[1]

(*a*) The Committee is satisfied that the detection of hostile aircraft at a much greater range from the coast than is now attainable and the maintenance of a more or less continuous record of their height, track and ground speed when the coast has been passed, is a problem of the first importance for air defence ; it is, of course, essential that these data should be obtained for all heights of approach and for all conditions of visibility.

(*b*) The Committee believes that, with any practicable form of listening device, no material improvement of the average time of warning, now given by the 200-foot mirror, is likely to be obtained. The increasing speeds and operating heights of aircraft and improved technique of silencing are likely more than to outweigh technical advances in acoustical research. Moreover, the nature of the propagation of sound in the atmosphere severely limits the attainable accuracy of three-dimensional location of rapidly moving sources of sound, such as aircraft, and the rapidity with which the data can be obtained and used. It is clear, however, that sound location is the only non-visual method of locating aircraft now available, and the Committee assumes that the development of sound location will continue until more accurate means can be evolved.

(*c*) The Committee considers that the detection of heat radiation from an aircraft engine or of energy radiated by an aircraft engine magneto offer no prospects of success ; each of these methods has been the subject of experiment.

(*d*) It therefore appears certain that no form of radiation from the aircraft itself will suffice to locate aircraft with sufficient accuracy, under all conditions of visibility ; the only alternative is to use a ground source of primary radiation. Mr. Watson Watt, of the National Physical Laboratory, Teddington, has submitted to the Committee a proposal for the detection and location of aircraft by radio methods. His proposal is that the zone in which detection is required should be " floodlighted " with electro-magnetic waves transmitted from a number of ground stations ; metal components of an aircraft structure, such as wing spars or struts, or even engine parts, would then constitute sources of secondary electro-magnetic radiation which might be detected and located.

In order, as a preliminary measure, to determine whether this method of detection held any promise of success, a Heyford aircraft was flown in the path of the 50-metre Daventry beam, to and fro over a hastily erected and, for this purpose, relatively inefficient receiving station. A definite and continuous indication of the presence of the aircraft was obtained up to a range of 8 miles from the receiving station ; in the circumstances, the result was much beyond expectation. The equipment available served only for detection ; no attempt was made to locate the aircraft. The Committee believes, however, that the special technique developed, for other purposes, at the Radio Research Station, Slough, affords, in principle, a means for obtaining accurate location of hostile and defending aircraft and probably of distinguishing between them. Thus a promising means presented itself for attaining the ideal solution of the fighter aircraft interception problem, defined in para. 3 (B) (*b*).[2]

With the approval of the Air Council and of the Treasury and with the co-operation of the Department of Scientific and Industrial Research steps were immediately taken by the Director of Scientific Research, Air Ministry, to provide facilities at

[1] A.M. File S.34763, Encl. 54A.

[2] Fighter aircraft should be made more or less continuously aware of the positions of hostile aircraft relative to their own positions, for a period sufficient for interception. The ideal would be to obtain, on the ground, a complete picture of the positions and movements of all hostile bombers and defending aircraft for a time period sufficient to enable fighter aircraft to be directed, by radio telephony, towards particular hostile bombers. The Committee is aware of the procedure at Headquarters, Air Defence of Great Britain, providing for the collection, co-ordination and dissemination of information obtained from visual and acoustic observations. It seems, however, that the ideal solution defined above is far from realisation.

Orfordness for the intensive study of this means for locating aircraft. Members of the staff of the Radio Research Station, Slough, who have had experience of the special technique involved, have been allotted by the Department of Scientific and Industrial Research for the work.

The following are the objects of the research, which has now been commenced at Orfordness :—

(i) Determination of the approximate positions of hostile aircraft at the maximum possible range from the coast under all meteorological conditions. It appears certain that 20 miles will be exceeded ; a range of 50 miles is likely ; whilst a considerably greater range of detection is possible.

This problem is a relatively simple one, and a range greater than is now obtainable with the 200-foot acoustical mirror is likely to be achieved within the next twelve months.

(ii) More or less continuous determination of the three-dimensional positions and movements of hostile and defending aircraft in all conditions of visibility.

The Committee has reason to hope that this ideal means for effecting interception can ultimately be attained by radio methods.

(iii) The control of A.A. guns by radio methods is a future possibility. This problem, however, requires a much higher degree of accuracy and rapidity of the determination of data than are needed for the objectives stated in paragraph 5 (C) (4) (i), and no forecast of the period necessary for research can usefully be made until the conclusion of the preliminary work now in progress.[1]

The Committee wishes to emphasise that, although it seems likely that accurate location by radio methods will ultimately replace sound location, there is little possibility that the method can be made available to the Services within two years. Long range detection, as a means of obtaining early warning of approach of hostile aircraft, may become practicable within a much shorter period. Research of a fundamental character is necessary over a period which cannot now be accurately assessed. In this connection the Committee notes the extent of the organisation, provided over a long period, which has been necessary to achieve the present results with sound location.

It is of great importance that secrecy should be observed in the experiments now commencing at Orfordness ; to this end it has been arranged to disseminate the idea that the work is associated with existing researches on the nature of the ionosphere.

The Committee has considered the obvious objection that radio methods of location may be rendered useless by jamming. It is believed that the method proposed by Mr. Watson Watt will prove to be free from this objection, but a definite opinion cannot be given until the experiments have progressed further.

Summary of C.S.S.A.D. Report on Radio Detection

The Committee summarised its conclusions and recommendations as follows :—

" (A) *Detection and Location*

(*a*) The Committee is satisfied that the provision of earlier warning and of a continuous and accurate record of the movements of hostile aircraft is vital to air defence. It considers that radio methods are likely ultimately to prove the most effective non-visual means for long range detection and accurate location. It therefore recommends that every practicable facility be given for the conduct of the research work now commencing at Orfordness.

[1] Means for controlling A.A. fire against obscured targets must be improved. The Committee is aware of the high degree of technical skill employed in an attempt to fulfil this requirement by sound location. It considers, however, that natural limitations, such as the speed of sound and the nature of the atmosphere in which it is propagated, will always preclude a sufficient accuracy and rapidity of location by this means. The accuracy of any method employed must approach that provided by visual observations, and the Committee believes that this accuracy can only be approached by a radio method referred to later in this Report.

(*b*) The Committee recommends that, until it is certain that the radio method of detection and location will, in all respects, be superior to other non-visual methods, the development of sound location should continue."

"The Committee wishes to record an interim forecast of the nature of an Air Defence Scheme which may reasonably be expected to result from, say, five years intensive research; most of the features of the scheme should be available within a shorter period.

Hostile aircraft might be detected and approximately located, by radio means, at a range of between 60 and 100 miles from the coast. When nearing the coast their positions and movements, as also those of defending aircraft, might be known with sufficient accuracy to ensure interception, by day and night, and in all meteorological conditions; provided only that hostile aircraft are not in cloud. If this can be achieved it would seem that hostile aircraft will usually be harassed from the coast to their targets. It must be assumed, of course, that fighter aircraft are able successfully to engage hostile bombing aircraft when interception has been effected.

Aircraft approaching their targets in cloud might be countered by A.A. fire using radio methods of detection.

If these means for defence can be made available, in conjunction with the counter-offensive and means for passive defence, it appears that the problem of air defence will present far less difficulty than it does at present. If the experiments proposed in this report are successful, defensive measures can be greatly increased. It is probable that nothing that the Committee has considered will prevent a determined enemy from making a serious and partially successful raid on a large area such as London; enemy losses should, however, be such that continuous repetition of such raids would be improbable.

This forecast of future possibilities may appear unduly optimistic; the Committee is satisfied, however, that its realisation can be approached provided that sufficient effort is forthcoming. The Committee does not minimise the magnitude of the effort required, and it assumes that the multiplication of equipment, such as fighter aircraft and A.A. guns, will not be made at the expense of research or of Service trials and exercises directed towards determining the probable nature of air attack and the efficacy of means of countering it."

APPENDIX No. 3

MR. WATSON WATT'S MEMORANDUM TO THE C.S.S.A.D. ON THE STATE OF R.D.F. RESEARCH, 9 SEPTEMBER 1935

The proposals for detection and location of aircraft by radio means, made in detail in February, tested in a single experiment at Daventry in March, and developed, in work at Ordfordness since May, have led to the following of metal-framed aircraft to distances of 92 km., to their detection (when expected with a doubt of some twenty minutes) at distances over 60 km., and (when completely unexpected) at distances over 50 km. In all cases where detection is possible the distance of the craft from the observing station can be measured with an accuracy of the order of 1 km. The tests have mainly been made on craft flying above 10,000 feet, with a few trials at 7,000 and 5,000 feet, and one at 1,000 feet. The craft observed include land craft (Bristol R.120, Hart, Valentia, Vildebeeste, Virginia, Wallace) and marine aircraft (Osprey, Scapa, Seal, Singapore, Southampton), with spans varying over a range exceeding three to one. If failure to follow to or detect at 20 km. be taken as the criterion of failure, only three failures have been experienced in the experiments. One, due to excessively heavy atmospheric disturbance and very bad flying conditions, was in observation on a craft which was followed in another test to 55 km. and detected at 46 km.; one, partly due to engine failure, was on a craft which on another occasion was detected, quite unexpectedly, at 19 km. (on leaving Martlesham); the third, due to unfavourable course and flying height, was on a craft with which long ranges have been obtained frequently. Comparable performances have been obtained on wavelengths of 50, 28, 27 26 and 25 metres. No success has yet been attained in a few trials on 8 metres wavelength.

Experiments on measuring the angle of elevation of the craft detected are now being undertaken, but no tests have yet been made.

For the range of low angles of elevation involved in the distant detection and location problem the amplitude of the deflection on the measuring instrument may be taken as proportional to—

$$\frac{h^2 H^2}{\lambda^2 d^4}$$

where h = height of (identical) sending and receiving aerials.
H = flying height.
λ = wavelength used.
d = distance of craft from practically coincident sending and receiving stations.

The present state of radio technique does not guarantee the early attainment of ranges on wavelengths under 25 metres, comparable with those obtained on that wavelength, so *that*, for early applications, must be taken as fixed. The limiting range of detection with the present type of installation thus varies as $\sqrt{h \, . \, H}$. Since the detection of low flying craft is important, increase of h, the aerial height, is important. It can be obtained by additional mast height or by selecting coastal sites well above sea-level, *i.e.*, on cliffs. The cost of masts varies roughly as h^2 up to 200 feet, and roughly as h^3 between 200 and 500 feet. A 200-foot mast system on a 50-foot cliff would offer a valuable improvement in performance, and proposals for direct trials of this system are in hand. The immediate improvements which can be made inside the sending and receiving rooms are believed to justify the acceptance of a 60-km. detection range (using 75-foot masts) as a conservative estimate of immediate average performance on craft flying at 13,000 feet, the improvements being taken only as converting the present not infrequent achievement of 60 km. into a normal performance.

Table I gives a series of estimates of performance based on this experimentally established figure of 60 km. for 13,000 feet. Line 1 quotes this basis, line 2 gives the probable performance with 200-foot masts on a 50-foot cliff, for different flying heights. These two lines are doubly conservative, as they do not take account of the certainty of further improvements in receivers, and do not take account of the improvements to be derived from simple antenna arrays. Line 3 represents a very conservative estimate of performance based on a qualified optimism on these points. Lines 4 and 5 show, on the same basis as that of line 3, the performance that can virtually be guaranteed now from 200-foot masts on a 200-foot cliff and from an 800-foot system, for example of 400-foot masts on a 400-foot cliff, where such provision is possible and economically justifiable.

While these " guaranteed " improvements are attainable by high masts or by a high site, interchangeably, great additional advantages from antenna arrays are limited to that part of the total height which is provided by mast height only. The argument outlined may suggest that a high hill inland may be a better site than a low coastal site. While this is true for high-flying craft, closer examination indicates that for low-flying craft it is desirable that the sites of the detecting installations should be within a kilometre or two of the coast. The existing information about the absorption of downcoming waves over imperfectly conducting ground does not permit an exact theoretical prediction beyond this condition in the low-flying case, governing the siting of the main chain of stations. A second line of detection stations on hills over 750 feet high would, however, probably be a very valuable addition to the network, on grounds of reduced vulnerability and of improved watch over land areas, and it is very desirable that early experiments be initiated with one transmitting and one receiving station on such elevations as are readily available in England. This experiment might be combined with preliminary provision for the defence of the Tyne estuary by using the high country of Durham and Northumberland.

The ranges discussed deal with approach along the axis of maximum sensitivity for such an installation as that at Orfordness, with transmitter and receiver less than a kilometre apart. The most effective and economical distribution of a chain of transmitters and receivers to throw out a " detection frontier " and a " location frontier " substantially parallel to and at useful distances from the physical coast line will depend partly on radio-technical factors, but partly on other factors, especially speed of working and reduction of intercommunication channels between units. The most expensive single items of equipment are masts, and more masts are required at the receiving than at the transmitting station (because of the need for angle of elevation measurements).

An economical arrangement for giving a good detection frontier would appear to be that in which transmitting and receiving stations are planted alternately at equal intervals of some 30 kms. along the coast. For 200-foot masts and 50-foot cliffs the detection frontiers for different flying heights are obtained, approximately, as in Fig. 1. It will be seen that for high-flying craft the frontier is good and has no important bays, and that even for low-flying craft the bays are not very deep, while the frontier is sufficiently advanced if the incoming low-flying craft is assumed to be under the necessity of spending time in climbing near or within the coast line before action.

The areas, inside the detection frontier, over which location by rangefinding alone can be effected are shown shaded in Fig. 1. Superficially the situation in respect of high-flying craft would appear sufficiently good, but for low-flying craft there are open corridors to the coast. Moreover, even in the case of high-flying craft there are ambiguities in location where simultaneously detected craft in separate formations have to be dealt with.

It is therefore necessary to improve the location frontier and to remove these ambiguities. Both ends can be met, and, in addition, the speed of handling the location data can be much improved, by the addition of a transmitting installation, with no substantial addition to the receiving installation, at each receiving site. The detection frontier is then slightly improved, but the location frontier is satisfactorily closed, the areas between them for all save very low-flying craft now being reduced to the quite small butterfly patterns shaded in Fig. 2.

It will be recognised that at this early stage in a new technique there are substantial elements of uncertainty in the estimates given. Only because the circumstances of the moment are emergency circumstances has any estimate at all been attempted now. But if these circumstances should be considered as demanding immediate action, then the following summary is considered a fair and not over-optimistic estimate of what can be done with no methods other than those tested in the four months of experimental work already carried out. The summary is based on plans which allow for the introduction of improvements without substantial scrapping, *i.e.*, the plans call only for elements which are virtually certain to be embodied in the " standard " installation in its quasi-final state.

A chain of stations with transmitters every 20 miles along the coast to be defended, and with receiving installations at each alternate station, *i.e.*, every 40 miles, is required. The transmitters should have two masts not under 200 feet high, situated on land not less than 50 feet above M.S.L., not more than 2 miles from the coast. The cost of the transmitter from power terminals to aerial, *i.e.*, including transmitter proper, masts and aerials, but excluding land building, power supply and communications, is estimated not to exceed £3,000 ; the crew required need provide only one man for transmitter operation ; and the mean power taken is under 5 kilowatts. Replacement of valves, the only important replacement cost, is on a scale not exceeding £1 per 5 hours' running ; this may be substantially improved on. Connection to the grid system is desirable but not essential ; stand-by equipment for power supply will be required on account of the vulnerability of the grid system. Communication with the receiving station is not required in operation.

The receiving station required two similar masts similarly sited, and these may be within a kilometre of the local transmitter. Each receiving station utilises its one pair of masts, its one antenna array and its one radio receiver to feed three indicating instruments, one for each of the three transmitters with which it works (*i.e.*, its local transmitter and its immediate neighbour on each side). The receiving station is thus its own local control station, giving location fixes for the craft within its sector, with no need for intercommunication with transmitters or other receivers. The receiving station, with its triple function, costs also approximately £3,000, again excluding land, buildings, power supply and communications. In this case, of course, communication to headquarters, probably via one intermediate area control room dealing with four receiving stations, is essential. The actual observing team would probably be three. Replacement costs would be of the order of £1 per 100 hours.

A chain of this character should be able to locate accurately and count roughly any reasonable number—of the order of thirty per sector per five minutes—of metal-framed aircraft between the coast and the location frontiers. These frontiers are not likely to lie within 130 km. for craft flying at 13,000 feet, 80 km. for 5,000 feet, 55 km. for 2,000 feet, and 40 km. for 1,000 feet, on the costs shown, and can be pushed forward at a substantial additional cost.

The installation outlined can locate in plan position only, and cannot measure flying height. The reasonable certainties discussed above give place to high probabilities only when this problem is discussed thus early.* It appears very probable, however, that at an additional cost of £2,000 per receiving station, with no additional cost at the transmitters, provision can be made for height estimation to an accuracy which may fairly be expected to reach, after a year or less of research, discrimination to 1,000 feet, save in the lowest 2,000 feet, at half of the maximum location range. A similar accuracy at quarter maximum range can probably be attained, at the same cost, within six months of research, with the team envisaged below. The probabilities of success are so high that if immediate building of any part of an interim defensive chain is undertaken the four masts required for location in plan and elevation, as opposed to two for location in plan only, should be provided at each receiving station.

The scheme detailed does not provide for following the craft after they have crossed the coast. While this could be done from the coastal chain, the additional capital cost would not be notably less than that required for separate provision, and while manning costs would be less, the risk of organisational breakdown in a large scale operation is serious. It is therefore considered that the provision for overland following should take the form of a " second line," the chain of inland hill stations mentioned earlier.

The scheme outlined included provision for minimising the effect of interference, especially of deliberate jamming. Should present expectations in respect of interference elimination be disappointed, the impossibility of keeping secret working wavelength (common to all the transmitters and receivers of one chain) or of providing a sufficiently advanced location frontier with receivers capable of quick change of wavelength, would force a decision as between two possible courses. Two or even three working wavelengths could be provided at transmitters and at plan-locating receivers at no great increase in cost, the increase not reaching 20 per cent. But at receiving stations equipped for height measurement the cost of the receiving equipment might be nearly proportional to the number of wavelengths provided. This may be avoided by further research. Meanwhile the possibility must be noted, but interim planning may proceed on the more optimistic assumption that the anti-jamming design is likely to be so effective that quick wavelength changes will not be required.

It appears essential, especially if the inland chain be added, that our own interceptor and fighter craft should be fitted with means for their identification when located by the radio chain. The fitting of these craft with special tuned aerials, automatically interrupted to give identification, seems possible at a negligible increase in weight and a small increase in drag, but *ad hoc* experiment is required and has not yet been undertaken.

It will be observed that no proposals for directional transmission or reception are embodied in this interim scheme. Were directional reception available on a footing of equal operational ease with the range-finding gear, the cost of the chain could be substantially reduced. But research extending over two years or more may well be required before instantaneous direction-finding of the required high sensitivity can be developed. This work should be undertaken, but since the main aim of the present note is to indicate what may fairly be relied on within the next twelve months, directional methods are excluded from the scheme, which is a flood-lighting scheme involving no " search " whatever, *i.e.*, no manipulative action at transmitter or receiver, for plan-location, and only the simplest electrical manipulation, the turning of one control knob, for height measurement. Directional methods may usefully supplement this static observational system, but they should be supplementary and not integral; research on these lines is proposed.

Such forecasts as have been made above have not touched the problem of the utilisation of ultra-short waves of wavelength 2 to 10 metres, which may offer a solution, applicable to the chain already outlined, of the very difficult problem of the low-flying craft and the, perhaps, still more difficult problem of ship detection. The disappointing results of one or two recent trials, of a rudimentary character, indicate the desirability of basing any urgent application work on the 25-metre results already achieved, and of leaving the ultra-short-wave developments to take the next place in priority.

Still more remote is the ultimate goal of making effective use of waves so short (·5 m.) that they would be useful in detecting a metallic engine supported in an otherwise completely non-metallic craft. Work towards this goal should begin without delay, but the technique, especially on the receiving side, is so backward that several years of work are likely to be spent before useful results are in sight.

In parallel with these investigations there should run the closely related work on the more or less direct control of mechanisms by the cathode-ray or other indicating gear utilised in location. It is doubtful whether, in view of the dependence of this work on that already outlined, any reliance should be placed on the availability of such methods of control within two or three years.

Close consideration has been given to the nature of the provision required for advancing the numerous lines of research indicated herein. The provision of a suitably situated central research and development station, of large size and with ground space for a considerable number of mast and aerial systems is a first highly urgent necessity. It should provide living accommodation for the resident Director of the radio investigations and for unmarried members of his research team and their assistants. Material provision, even on the considerable scale which is clearly necessary, is not, however, the most difficult provision. The rate of progress will be governed by the availability of a research staff of exceptional quality, and a staff of this quality and with earlier experience of the right kind can never be a very large one.

Detailed discussion of possible recruits, believed to be based on sufficient knowledge of the field of recruitment, has resulted in the finding of only four names to be put forward with a view to appointment to the research staff, in addition to the D.S.I.R., Air Ministry, and Admiralty workers already attached or available. For further part-time assistance special reliance is placed on other members of staff of the Radio Department, N.P.L., who are working on fundamental problems so closely bearing on the work that they should be brought in as consultants without being withdrawn from their present spheres save for very brief periods. The research and development team envisaged in the scheme laid down in this memorandum would thus have a Director and two Scientific Officers provided by D.S.R., Air Ministry, one or two attached by D.S.R., Admiralty, possibly corresponding officers attached by D.S.I.R. or Air Ministry, together with part-time services from other D.S.I.R. officers, a total of probably twelve full-time and three part-time officers. The ancillary staff on the research and development side should include twelve Assistants II and III, four laboratory assistants and four to six industrial staff (mechanics, carpenters and labourers).

It would also appear desirable that the training of the operating and observing corps for the chain should begin at a very early date, and that the nucleus of the corps should have its headquarters in the central research and development station so long as the exigencies of the investigational work and the organisation of the corps permitted. It is believed that the individual stations could be best manned by R.A.F. personnel of the Wireless Operator Mechanic type, with, perhaps, one officer per " unit " of one separate transmitting station and one joint transmitting and multiple receiving station. The research and development team would then have the dual role of independent investigation, for which its Director would be responsible to Air Ministry through D.S.I.R., and of consultantship to the Commanding Officer of the new signals unit responsible for the chain. It would, however, be essential that the Director should have authority to resolve minor conflicting claims on his team or to refer major claims to Air Ministry for resolution.

APPENDIX No. 4

ESTIMATES FOR RADIO DIRECTION FINDING STATIONS 10 AUGUST 1937

S.35982 (F.5). Air Ministry Memorandum No. 133

In Treasury letter S.26350/02 of 19 December 1935, sanction was given for the establishment of four radio direction-finding stations which would, with the research station at Bawdsey, form the first portion of a chain of such stations required for detection and location of enemy aircraft approaching the existing aircraft fighting zone. It was intended to carry out Service trials with these stations, and in the light of the results obtained determine the desirability of extending the system to cover the whole of the coast line concerned.

Owing to the novelty of the problems involved, there has been considerable delay in completing the works and apart from the auxiliary research station at Orfordness, only Bawdsey, Canewdon and Dover are in operation. The experiments that have been conducted have, however, been so successful that the "Defence" Plans (Policy) Sub-Committee of the Committee of Imperial Defence (4th Meeting—2) has decided that the organisation of the full chain of twenty stations should be proceeded with as quickly as possible, subject to sanction for the expenditure being obtained through the Treasury Inter-Service Committee.

The expenditure sanctioned in the Treasury letter of 19 December 1935 was :—

	£
(*a*) Purchase of sites	2,000
(*b*) Provision of eleven timber towers	38,500
(*c*) Power supply, etc.	20,000
(*d*) Incidental works	4,000
(*e*) Transmitting and receiving apparatus	3,500

Of the expenditure under (*b*), (*c*) and (*d*), £14,500 was in respect of Bawdsey and is merged in Part I, Item 5, in Air Vote 4B 1937, the remaining £48,000 being in Item 104, which also includes £7,000 in respect of the preliminary experimental station at Orfordness.

The technical developments which have since taken place call for a considerable revision of the previous proposal which was for (*a*) transmitting (only) stations and (*b*) transmitting and receiving stations to be sited alternately along the coast. All stations are now to be both transmitting and receiving and the number of towers at each will require to be increased to eight. The estimated additional cost of land and works at the five stations already approved will be :—

	£	
Bawdsey	27,000	
Great Bromley	32,000	(including £2,000 for land)
Canewdon	24,000	ditto
Dunkirk	32,000	ditto
Dover	22,000	
	£137,000	

The probable average cost of each of the fifteen new stations required to form the complete chain is :—

	£
(*a*) Land	3,000
(*b*) Towers	28,000
(*c*) Power supply, electrical distribution, stand-by plant, etc.	8,000
(*d*) Operational buildings	3,000
(*e*) Roads, paths and fencing	5,000
(*f*) Quarters for two warders	1,200
(*g*) Contingencies	3,800
	£52,000

making a total of £780,000 for the fifteen stations.

Considerably more powerful apparatus will be required than has been provided for the experimental scheme, and the cost is now estimated at £16,000 for each of the twenty stations, making a total of £320,000.

The annual operational costs of the complete chain are estimated at £174,000, made up of :—

	£
Pay of personnel	57,000
Works maintenance	20,000
Transport	10,000
Electricity, fuel and water	2,000
Telephone rentals	60,000
Maintenance of equipment	25,000

All the above estimates are necessarily provisional, but the authority of the Committee is sought for immediate action to acquire sites and to incur expenditure on works and apparatus within the figures given.

Air Ministry.
10 August 1937.

APPENDIX No. 5

NOTE BY H.Q. No. 60 GROUP ON R.D.F. CONSTRUCTION

S.A.T.'s suggestions are a valuable commentary on the urgent problem of R.D.F. construction. It is suggested, however, that they go too far in the assumption that one firm can be found who are first-class experts in civil engineering, electrical engineering, high frequency radio engineering and automatic telephone equipment. These are widely differing and highly specialised spheres, and while large firms can be found who are first-class in the one activity or another, no firm can be first-class in all. If we want the best goods in any particular class, we should go to the best shop for that class of merchandise. S.A.T.'s suggestions do not go far enough in that they fail to ensure the adequate representation at each stage of the operational, technical maintenance, and administrative considerations which are the ultimate result of construction and which are the immediate concern of the Commander-in-Chief, represented in many respects by No. 60 Group. The " user " authority's needs must be fully represented at each and every step, and he must be brought gradually into the picture as a station proceeds from conception to completion.

The process of producing an R.D.F. station in its final form is one covering many more stages and activities than can be adequately represented by the phrase " R.D.F. construction." The following table details these stages, contrasts the present authorities responsible with a suggested re-arrangement to give effect to S.A.T.'s entirely sound objective, while taking note of the points summarised in paragraph 1 :—

Stage.	*Present Authority.*	*Remarks.*	*Suggested Authority.*
1. Representation of operational requirements.	Air Ministry, Fighter Command.	—	Air Ministry (C.A.S.) and Fighter Command.
2. Definition of operational requirements.	Air Ministry, Fighter Command, and M.A.P. (D.C.D.).	60 Group can often suggest solutions based on operating experience.	Air Ministry (D. of S.) (consulting Fighter Command and 60 Group).
3. Design	M.A.P. (D.C.D.)	—	M.A.P. (D.C.D.).
4. Development ..	M.A.P. (D.C.D.) working through R.A.E.	Development is often omitted altogether under pressure of war urgency.	M.A.P. (D.C.D.) (working through " specialist " contractors).

Stage.	*Present Authority.*	*Remarks.*	*Suggested Authority.*
5. Production of installation drawings, *i.e.* technical equipment, aerials, etc.	M.A.P. (D.C.D.) working through R.A.E.	Drawing office bottle neck must be avoided. Operational and maintenance considerations are sometimes overlooked.	" Specialist " contractors (working from D.C.D.'s general arrangement sketches, which must be agreed with 60 Group).
6. Siting	M.A.P. (D.C.D.)	Practical operating and administrative considerations are not always fully considered.	Air Ministry (D. of S.) (working through siting parties composed of representatives of No. 60 Group, D. of W. and D.C.D.).
7. Layout	M.A.P. (D.C.D.)	—	Air Ministry (D. of S.) in consultation with D.G. of W., M.A.P. (D.C.D.), and 60 Group.
8. Layout drawings	M.A.P. (D.C.D.), Air Ministry (D.G. of W.).	—	Air Ministry (D.G., of W.) (guided by D. of S.).
9. Construction-schedule and time-table.	No. 60 Group	60 Group cannot enforce hastening action or cut out delaying factors.	M.A.P. (D.C.D.) 60 Group must watch progress on behalf of C.-in-C., Fighter Command.
10. Civil Engineering Construction.	Air Ministry (D.G. of W.).	Delay caused by controlling a multitude of contractors through many junior authorities.	Air Ministry (D.G. of W.) (directing one major civil engineering contractor direct).
11. Technical construction and installation.	60 Group, M.A.P. (D.C.D.), D.G. of W., G.P.O., Metro Vicks, Cossors.	Difficulty of coordination by 60 Group without power to order.	" Specialist " contractor firms working under M.A.P. (D.C.D.), 60 Gp. to watch as in item 9.
12. Testing	60 Group, M.A.P. (D.C.D.), G.P.O., Metro Vicks., Cossors.	No acceptance tests really exist under present system.	60 Gp. and M.A.P. (D.C.D.) carry out acceptance tests.
13. Phasing calibration.	60 Group ..	Shortage of aircraft and equipment.	60 Group.
14. Operational testing.	M.A.P. (D.C.D.)	No delay and efficiently done, but testing parties should be controlled by and report to operational authority.	60 Group.
15. Operation maintenance administration.	60 Group.. ..	—	60 Group.

It is suggested that the above proposals provide for a logical transfer of responsibility at well defined stages. They ensure that the ultimate users are advisers in the early stages, and that the designers become advisers in the later stages. They ensure the adequate representation of operational, administrative and practical operating considerations at every stage, and provide the means of removing most of the delays which occur at present, and for which no one authority can solely be held responsible.

Two other factors productive of delay must be mentioned :—

(*a*) The embodiment of untried and experimental equipment must be rigidly controlled. It has several times been decided that the equipment of the Chain must be standardised for a period. Perfection is the enemy of progress, and standardisation in spite of the well meant efforts of everyone concerned is conspicuous by its absence.

(*b*) Probably the most fruitful sources of delay have been the frequent changes of detail made after construction has been started. Some are unavoidable, others are not. If delay is to be avoided such changes must be stringently filtered.

(*c*) One other aspect is outside the province of 60 Group. Provisioning is the responsibility of M.A.P. (D.R.P.), advised by M.A.P. (D.C.D.) in the early stages and by Air Ministry (A.M.S.O.) later. It appears, possibly erroneously, to 60 Group H.Q. that insufficient estimates of requirements are often made in the early stages as regards spares, test gear, wavemeters, calibration equipment for aircraft and such ancillary items which, though ancillary, are none the less essential in the later stages of construction and are indispensable for technical maintenance. It also appears to 60 Group H.Q. to be many months after a station or an equipment is in operation before the necessary spares appear in the R.A.F.'s shop windows, the Maintenance Units. It is suggested that these two aspects are deserving a further examination.

APPENDIX No. 6

NOTE OF MEETING HELD ON MONDAY 6 JANUARY 1941, TO DISCUSS THE CONSTRUCTION OF R.D.F. STATIONS

Present : U.S. of S. ; A.M.S.O. ; P.U.S. ; A.C.A.S.(R.) ; D.G.W. ; D. of S. ; S.A.T. ; D.C.D. ; D.D.O.P. ; W.2 (Mr. W. G. Pullan) ; P.P.S. to U.S. of S. ; P.S. to U.S. of S. (Secretary).

U.S. of S. said that the Committee had been appointed as a result of the Secretary of State's conference on Night Interception, held on 1 January, with the following terms of reference :—

(*a*) To consider the best organisation for dealing with long term problems ; and

(*b*) To consider the exact nature of the bottlenecks which were checking work now in hand, and the best means of overcoming them.

U.S. of S. referred to the views which had been expressed in the various memoranda circulated for discussion by the Committee. The proposal by S.A.T. for overcoming the disadvantage of dispersion of effort by allocating responsibility for constructional work to a single civil engineering firm, was not considered to be practicable for the reasons given by A.M.S.O., A.C.A.S.(R.), and 60 Group. Nevertheless, all were agreed that the objective which S.A.T. had in mind was the right one.

Continuing, *U.S. of S.* said that he was impressed by the extent to which both executive responsibility and authority were subdivided. This was illustrated by the chart showing the present organisation, which A.C.A.S.(R.) had circulated. U.S. of S. had given some thought to the problem of organisation, and it seemed to him that the direction, control and execution of R.D.F. work need reorientation. At present those concerned were overburdened with other work—much of it of high priority—and there were many conflicting interests to be reconciled. It was shown by the notes by A.M.S.O. and A.C.A.S.(R.) that the idea of single units to do R.D.F.

work exclusively was already taking shape (*a*) in A.M.S.O.'s Department, where one Works Branch, under D.G.W., had a single responsibility to deal with the R.D.F. programme, and (*b*) at the R.A.E., where Sir Frank Smith was contemplating creating a special Drawing Department. *U.S. of S.* put forward as a basis for discussion the suggestion that this idea of single units should be the principle which should motivate the complete organisation. By this means those working on the different aspects would be freed from their other duties and given a single-minded purpose. If this proposal was felt by the Committee to offer the most acceptable method of speeding up R.D.F. work, a special Technical Committee might be formed from senior representatives of the different Departments in the Air Ministry and the Ministry of Aircraft Production. Each representative on such a Technical Committee should be given the responsibility of following up his particular speciality, and the Committee should be invested collectively with the powers now held severally by so many. It was for consideration whether, over and above such a Technical Committee, there might be a supervisory body to whom the Technical Committee should report, and who should be charged with the responsibility of ensuring that the Technical Committee was achieving the progress desired. If the segregation of staff for R.D.F. work resulted in a loss of work on other subjects of high priority, then it seemed that additional staff should be recruited to carry on this other work. It might be a direction to the Technical Committee, if formed, that while technical perfection was a desirable aim, the immediate need was the maximum amount of standardisation so that production and installation could proceed with greater certainty. No. 60 Group had remarked in their memorandum, " Perfection is the enemy of progress," and there did seem to be a need for early agreement on the technical equipment required, even if this was at the moment slightly imperfect.

A.M.S.O. felt that the reasons for delays in the past should be analysed if these were not to recur in the future, and means were to be devised for a general speed up. He did not think that the Works Directorate could be held responsible for any material part of the delay which had occurred.

A.C.A.S.(R.) agreed that very little delay was due to the Works Organisation in creating new stations. In certain circumstances and in certain areas construction might have proceeded more quickly if we had had more control over labour. The difficulty was, however, that we had to choose sites in remote places, and the bringing of labour to such areas was always a problem.

D.G.W. expressed the view that the chief danger of delay lay in the preliminary chain of procedure. The different stages of this preliminary action had all to be gone through before the Works Directorate could begin to function. These various preliminary stages were as follows :—

(*a*) The Air Staff determination of the requirement for a particular area.

(*b*) Reference to D.C.D. and S.A.T. as to number and type of stations, and the instruction to T.R.E. to recommend sites.

(*c*) Approval for establishment by the Inter-Services R.D.F. Committee.

(*d*) Notification by Signals 4 of the decision of the Inter-Services Committee.

(*e*) Financial approval.

(*f*) Submission of siting proposals by T.R.E. to D.C.D.

(*g*) Reference of siting proposals to Signals 4.

(*h*) Approval of site by D.G.O.

(*i*) Visit to site of representative party to prepare layout.

(*j*) Meeting between D.C.D., Signals 4, 60 Group and others to approve layout plans.

These preliminaries took, on the average, sometimes one month and sometimes several months, but until they were completed a target price could not be assessed nor could contracts be put out to tender and let.

A.C.A.S.(R.) thought that the responsibility for delay rested principally with D.C.D. on account of technical uncertainties, with D. of S. on account of changes of policy and with Home Forces in connection with the requirements of garrisoning the stations. Sometimes, after a site had been chosen, D.G.O. felt it necessary to object because of a prospective nearby aerodrome. The difficulties with Home Forces had now been overcome and delay on this score was not likely to recur following agreement on general principles with all Commands.

In reply to U.S. of S., *D.G.W.* said that contracts were put out to a short list of firms for competitive tender. The time allowed for tendering was seven days, and although tenders were considered straight away, the placing of the contract could not be done until technical details were approved.

D. of S. referred to two important factors in his experience which gave rise to delay. The first was that the Air Staff requirement was often varied, and the second was the lack of technical information required to implement the aim, once determined. He instanced the examples of the first five stations of the Western chain, concerning which there had been considerable delay because final technical proposals were not forthcoming until after the initial work had begun. He felt that early standardisation would greatly facilitate constructional work, and that much time would be saved by D.C.D. once he had produced the necessary technical information, passing out the work of preparing the necessary drawings to reputable commercial firms. By this means, not only would we be using the facilities of commercial firms of which we were in need, but the firms would be able to assist us in making sure that the particular specification was a practicable proposition.

S.A.T. referred to his note to the Secretary of State of the 21 December. In this note he expressed the view that we had not yet proportioned our effort in the installation of R.D.F. stations to the size and urgency of the programme, and that our partial failure was due to planning on too small a scale and to dispersion of interest and effort. He would ask D.G.W., D.C.D., D. of S. and other heads of Departments how many of their officers were allocated to R.D.F. work and then, in the light of the answers, whether the numbers were proportioned to the problem involved. He thought that the answer could only be that the numbers engaged on the work were small relative to the need. One reason given as a cause of delay was that the scientists frequently changed their minds as to the technical requirements ; but it might be argued that if the numbers responsible for the work of installation had been large enough, many of the stations required would have been well on the way to erection before the scientists would have had time to vary their views. A year ago, when he had left D.C.D., a policy had been agreed for twenty stations on the East Coast. The installations for these had been designed, but now, a year later, not one of the stations was in a final state.

D.C.D. said that the programme provided for a hundred stations in the next fifteen months in England alone. He, for his part, was prepared to say that the necessary technical information would be forthcoming in the time required, subject to—

(i) Broad scale planning being expressed in terms of number of stations per month and related to definite places on which siting parties could get busy ;

(ii) The siting parties including all interests, and their report being rendered to a committee who should have power to accept a particular site finally ; and

(iii) Limited standardisation, with control over the introduction of untried and experimental equipment.

The programme could then be translated in terms of target dates for the completion of the different stages and the necessary provision could be made for any extra staff required to implement the agreed time-table.

In reply to U.S. of S., *D.D.O.P.* said that there had been no material delay in the past in connection with the requisitioning of sites for R.D.F. stations. Normally, as soon as the siting party's recommendations were received, D.G.W. was asked to go forward at once unless there was objection to a particular site because of the conflicting claims for aerodrome construction.

U.S. of S. said that the Committee were in general agreement that an R.D.F. Technical Committee would serve a valuable purpose, and he proposed that a recommendation should be made to the Secretary of State in favour of the setting up of a high level standing R.D.F. Committee. He would suggest that until such a Committee had clarified the present position and had succeeded in clearing the existing bottle-necks, it should meet weekly, and that its broad terms of reference should be to review the current position, to define the objectives and agree programmes, to endeavour to stage out the work and arrive at target dates for completion, and generally to watch progress and co-ordinate the work throughout the different stages. He would recommend that the personnel of this Committee should consist of A.C.A.S.(R.) as Chairman, D.G.W., D. of S., S.A.T., D.C.D., D.D.O.P., a representative of the Air Staff and a representative of Finance to be nominated by P.U.S., together with a Secretary. It was for the consideration of the Chairman designate whether a senior officer of Fighter Command should also be a member. This Committee would have a common and collective responsibility, but it could not be a Committee which worked by vote because each representative would have his own responsibility and could not be voted down. The relation between Fighter Command and the Air Staff would need clarification. It was felt that D.H.O. should represent the Air Staff, and A.C.A.S.(R.) undertook to obtain C.A.S.'s approval to this.

Some discussion took place in regard to the relation of such a Technical Committee to the Inter-Services R.D.F. Committee and to the R.D.F. Panel of that Committee. It was agreed that the new Technical Committee should not be allowed to interfere in any way with the Inter-Services Committee, since the objectives of each were quite distinct. The new Committee's main function would be that of watching progress and it should not become involved in a discussion of radio techniques, which was the responsibility of the Inter-Services Committee.

It was also agreed that those senior officers appointed to membership of the new Committee should be made aware of the importance of the work, and that they should be asked themselves to attend meetings whenever possible and not to send members of their staff to represent them.

APPENDIX No. 7

LIST OF R.D.F. STATIONS EXISTING AND PROJECTED, JANUARY 1941

No.	*Name.*	*Present State.*	*Eventually to be.*	*Remarks*
56	Skaw	A.C.H.	C.H.	
56A	Saxa Vord	C.H.L.	C.H.L.	
54	Noss Hill	A.C.H.	C.H.	
54A	Grutness	C.H.L.	C.H.L.	
53A	Fair Isle N.	C.H.L.	C.H.L.	
53B	Fair Isle S.	C.H.L.	C.H.L.	
51	Whale Head	Under constrn.	C.H.	
51A	Sanday	Proposed	C.H.L.	
72	Crustan	Under constrn.	C.H.L.	
50	Nether Button	C.H.	C.H.	
50A	Deerness	C.H.L.	C.H.L.	
50B	S. Ronaldsay	C.H.L.	C.H.L.	
49	Thrumster	A.C.H.	C.H.	
49A	Tannach	C.H.L.	C.H.L.	
49B	Dunnet Head	C.H.L.	C.H.L.	
48	Loth	Final layout approved.	C.H.	
48A	Cromarty	C.H.L.	C.H.L.	
47	Hillhead	I.C.H.	C.H.	
47A	Rosehearty	C.H.L.	C.H.L.	
47B	Cocklaw	Under constrn.	C.H.L.	
46	Schoolhill	C.H.	C.H.	
46A	Doonies Hill	C.H.L.	C.H.L.	
45A	St. Cyrus	C.H.L.	C.H.L.	

No.	*Name.*	*Present State.*	*Eventually to be.*	*Remarks*
44	Douglas Wood ..	C.H.	C.H.	
43A	Anstruther	C.H.L. ..	C.H.L.	
42	Drone Hill	C.H.	C.H.	
42A	Cockburnspath ..	C.H.L. ..	C.H.L.	
41A	Bamburgh	C.H.L. ..	C.H.L.	
40	Ottercops	C.H.	C.H.	
40A	Cresswell	C.H.L. ..	C.H.L.	
39A	Shotton	C.H.L. ..	C.H.L.	
38	Danby Beacon ..	C.H.	C.H.	
37A	Bempton	C.H.L. ..	C.H.L.	
36	Staxton Wold ..	C.H.	C.H.	
35A	Easington	C.H.L. ..	C.H.L.	
34	Stenigot	C.H.	C.H.	
34A	Skendleby	C.H.L. ..	C.H.L.	
32	West Beckham ..	C.H.	C.H.	
(32M	Kelling)	Proposed ..	Emergency. Alternative M.R.U.	
31A	Happisburgh ..	C.H.L. ...	C.H.L.	
30	Stoke Holy Cross ..	C.H.	C.H.	
(30M	Avenue)	Proposed ..	Emergency. Alternative M.R.U.	
30A	Hopton	C.H.L. ..	C.H.L.	
38	Hight Street, Darsham	C.H.	C.H.	
(28M	Hinton)	M.R.U. ..	Emergency. Alternative M.R.U.	
28A	Dunwich	C.H.L. ..	C.H.L.	
26	Bawdsey	C.H.	C.H.	
(26M	Cedars)	Proposed ..	Emergency. Alternative M.R.U.	
26A	Bawdsey	C.H.L. exp. ..	C.H.L. for Naval use.	
24	Great Bromley ..	C.H.	C.H.	
(24M	Frating)	Proposed ..	Emergency. Alternative M.R.U.	
23A	Walton	C.H.L. ..	C.H.L.	
22	Canewdon	C.H.	C.H.	
(22M	Loftmans)	Proposed ..	Emergency. Alternative M.R.U.	
02	Dunkirk	C.H.	C.H.	
(02M	Cutballs)	M.R.U. ..	Emergency. Alternative M.R.U.	
02A	Whitstable	C.H.L. ..	C.H.L.	
03A	Foreness 1	C.H.L. ..	C.H.L.	Held as reserve.
03B	Foreness 2	C.H.L. ..	C.H.L.	
04	Swingate	C.H.	C.H.	
04A	Swingate	C.H.L. ..	C.H.L.	
(04M	Hollingbury) ..	M.R.U. ..	Emergency .. Alternative M.R.U.	Now mobile for Newchurch.
73	Newchurch	I.C.H. under construction.	C.M.	
05	Rye	C.H.	C.H.	
(05M	Harvey)	M.R.U. ..	Emergency. Alternative M.R.U.	
05A	Fairlight	C.H.L. ..	C.H.L.	
07	Pevensey	C.H.	C.H.	
(07M	Chilley)	M.R.U. ..	Emergency. Alternative M.R.U.	
07A	Beachy Head ..	C.H.L. ..	C.H.L.	
07B	Truleigh Hill ..	C.H.L. ..	C.H.L.	
08	Poling	C.H.	C.H.	
(08M	Angmering Park) ..	M.R.U. ..	Emergency. Alternative M.R.U.	

No.	Name.	Present State.	Eventually to be.	Remarks.
10	Ventnor	C.H.	C.H.	
(10M	Paradise)	Proposed	Emergency. Alternative M.R.U.	
10A	Bembridge	C.H.L.	C.H.L.	
11	Southbourne	Under constrn.	C.H.	Short masts.
12	Worth Matravers	I.C.H.	Research.	
12A	Worth Matravers	C.H.L.	C.H.L.	
12	Ringstead	Under constrn.	C.H.	
13	Branscombe	A.C.H.	C.H.	
14	West Prawle	A.C.H.	C.H.	
14A	West Prawle	C.H.L.	Withdraw when Kingswear ready.	
14A	Kingswear	Under constrn.	C.H.L.	
15	Downderry	A.C.H.	C.H.	
15M	Hawkstor	A.C.H.	Reserve.	
15A	Rame Head	C.H.L.	C.H.L.	
64	Tower BLACKPOOL	Under constrn.	C.H.	Special C.H.
64B	Tower	Under constrn.	C.H.L. (Naval)	Special C.H.L.
64A	Formby	Under constrn.	C.H.L.	
78	Kilkeel	Sited	C.H.	
78A	Ballymartin	Proposed	C.H.L.	
63A	Cregneish	C.H.L.	C.H.L.	
63	Scarlet	A.C.H.	C.H.	
79	Dalby	Layout done	C.H.	
62A	Maughold	Proposed	C.H.L.	
62	Bride	A.C.H.	C.H.	
61	Greystone	Sited	C.H.	Resite of Kirkistown Castle.
61A	Roddans Port	Proposed	C.H.L.	Resite of Ballycranmore.
60	North Cairn	A.C.H.	C.H.	
60A	Glenarm	C.H.L.	C.H.L.	
59	Castlerock	A.C.H.	C.H.	
59A	Downhill	C.H.L.	C.H.L.	
58A	Kilchiaran	C.H.L.	C.H.L.	
58	Saligo	A.C.H.	C.H.	
80A	Easdale	Proposed	C.H.L.	Area proposed. Names and sites chosen.
82	Tiree	Proposed	C.H.	Ditto.
83	Tiree	Proposed	C.H./B.	Ditto.
84A	Port A	Proposed	C.H.L.	Ditto.
84	Port A	Proposed	C.H./B.	Ditto.
85	Butt of Lewis	Proposed	C.H./B.	Ditto.
85A	Butt of Lewis	Proposed	C.H.L.	Ditto.
77	Islay	Proposed	C.H./B.	Ditto.
57	Sango	A.C.H.	C.H.	
57A	Sango	Proposed	C.H.L.	

Note.—Names of " Proposed " stations have in some cases not been approved by D.G.O.

APPENDIX No. 8

THE DEVELOPMENT OF THE HIGH POWER PULSED MAGNETRON VALVE AND ULTRA HIGH FREQUENCY R.D.F. TECHNIQUE

At the sixteenth Meeting of the Committee for the Scientific Survey of Air Defence on 25 February 1936, Sir Robert Watson Watt pointed out the possibility of using wavelengths of the order of 1 centimetre for R.D.F. purposes.[1] The technical difficulties in the way of generating such wavelengths in adequate transmitting power were formidable, and during the early development of R.D.F. pre-war such research could not be undertaken—all efforts were directed to the development of the Home Chain and early airborne R.D.F. equipment. With the introduction of teams of scientists working at various University centres after the outbreak of war it was possible to undertake specialised research in ultra-high frequency techniques.

Theoretical studies made years before the war had shown that efficient oscillatory circuits could be made by using metal cavities proportioned to resonate electrically at the wavelength concerned. Similarly, the general nature of aerials and feeders most suitable for centimetric wavelengths had been established theoretically,but these theories were not well co-ordinated and were outside the field of most radio engineers.

In the matter of valves the position was rather more advanced. It was known that ordinary valves could not be used, but special valves had been developed though the power generated was small. The two important types of valves which could be employed to oscillate at these ultra high frequencies were—

(*a*) The Split Anode Magnetron.
(*b*) The Klystron Valve.

The Split Anode Magnetron Valve was first described by Hull in the United States in 1921, and later had been applied by Yagi, in Japan, for the generation of short wave oscillations. The valve had been developed considerably, especially by the G.E.C. Reseach Laboratories and the S.F.R. Laboratories in Paris. The most important advance made by these workers was to use a segmented anode in the valve, these segments being cut to resonate at the required ultra-high frequency. By mid-1939 peak pulse powers of the order of 1 kilowatt had been obtained at wavelengths of the order of 40 centimetres, but the power output dropped rapidly when the wavelength was decreased to the 10 centimetre region.

The Klystron Valve had been invented in the United States of America and worked on a different principle from the Magnetron. It made use of resonant cavities (so called rhumbatrons). Continuous powers of about 100 watts had been obtained at wavelengths around 10 centimetres, but the valves were complicated and required continuous evacuation.

Such was the position in the autumn of 1939 when Professor M. L. Oliphant, of the University of Birmingham, agreed with the Director of Scientific Research, the Admiralty, to undertake a programme of research on the production of wireless waves of wavelengths between 5 and 15 centimetres with much higher power output than the then known valves permitted.[2]

An examination of first principles and also the most recent literature on the production and detection of wireless waves of a frequency of 3,000 megacycles per second or greater showed that the only hope of producing efficient generators of such oscillations was to combine the generator and circuit in a single unit, and that the circuit should be one of high efficiency made from the best possible electrical conductors. A superficial examination of existing magnetron devices showed that the circuits were made of highly resistant materials and in a form where radiative and resistant damping seriously reduced the efficiency. Accordingly, a programme was drawn up for the detailed investigation of the velocity-modulation methods using rhumbatron resonators, together with the possibility of introducing the rhumbatron technique to improve the circuit of the magnetrons. Plans were drawn up of a possible trial apparatus and the work was entrusted to Dr. (later Professor) J. T. Randall and Mr. H. A. H. Boot. They found it was far from easy to transform the existing types of resonator rhumbatrons for use in the magnetron,

[1] Minutes of C.S.S.A.D., 16th Meeting, 25.2.26.
[2] D.S.R. Admiralty Folder, C.V.D. 371.

and, with considerable insight, decided to try the less efficient cylindrical form of resonator—which was at once successful. The general form of their ideas at that time with regard to the mode of action and general construction have been little modified by subsequent work.

Their valve worked for the first time on 21 February 1940, giving 500 watts of continuous power on a wavelength of 10 centimetres—a tenfold increase over the previous best.[1] This first cavity magnetron was a laboratory model—somewhat clumsy—and it had to be evacuated continuously so that the additional bulk of a high vacuum pump was involved. The success of this new development of the cavity magnetron nevertheless revolutionised the methods of centimetre wavelength radio engineering.

In April 1940 the General Electric Company were shown the valve and agreed to make a sealed-off version. A smaller and properly engineered valve was produced by them during May 1940, the E.1188, and the first sample was sent to Birmingham University in July 1940—only nine months after the original research had been undertaken there which had led to the Randall-Boot Magnetron.[2] The output of this valve at 10 centimetres wavelength was of the order of ½ kilowatt.

Fortuitously, during May 1940, just before France was overrun by the enemy, representatives of the S.F.R. Laboratories, Paris, visited the G.E.C. Research Laboratories, bringing with them samples of their M.16 resonant segment magnetron with permission from the French Government to disclose all details of its development. These valves had been greatly improved by the inclusion of a large oxide cathode instead of the usual thoriated tungsten cathode. The power output of this valve was about ½ kilowatt, but the oxide cathode principle appeared to have application at higher voltages and powers in its use in transmitting valves of this type. The G.E.C. Research Laboratories produced a new design of valve (the E.1189), using the Randall-Boot cavity magnetron with an oxide cathode—with immediate success when this valve first operated in June 1940. The pulse output was of the magnitude 10 kilowatts on a wavelength of 10 centimetres—a twenty-fold increase in power over the previous valves. These principles soon spread to larger transmitting valves so the French had made a useful contribution to British Radar by their disclosure of the success of oxide cathodes. This new valve (the E.1189) also made use of permanent magnets instead of the electro-magnets used in the original Randall-Boot design, thus giving a further important saving in bulk and weight.

In the meantime, work on centimetre wavelengths on the receiving valve side had been going on at the Clarendon Laboratory, Oxford, and by the Admiralty Signals Establishment team at Bristol University. Work was also done at the research laboratories of Electrical and Musical Industries and Standard Telephones and Cables.

Early in 1940 the Telecommunications Research Establishment team at Dundee began studying ultra-high frequency circuits, whilst the airborne group at St. Athan considered the scanning methods in centimetre A.I. The culminating point in the basic phase of centimetric development was reached at T.R.E. on 13 August 1940, when echoes were obtained from a Battle aircraft, and later at five miles on a Blenheim aircraft in September.

The history of the development of centimetre R.D.F. is one of the most striking in the whole course of war-time technical development. It sprang from the R.D.F. scientists' appreciation of the tactical possibilities of this new technique, from their realisation at a very early stage in their work that the fullest exploitation of R.D.F. for the purpose of A.I. and gunnery control demanded the use of very much shorter wavelengths at a power which then could not be generated.

The most important and revolutionary development, the cavity magnetron, was working within three months of the problem being given to the inventor. Only eighteen months later, centimetre R.D.F. was in daily use by both the Royal Navy and the Royal Air Force. The whole development is one of a magnificently co-ordinated effort, from the original research, through the testing and production stages, to the Service employment of the centimetre equipment, all taking place in the minimum of time.

[1] C.V.D. Report, May 1941, " Magnetron Development in the University of Birmingham."
[2] G.E.C. Report No. 8717, Ref. C.V.D., 30.8.45.

APPENDIX No. 9

R.D.F. CONSTRUCTION PROGRAMME IN CONNEXION WITH THE BATTLE OF THE ATLANTIC

C.H.L. Stations

Priority.	Area where Improvement is Necessary.	Station.	Action.
1	Liverpool and Approaches.	(*a*) Cregneish, I.O.M.	VT.98s switched T. & R., P.P.I.-11.
		(*b*) South Stack ..	New station, VT.98s, power turning, P.P.I.
		(*c*) Prestatyn ..	VT.98s switched T. & R.
		(*d*) St. Bees Head	New station, site selected and laid out.
		(*e*) Barrow ..	New station sited, layout proceeding.
		(*f*) Gt. Ormes Head	New station, VT.98s and P.P.I
		(*g*) Peny-bryn ..	New station, power turning, VT.98s.
2	Bristol Channel and Approaches.	(*a*) Kete	New station, VT.98s, power turning, P.P.I.
		(*b*) St. Twynnells..	VT.98s switched T. & R.,P.P.I.
		(*c*) Strumble Head	VT.98s switched T. & R.
		(*d*) Hartland ..	New station, VT.98s, power turning, P.P.I.
		(*e*) Trevose ..	New station, power turning, VT.98s.
		(*f*) Marks Castle ..	New station, power turning, VT.98s and P.P.I.
3	Isle of Wight to The Wash.	Bembridge ..	60 Group to improve existing installation and make recommendation on layout of completely new station.
		Truleigh Hill ..	VT.98s switched T. & R., P.P.I.
		Beachy Head ..	VT.98s switched T. & R., P.P.I.
		Fairlight	VT.98s switched T. & R.
		Whitstable ..	VT.98s switched T. & R., P.P.I.
		Hopton ..	VT.98s switched T. & R.
		Bawdsey	P.P.I.
		Walton	VT.98s.
		Dunwich	VT.98s.
		Happisburgh ..	VT.98s and P.P.I.
4	Firth of Forth ..	Anstruther } Cockburnspath }	Both these stations already fitted VT.98s. Switched T. & R. will be fitted at Anstruther.
5	Rattray Head ..	Cocklaw	Station recently installed; VT.98 coverage should now be adequate.
6	The Clyde ..	Glenana	VT.98s, switched T. & R., P.P.I
7	South West Coast	Kingswear } Pen Olver }	New station, power turning, VT.98s. New station, special type.

Note.—Only fourteen hand-made P.P.I.s can be made available on a short term basis. Thirteen are allocated above and one will be kept against emergency requirements. Power turning gear can only be provided on a short term basis at stations where the gantries have been suitably designed. The conversion of existing stations is a longer term project. The priority within a given area is indicated, but may be varied by No. 60 Group to suit their installation programme.

C.H. Stations

Northern Area

Skaw .. .. .. Noss Hill .. .. Whale Head	The T-towers (360 feet) are complete at all these stations. At least one R-tower is complete at each station. Aerial fabrication will be started this week and erection is planned to be complete this month. The final buildings are now sufficiently advanced to enable the equipment to be shipped. Whale Head is to be equipped with all-round looking aerials and should then plot high-flying aircraft successfully over the Flow.
Nether Button ..	The all-round looking array with full power gap fillers is being lined up this week. The completion of the stand-by power has been greatly delayed by the sinking of a ship, but replacement parts will be provided very shortly.
Hillhead	This is operating as an I.C.H., but with the reduced power available from an M.B. Ia. The Met-Vick C.H. transmitters are being installed and one will be ready 1.5.41. The T-masts have been greatly delayed, but are now nearly complete, and it is planned to have T-aerials erected by the time the transmitter is ready.
Loth .. .. .. Thrumster	These are operating as A.C.H. stations. Work is not well advanced, but their completion is required less urgently than the above.

East and South-East Coast Area

Stoke Holy Cross ..	A 2 I.U. party is at present on site in order to swing the T-array 15°. This should help to fill the gap.
High Street	If the swinging is successful at Stoke Holy Cross, High Street's T-aerials will be swung 10° North.
Newchurch	Works progress on this station has been very slow.

Isle of Wight to Portland Bill

Southbourne .. .. Ringstead	Layout was approved on 25.11.40, but Works services are taking an unconscionable time. On 11 March there were only twenty workpeople at each of these stations.

Portland Bill to Land's End

Branscombe .. .. Dry Tree	The " Short term installation programme " provides for I.C.H. at both these stations, and these now operating.
West Prawle	Final Works services are practically complete. The installation of final equipment is proceeding.
Trelanvean	This site has now been found satisfactory for a final station and a layout was approved.

Land's End to Pembroke

Trerew	A " Short term installation programme " provided for I.C.H. at both these stations. It is planned to complete the calibration and phasing, weather permitting, by 10 April.
Hawks Tor	Instructions have been issued to provide this station with an H.F.7 receiver.
Northam	The height calibration of the A.C.H. station was completed on 19 March.

St. David's Head

Hays Castle Cross ..	The short term installation programme provided for I.C.H. at these stations, and this is at present being phased.
Folly	A final layout was approved (including VEB) for this station on 24.3.41. In order to provide immediate cover a mobile is being erected two miles north of the final site. Later the mobile stage will be converted to A.C.H., when height-finding over a limited azimuth will be provided.

Cardigan Bay No comments.

Approaches to Liverpool

Nevin	This station is now operational as an I.C.H.
Rhuddlan	This station is now operational as an A.C.H. and should give greatly improved performances over the mobile which was operating at St. Georges. Limited height-finding should now be possible.
Scarlet .. .. .. Bride	Works services on the final C.H. progressing slowly. Both operating as an A.C.H.
Kilkeel	Considerable shipping difficulty was encountered in transporting gear across to Kilkeel. This is now overcome and Kilkeel will not be long delayed.
Wylfa	On 4 February Works undertook to do a survey as the ground was very uneven and it was necessary to get the mast levels for the final station correct. Works services progressing slowly.
Tower	This station is of special construction and work has consequently been delayed; we are informed by D.C.D. that this station will not become operational before the end of May.

North Channel Area

North Cairn	The final T-towers (360 feet) and R-towers are complete. The final buildings are almost complete and it is planned that this station should become operational with final equipment by the end of May. Further progress towards the final stage at the remaining stations in this area is dependent upon the completion of Works services.

Glasgow

Kilmacolm	This station was erected at the express wish of the C.-in-C., Rosyth, in order to provide early warning of high flying aircraft approaching Rosyth from the Glasgow area. Considerable difficulty has been experienced in obtaining acceptance of this station's plots due to the fact that the G.P.O. are unable to provide a line to the N.W. Filter Room. Lines were provided to Turnhouse and Prestwick, but these stations were unused to accepting unfiltered plots. As a result no use was made of the station. It is understood that you have now instructed these stations to make use of Kilmacolm plots and to ensure that the information is passed to Rosyth.

West Coast of Scotland

Portmor (Tiree) .. Works services for an A.C.H. station have been completed for four weeks, but considerable delay has been experienced due to limitations of landing and transport facilities. This matter has now been cleared, and the equipment will be shipped the second week of April.

Barrapol .. .. The 17th Meeting of the Inter-Service Committee held on 18 March deferred approval for this station as S.A.T. questioned whether it would serve a useful function. A comprehensive plan to provide high and low coverage in the Hebrides area was given provisional approval on 24.3.41 at a meeting at which your Headquarters was represented. The recommendations are being submitted to the next meeting of the Inter-Services Committee.

Height Finding—General

In view of the difficulty of finding suitable sites in the west, D.C.D.'s new method of height-finding (VEB) is to be tried out at Folly (St. David's Head) on a 240-foot timber tower. Air Ministry have asked that D.C.D. should endeavour to develop this system using 120-foot towers and one of these towers has been sent to North Cairn in order that experiments may be conducted.

APPENDIX No. 10

SUMMARY OF THE TYPES OF R.D.F. STATIONS FOR USE OVERSEAS, 1940

(Extracted from an Air Ministry Memorandum to the General Plan for A.M.E. Stations in the Middle East.)[1]

Type.	Purpose.	Approx. Range.	Transmitter Towers.	Receiver Towers.	Height-Finding.	Remarks.
C.O.	Long range aircraft detection.	100 miles	325 feet steel masts.	240 feet, wood, self-supporting.	Yes	All-round illuminations.
C.O.L.	Detection of low-flying aircraft.	30 to 50 miles, depending on site.	None at present—new type under development with towers.		No—possibly Yes with new type.	Also detected high flying aircraft. Same as Army G.L.
MB1	As C.O.	35 miles	Both towers are 70 feet demountable.		Height-finding in some circumstances.	Site can be changed in three to four days.
G.M.	As M.B1	30 miles	As MB1	As MB1	—	Emergency equipment, Army G.L. transmitter and receiver modifies MB towers.

At those stations which were considered to be in the cyclone area the 325-foot steel transmitting masts and the 240-foot wood receiving towers were to be replaced by 200-foot steel masts and 125-foot timber towers which had been designed to suit hurricane conditions.[2]

[1] A.M. File S.5734, Encl. 51B.

[2] A.M. File S.44211, Encl. 71B.

APPENDIX No. 11

SUMMARY OF R.D.F. OVERSEAS, OCTOBER 1940

Area.	C.O.	C.O.L.	T.R.U.	M.R.U.
Egypt ..	Ikingi Mariut* Damietta* Gebel Qatrani* Wadi Natrum* Ismailia 6th Station	Alexandria No. 9. One in reserve, No. 10.		Ikingi Mariut *Op.* El Dhaba (204) *Op.* Aboukir (205) *Op.* Sidi Barakat (252) *Op.* Ikingi Mariut (219) *S.* Four more stations†.
Sudan ..	Khartoum* Port Sudan			Khartoum (221). Port Sudan (251) *Op.*
Aden ..	Aden	Ras Marshag No. 5* *S.*	Amman Khal *Op.*	Aden (220) *S.*
Mediterranean.	Malta* Haifa* Gibraltar	Malta, Maddelena* *S.* Ta Silch* *S.* Dingli* *S.* Haifa, No. 4* *S.* Haifa, No. 8 Gibraltar, No. 7.	Malta (two) *Op.* (241 & 242) Haifa (one) *Op.* (236)	
East Africa	Mombassa*			Mombassa (218) *S.*
West Africa	Freetown Takoradi	Freetown (two)†.	Freetown (one).†	Freetown (one).†
Far East ..	Singapore Hong Kong Trincomalee Rangoon Colombo Penang	Singapore (two).†	Singapore (one).†	Singapore (one).†
West Indies	Trinidad			
India ..		Karachi Bombay Cochin Madras	Calcutta	

Op. = Now operating.
* = Under construction.
S = Soon operating (probably within one month).
† = Intention to despatch about 31.11.40.

SUMMARY OF R.D.F. POSITION IN THE MIDDLE EAST COMMAND PREPARED FROM INFORMATION AVAILABLE ON 7 MARCH 1941[1]

1. Egypt

(*a*) *In Operation.*

204 M.R.U. At El Dhaba.*
205 M.R.U. At Aboukir.
219 M.R.U. At Port Said.
A.M.E.S. (Intermediate C.O.). At Ikingi Mariut.

* To be removed to Malta.

(*b*) *In the course of being installed.*

216 M.R.U. Tobruk.
235 M.R.U. Benghazi.

(*c*) *Planned.*

(i) Further M.R.U.s had been shipped, details of which were as follows :—

M.R.U.	*Date of Despatch.*	*Estimated Date of Arrival.*	*Destination.*
253	18.1.41	—	Khartoum, Sudan.
254	18.1.41	—	Heraklion, Crete.
255	18.2.41	30.4.41	To replace 204 M.R.U.
256	18.2.41	30.4.41	To replace 205 M.R.U.
257	21.2.41	30.4.41	To replace 219 M.R.U.
258	21.2.41	30.4.41	To replace 251 M.R.U.
259	21.2.41	30.4.41	To replace 252 M.R.U.
260	21.2.41	30.4.41	Burg El Arab area (Egypt).
261	Awaiting despatch.		Fuka area.
262	Awaiting despatch.		Sidi Barrani.
263	Awaiting despatch.		Command Reserve.
264	Awaiting despatch.		Command Reserve.

M.R.U. 265 and T.R.U. 244 were being transferred immediately to the Middle East, T.R.U. 244 to sail on 10.3.41, but shipping space had not yet been allocated to M.R.U. 265.

(ii) C.O.L. stations had been despatched as follows :—

C.O.L. Stations.	*Date of Despatch.*
9	30.1.41. For Sidi Barrakat.
10	30.1.41. For Command Reserve.
15, 16, 19, 20	Still being assembled for Command Reserve.

2. Sudan

(*a*) *In Operation.*
251 M.R.U. At Port Sudan.

(*b*) *Planned.*

At the request of Headquarters, Middle East, all work had been stopped on the C.O. sites under construction at Port Sudan and Khartoum.

[1] A.H.B/IIE/70, Encl. 187A.

3. Palestine

(*a*) *In Operation.*

236 T.R.U.	At Mount Carmel, Haifa.
3 C.O.L.	At Stella Maris, Haifa.

(*b*) *Planned.*

A further C.O.L. station, No. 8, had been despatched on 18.1.41, to be installed at Nesher, Haifa, to give cover to the North East. The site had been selected and erection was proceeding. The site for the C.O. station at Athlit had also been selected.

4. Aden

(*a*) *In Operation.*

240 T.R.U.	At Aman Khal.
6 C.O.L.	At Ras Marshag.

(*b*) *Being Installed.*

5 C.O.L.	At Bir Fukum.
220 M.R.U.	At Aden.

(*c*) *Planned.*

The construction of a C.O. station at Lahej was in abeyance.

5. Kenya

(*a*) *In Operation.*

218 M.R.U. At Lakoni, Mombasa.

(*b*) *Planned.*

Additional cover was at present afforded by two small sets of equipment provided by the South African Army. It was proposed eventually to replace these by C.O.L. stations, but no date could be forecast. A C.O. station was also sited at Mombasa.

6. Malta

(*a*) *In Operation.*

241 T.R.U. 242 T.R.U.	At Fort Dingli.
2 C.O.L.	At Fort Madalena.
1 C.O.L.	At Fort Ta Silch.
4 C.O.L.	At Fort Dingli.

T.R.U.s 241 and 242 were on the same site in order to give twenty-four hour operational cover.

(*b*) *Planned.*

M.R.U. 204 was being transferred to Malta from El Dhaba. A C.O. station was under construction at Rabat, but no indication as to its becoming operational could be given.

7. Iraq

No equipment had been allocated and the plan for this area was still in abeyance.

8. West Africa

M.R.U. 256 and T.R.U. 244 were being transferred from Freetown to Egypt. Two C.O.L. stations (Nos. 13 and 14) had been despatched to Freetown, but all equipment had been lost en route.

Planned.

A C.O. station had been sited at Freetown and instructions to proceed with the erection given.

The provision of R.D.F. cover had been authorised for Takoradi, but no instructions had been received for works services to proceed.

9. Greece

(*a*) *In Operation.*

221 M.R.U. At Araxos.

(*b*) *Planned.*

No definite plans had been made for further equipment for Greece, but it was thought that additional cover might be required in the Larissa and Salonika areas. Survey of this country, however, had made it clear that the terrain was most unsuitable for the type of equipment likely to be available.

10. Crete

(*a*) *In Operation.*

252 M.R.U. At Aroni, Suda Bay.

This A.M.E.S. was scheduled for a site at Maleme, but owing to flooded roads had not yet been able to take up its correct position. It was hoped that a move would be possible soon.

(*b*) *Planned.*

A second M.R.U. was anticipated for the Heraklion area, but no date was predicted.

APPENDIX No. 13

AN APPRECIATION OF THE ATTEMPT TO DEVELOP SATISFACTORY R.D.F. COVER FOR ADEN

By 21 October 1940 No. 220 M.R.U. and Nos. 5 and 6 C.O.L. Units had arrived in the Convoy "Appeal" at Headquarters, Middle East, where they awaited transport to Aden.[1] Then began a long and complicated three-cornered correspondence between Air Ministry, Air Headquarters, Middle East, and Air Headquarters, Aden, as to where the equipment should be sited. Air Headquarters, Aden, complained that sites quoted by the Air Ministry had been selected long before the latest information of the effect of siting on performance had been propounded, and that they were consequently out of date and it was essential that an R.D.F. expert should visit the area and advise generally on the situation.[2] As a further incentive they pointed out that much expense might be saved by the equipment being installed on the correct sites from the start.

Coincident with the arrival of this R.D.F. equipment in Cairo came the appeal for aid to Greece, and it was decided to send M.R.U. 220 to Khartoum for possible later shipment to Greece and to cancel the C.O. station for Aden indefinitely.[3] A suggestion was made that the poor performance of the only existing piece of

[1] A.M. File M.S. 50530/R, Encl. 16A. [2] *Ibid.*, Encl. 23A. [3] *Ibid.*, Encl. 28A.

R.D.F. equipment at Aden, the T.R.U. at Amman Khal, might be improved by the provision of a new MB2 transmitter, a new RM3A receiver, Lister diesel power supplies and new aerial arrays looking North and South; but it was doubtful whether it was worth attempting to get this equipment up the mountain side, as permanent echoes rendered much improvement of the performance more or less impossible.[1] Many other solutions were proffered from all sides and finally reports were made locally on each proposed site and sent to Headquarters, Middle East, for perusal by the Chief Radio Officer, Wing Commander Tester. From these it could be deduced that Ras Marshag appeared to be the only site that would be satisfactory from a technical point of view for No. 6 C.O.L. Unit, but there were several possible sites for No. 5 C.O.L.[2] None were outstanding and all had certain bad drawbacks. Bir Fukum[3] was thought to be an exceptionally poor site, and the siting of a station at this spot was considered by the local surveying party to be a complete waste of time, labour, and valuable equipment. The remaining proposed sites lay at Little Aden, Aden, and Ras Imran, all of which had some favourable point to recommend them.

The siting of the M.R.U. was an easier problem as removal to a more suitable site could be easily effected. A site slightly south of Sheik Othman on the flat ground North of Aden was chosen. This would enable the M.R.U. to look in an easterly and south-easterly direction, from which enemy aircraft were expected, and with its floodlight coverage it would be possible to give directives to the C.O.L. stations. It was not expected that it would be able to identify aircraft within twelve miles of Aden, due to the mass of permanent echoes from the wireless masts at Khormaksar, from Aden, and from Little Aden, but the further the station was removed from Aden the greater this dead area would be.

By 4 January 1941 the equipment for No. 5 C.O.L. had arrived at Aden, and still no site had been officially approved or surveyed by experts.[4] So great had the problem of siting at Aden proved that numerous experts were giving it attention, and a conference was held at Air Ministry to discuss the difficulties. As a result of the decisions reached at this conference, a signal was sent to Aden on 20 January 1941 requesting that the erection of technical huts should be begun on the original site of Bir Fukum for No. 5 C.O.L. station. No. 6 C.O.L. station by this time had been installed at Ras Marshag in incomplete buildings.

The main obstacle to smooth running of R.D.F. in Aden seemed to be the weather.[5] With its oppressive climate and psychologically depressing outlook it was not an ideal locality for trying out new and highly technical projects. There was an absence of raids and a growing feeling that as the war was moving away from that part of the world, the subject was of diminishing importance, which led to apathy and lack of keenness. There was an insufficient grasp of the method of application of R.D.F., the idea of a limited coverage either in the vertical or horizontal plane being one of the problems not easily understood by the authorities there. The fullest use of information available was not always made, and minor irritations, unavoidable amongst people who had served long periods in this unattractive climate, tended to produce friction on all sides.

Although the temperature was not exceedingly high, it felt very much higher due to the ever prevailing dampness of the air. It was thought that this high degree of humidity might have a marked effect at frequencies of the order of 200 megacycles, which came within the frequency band of C.O.L. stations, and might account for the poor sensitivity of the equipment at Ras Marshag. Naval R.D.F. personnel on the aircraft carrier H.M.S. *Formidable* had reported reduced efficiency in this part of the world. It was also noticeable that the R.D.F. response from an aircraft of the Blenheim type was considerably less than that of a Gladiator.

The performance of the R.D.F. stations at Aden was definitely poor. The position of Amman Khal was such that ranges of at least seventy miles should have been reached at this R.D.F. station on incoming aircraft, but the average pick-up ranges were never beyond thirty to forty miles on aircraft and twenty miles on ships. In addition to the three A.M.E. stations at Aden there were two G.L. sets, " NEST "

[1] *Ibid.*, Encls. 29A and 30A. [2] *Ibid.*, Encl. 33B. [3] *See* Map No. 5.
[4] A.M. File M.S. 50530/R, Encl. 33A. [5] A.M. File S.1056, Encl. 71A.

and " SAND," belonging to the Army, one of which was modified to give advance warning of approaching aircraft and worked in conjunction with the T.R.U. at Amman Khal.

No. 6 C.O.L. Unit on its 216-foot site at Ras Marshag was found to be working at maximum efficiency, but gave disappointing results on test flights when compared with data taken from similar equipment in England. There appeared to be a complete absence of gap-filling lobes and the sensitivity of the station was poor. Aircraft at ranges up to fifteen miles gave saturation responses, but after this they fell away rapidly and were very poor even at lobe maxima. Results on shipping were slightly better and ranges up to sixty-three miles had been obtained.

No. 5 C.O.L. Unit was not yet operational at Bir Fukum, but from the nature of the site Flight Lieutenant Cooper, a siting expert, deduced that it was unlikely that there would be any gap-filling lobes. He inspected the alternative site at Gold Mohur but decided that it was in no way superior to Bir Fukum, and suffered from the drawback that a low-flying approach from the west would be effectively screened by the hills of Little Aden.

Shortly after Flight Lieutenant Cooper's visit, Air Headquarters, Aden, sent a signal to Headquarters, Middle East, stating that they were stopping building operations at Bir Fukum and Ras Marshag on the grounds that Ras Marshag failed to give adequate warning of a raid which came in due east and of subsequent interception practices.[1] As this station provided the sole R.D.F. cover east of Aden, this was considered to be a serious defect. Three weeks later Ras Marshag functioned normally for approximately six hours. Aircraft were seen out to 95 miles and ships were plotted from 74 miles.[2] Investigations as to the reasons for this revealed the fact that the water content in the air for that day was abnormally low. Similar conditions were observed when the water content was low for short periods on subsequent days. This gave rise to the theory that the large moisture gradient in the atmosphere caused refraction downwards to the surface of the sea, so that all radiation was concentrated along the surface, thus giving abnormally long ranges.[3] Headquarters, Middle East, however, deprecated this theory on the grounds that as a C.O.L. station was known to work at angles of the order of 10 degrees, the density of atmosphere to produce the necessary refraction would have to reach an unlikely value. In answer to the charges that the equipment at Ras Marshag did not work and never would work, he admitted that high atmospheric moisture caused losses in the equipment feeder lines and aerials. It was undoubtedly true that the depositions of salt spray and moisture on insulators, feeders and aerials reduced the efficiency and ranges obtained from the station, but he pointed out that all R.D.F. stations overseas suffered in varying degrees from the same difficulties and that, given time to settle down and subjected to strict supervision, the station at Ras Marshag should show a marked improvement in performance.

No. 5 C.O.L. was still expected at Bir Fukum, but it had been diverted back to Egypt for installation at Sidi Barakat.[4] Later it was anticipated that modified equipment would be sent out by the end of August and buildings were to be completed by then.[5] By June 1941 orders were given to proceed with the layout and construction of buildings for a T.R.U. which was to be sited at Khormaksar, and was to replace the original C.O. station, which had been considered unsuitable for Aden owing to siting difficulties.[6] To avoid permanent echoes it was necessary to lower the aerials and the equipment would then resemble the T.R.U. type of station. It was to be known as No. 304 T.R.U. and would consist of an RF7 receiver, MB2 transmitter, and 105-foot transportable towers. An MB2 transmitter and RM3a receiver was expected to arrive at the end of December 1941 to modernise the original T.R.U. at Amman Khal.[7]

Throughout the summer months operations were still suspended at Ras Marshag and Bir Fukum while heated arguments were carried on by signal between Air Headquarters, Aden, and Command Headquarters, Middle East.[8] By the end of

[1] A.M. File M.S. 50530/R, Encl. 39A. [2] *Ibid.*, Encl. 42A. [3] *Ibid.*, Encl. 46A.
[4] H.Q.M.E., Form 540, 31 March 1941. A.M. File M.S. 50530/R, Encl. 53A.
[5] *Ibid.*, Encl. 57A. [6] *Ibid.*, Encl. 43A. [7] *Ibid.*, Encl. 74A.
[8] *Ibid.*, Encl. 90A.

August the estimated date of arrival of No. 304 M.R.U. had been postponed until the end of December 1941, and in September the promised modified equipment for Bir Fukum was diverted elsewhere.

In November 1941 a Directorate of Communications Development officer was sent to Aden with a four-fold object: to advise on a site for No. 304 T.R.U. that would give cover to the western approach to Aden; to make a decision regarding the semi-completed buildings at Bir Fukum which had been started over a year ago; to examine—and improve if possible—the performance of No. 6 C.O.L. station, Ras Marshag, now named A.M.E.S. 506; and the general use of one-and-a-half metre stations in the Aden area. He found the position of R.D.F. practically unchanged since F/Lt. Cooper's visit in February. The same problems existed and had so far not been overcome, and the feeling that the war had receded from Aden for good was greatly intensified. No hostile raids had been plotted since the victory in March 1941 of East Africa, and the amount of friendly activity was very small. Considerable difficulties still existed due to the relationship between the A.M.E. stations in Aden with Command Headquarters, Aden, and with Headquarters, Middle East. The officers commanding the R.D.F. stations felt they were serving two masters and conflicting instructions were often issued, the position of the Chief Signals Officer at Aden being still undefined with regard to R.D.F.

A flat site had been chosen for the T.R.U. 304 to give satisfactory height measurement.[1] With an RF7 and an MB2 the maximum range was expected to be 90 miles, and it was to have a four-way looking aerial array. The T.R.U. 240 at Amman Khal was giving detection of aircraft above 1,000 feet, the range of pick-up varying considerably with the height and azimuth of the aircraft. As a conservative statement it was safe to say that in the south it was unlikely that aircraft would be picked up at ranges greater than 70 miles or less than 25 miles. The performance in the west was limited to 50 miles at best, in the north to 40 miles, while the performance east was completely unreliable. Height measurement was impossible due to the site, but rough positions on ships could be given up to 15 miles. A.M.E.S. 506 at Ras Marshag was given a complete overhaul, and slight technical adjustments resulted in an increase of radiated power by a factor of 2 : 1. Test flights were run and results were compared with the theoretical data. The agreement in the position of the minima was very satisfactory, and it was felt that this agreement proved that refraction effects occurred in Aden, but that they were not responsible for the deterioration of station performance. It was noted that there was a strong feeling amongst the station personnel that the station would not work, and this was bound to reflect on the efficiency of the operating. The responsibility of ordering the station to concentrate on a particular track was handed to the Operations Officer as the operators tended to concentrate on every track, due to the scarcity of activity.

In addition to these technical and operational difficulties, there was an inadequate system for dealing with the R.D.F. information gleaned. There was a very small Operations Room, to which both stations plotted and which was only capable of taking plots within 50 miles of Aden. There was no provision for inter-Service liaison, and no provision for R/T control of fighters. The effect of reporting to such a room had certainly had a very marked effect on the watch discipline and the operational skill of the R.D.F. stations. If one station was plotting the other was told that its plots were not required. No. 240 A.M.E.S. plots were often taken in preference to those of No. 506, which probably accounted a great deal for the apathy on the part of this station. Tracks were rarely identified, and the system of passing the information was slack; the plotters were allowed to talk unnecessarily, besides showing little intelligence in their requests for plots out of No. 506's sweep. It was felt that there was great need for a Filter Room, run on the lines of those in the United Kingdom, and a strong recommendation was made for provision of an adequate reporting system, which would be even more essential when the four R.D.F. stations were operational and the Coast Defence system started.

In January 1942 a memorandum was issued on this report directing that the R.D.F. stations in Aden should be brought under Air Headquarters, Aden, and the Chief Signals Officer was thus to be responsible for them.[2] A Signals Radio Officer

[1] H.Q.M.E., Form 540, 31 March 1941. A.M. File M.S. 50530, Encl. 73c.
[2] A.M. File S.1956, Encl. 79B.

was to be responsible for the co-ordination of all R.D.F. in Aden and was to be established on the Chief Signals Officer's staff. Arrangements were to be made to transfer personnel periodically from the Aden stations to other stations where they would be likely to get increased operational experience. By the end of February 1942, after eighteen months of frustrated attempts to provide adequate R.D.F. cover in Aden, the position was much the same as it was in July 1940, with the C.O.L. station at Ras Marshag a doubtful aid to the broken down, antiquated set at Amman Khal.

By the latter part of 1942, when the war receded from the Middle East, really satisfactory R.D.F. cover was still not available at Aden in spite of the big effort made by a number of experts over a very long period.[1] Although relatively insignificant in other respects, the Aden R.D.F. story is a classical example of the impracticability of controlling radio operations so far away from the control authority as to make it impossible for the latter to keep abreast of and in sympathy with local conditions by means of frequent visits. The atmospheric conditions in the Mediterranean were quite different from those at Aden, and it is now known that the alleged "tropicalised" equipment then in use was far from satisfactory. Furthermore, it is now realised that the phenomenon of super-refraction was not entirely understood at that time. In view of the combined adversities—components of the R.D.F. sets and their operators being undermined by tropical heat and humidity; propagation being distorted by hills and super-refraction, and the local R.D.F. staff being chastised by a very preoccupied higher authority 1,200 miles away—it is not difficult to understand the failure of Aden's radar cover. There is, however, equal cause for sympathy with Headquarters, Middle East's R.D.F. staff. Although the strategic significance of Aden to the Mediterranean theatre never ceased, it began to wane after the Allied conquest of East Africa, and with the fall of Singapore and the turn of the tide in our favour in North Africa, Aden became, indeed, of more significance to Indian Ocean and Far East strategy than to that of the Mediterranean. It was unfortunate that Headquarters, Middle East, should have to continue to shoulder this Aden problem while its hands were so full of vital business close at hand. This experience—from both the technical and the control aspects—was an invaluable and a salutary one in the approach to the long-range problems of the Far East campaigns ahead.

[1] Narrator's comment.

APPENDIX No. 14

LOCATION OF A.M.E. STATIONS IN THE MIDDLE EAST, 30 NOVEMBER, 1941

Existing Stations

No.	*Location.*	*Country.*	*No.*	*Location.*	*Country.*
204	Damietta	Egypt.	262	Wadi Gindali ..	Egypt.
205	Aboukir	Egypt.	263	Sidi Barrani ..	Egypt.
216	Mersa Matruh ..	Egypt.	264	Shaibah	Iraq.
218	Morhou	Cyprus.	287	Beirut	Syria.
219	Port Said	Egypt.	401	Ikingi	Egypt.
220	Abu Hagag	Egypt.	501	Ta Silch	Malta.
221	Gebel Qatrani ..	Egypt.	502	Maddalena	Malta.
235	Tobruk	Libya.	503	Haifa	Palestine.
236	Haifa	Palestine.	504	Dingli	Malta.
240	Amman Khal ..	Aden.	505	Sidi Barakat ..	Egypt.
241	Dingli	Malta.	506	Ras Marshag ..	Aden.
242	Dingli	Malta.	508	Haifa	Palestine.
251	Wadi Watrun ..	Egypt.	509	Geneifa	Egypt.
252	Hurghada	Egypt.	510	Sidi Barrani ..	Egypt.
253	Baltim	Egypt.	*520	Maaten Bagush ..	Egypt.
254	Abu Zenima (U.S.) ..	Sinai.	*522	Maaten Bagush ..	Egypt.
255	Limassol (U.S.) ..	Cyprus.	†601	Maaten Bagush ..	Egypt.
256	Banadir	Iraq.	†602	Maaten Bagush ..	Egypt.
257	El Dhaba	Egypt.	603	Mex	Egypt.
259	Bir El Abd	Sinai.	SSS.1	Rafa	Sinai.
260	Sidi Bishr	Egypt.	SSS.2	El Arish	Sinai.
261	Tel El Kebir ..	Egypt.	SSS.3	El Ma'Aden	Sinai.

* Awaiting onward transit to advanced sites.
† Undergoing special inspection.

A.M.E.S. Standing by for Movement or en route to Site

No. 515 A.M.E.S. No. 516 A.M.E.S. No. 523 A.M.E.S. to Suez.
No. 258 A.M.E.S.

A.M.E.S. in Transit or Awaiting Despatch to Middle East Command

No. 209 A.M.E.S.	No. 275 A.M.E.S.	No. 527 A.M.E.S.	No. 826 A.M.E.S.
No. 212 A.M.E.S.	No. 402 A.M.E.S.	No. 528 A.M.E.S.	No. 831 A.M.E.S.
No. 214 A.M.E.S.	No. 403 A.M.E.S.	No. 531 A.M.E.S.	No. 832 A.M.E.S.
No. 215 A.M.E.S.	No. 404 A.M.E.S.	No. 532 A.M.E.S.	No. 833 A.M.E.S.
No. 229 A.M.E.S.	No. 405 A.M.E.S.	No. 533 A.M.E.S.	No. 842 A.M.E.S.
No. 231 A.M.E.S.	No. 406 A.M.E.S.	No. 534 A.M.E.S.	No. 843 A.M.E.S.
No. 233 A.M.E.S.	No. 407 A.M.E.S.	No. 535 A.M.E.S.	No. 844 A.M.E.S.
No. 237 A.M.E.S.	No. 519 A.M.E.S.	No. 536 A.M.E.S.	No. 845 A.M.E.S.
No. 249 A.M.E.S.	No. 524 A.M.E.S.	No. 537 A.M.E.S.	No. 846 A.M.E.S.
No. 272 A.M.E.S.	No. 525 A.M.E.S.	No. 540 A.M.E.S.	No. 847 A.M.E.S.
No. 274 A.M.E.S.	No. 526 A.M.E.S.	No. 541 A.M.E.S.	

No. 303 A.M.E.S.	Kilindini.
No. 304 A.M.E.S.	Aden.
No. 314 A.M.E.S.	Malta.
No. 521 A.M.E.S.	Malta.
No. 841 A.M.E.S.	Malta.

In Course of Manufacture

Nos. 604, 605, 606, 607 and 608 A.M.E. stations.

R.D.F. STATIONS PROGRAMME AFTER RETREAT TO EL ALAMEIN, JULY 1942

M.R.U. and T.R.U. Programme

No.	*Location.*	*Remarks.*	*No.*	*Location.*	*Remarks.*
Delta Area					
204	Damietta ..	Will be replaced by 402.	253	Baltim.	
205	Aboukir ..	Converted to T.R.U.	259	Bir El Abd ..	Converted to T.R.U.
219	Port Said.		260	Sidi Bishr.	
221	Gebel Qatrani	Will be replaced by 403.	261	Tel El Kebir.	
251	Wadi Natrun	Will be replaced by 404.	262	Wadi Gindali.	
252	Hurghada.				
Levant					
216	Tripoli ..	From Western Desert.	263	Site between Tel Aviv and Gaza.	From Western Desert.
220	El Hamman	From Western Desert.	287	Beirut.	
236	Haifa ..	Will be replaced by 407.			
257	Athlit ..	From Western Desert.			

Further stations required for Jaffa and two units to be available for Mersin and Skendirun if required.

Cyprus					
218	Morphou.		255	Limassol.	
237	Paphos.				
Malta					
241	Ghar Lapsi.		314	Kaura ..	T.R.U.
242	Dingli.				
Aden					
240	Amman Khal.		304	Sheikn Othman	T.R.U.
East Africa					
303	Mombasa ..	T.R.U.			
Iraq					
256	Tanuma.		264	Shaibah.	

Further stations required for Habbaniya, Baghdad, Ur of Chaldees, Ab-i-Laski, Koweit, Bahrein, Bushire, and probably Amara.

C.O. Programme

Delta Area			
401	Ikingi.	404	Wadi Natrun.
402	Damietta.	405	Ismailia.
403	Gebel Qatrani.	406	El Arish.
Levant			
407	Athlit.		

C.O.L. Programme

Delta Area

505 Sidi Barakat Will be replaced by *532 equipment.
508 Aboukir .. Will be replaced by *534 equipment.
509 Geneifa .. Will be replaced by *541 equipment.
†510 Edge of Western Desert.
†515 Alam Shaltut.
†516 Luxor.
*519 Port Said .. Will be replaced by *531 complete.
†522 Wadi Hagg.
523 Suez .. .. C.D./C.H.L. equipment.
†526 El Imayid.
533 Kantara.
535 Damietta.
581 Qait Bai .. C.D./C.H.L. equipment.

Levant

503 Haifa .. Will be replaced by *540 equipment.
Beirut.
Tripoli.

Cyprus

577 Larnaca .. C.D./C.H.L. equipment.
578 Paphos .. C.D./C.H.L. equipment.
579 Kyrenia .. C.D./C.H.L. equipment.

Malta

501 Ta Dilch.
502 Maddalena.
504 Dingli.
521 Gozo.

Aden

506 Ras Marshag Will be replaced by *565 equipment.
576 Bir Fukum .. C.D./C.H.L. equipment.

Iraq

Stations required at Tanuma, Fao, Koweit, Bahrein (2), Bushire, and four Mobiles for advance positions.

G.C.I. Programme

Delta Area

826 Tel El Kebir.
831 Aboukir.
832 Fayid.
833 Acre.. .. From Sidi Bu Amed.
842 Damietta.
843 Dekheila.
845 El Rus.
846 Faiyum Road.

Levant

Two units required at Haifa and Cyprus.

Aden

One unit required in this area.

Iraq

Three units required at Hammar, Tanuma and Ahwaz.

Malta

841 Takali.

* To become mobile units. † Mobile units.

APPENDIX No. 16

R.D.F. SURVEY—BURMA

1. Requirements

The main target areas requiring air defence are as follows :—

(a) *Rangoon.*

For the following reasons :—

Docks and harbour.
Centre of industry and communications.
Large native population.

(b) *Syriam.*

For the following reasons :—

Oil refinery.
Storage depot.
Workshops.

(c) *Lashio.*

The main depot for war convoys to China and the head of the Burma Road.

(d) *Sale Oilfields*

(e) *Aerodromes and Defence Centres.*

(A) Rangoon is most likely to be attacked from the east and south-east by aircraft operating from aerodromes in Thailand.

The form of the attack may be high altitude bombing against the docks or low-flying attacks against shipping and minelaying in the Rangoon River.

The fighter stations protecting Rangoon could be at Mingaladon and Moulmein.

(B) Syriam is subject to the same form of attack as Rangoon plus the possibility of bombardment from the sea. The same fighter stations will protect Syriam as well as Rangoon.

(C) Lashio is most likely to be attacked from the east and south-east by aircraft operating from bases in China and Indo-China.

(D) The oilfields are mainly liable to attack from the east.

2. Effectiveness of R.D.F.

Practically over the whole of Burma the terrain is decidedly unfavourable for R.D.F., consisting as it does of high mountain ranges running approximately north/south.

Due to the difficulties imposed by the country it is not possible, at the present stage of the art, to provide any comprehensive R.D.F. cover over Burma.

The notable exception is the Rangoon and Syriam areas where conditions are ideal for R.D.F.

The plan adopted has been to concentrate on the main target areas and provide the best R.D.F. cover compatible with technical difficulties and expense.

3. R.D.F. Plan

Rangoon and Syriam Areas

This area is suited to R.D.F. and it is proposed to erect the following stations.

(a) *A.C.O. Station* giving all round R.D.F. cover against aircraft flying above 3,000 feet.
Height-finding will be possible.
This station is sited approximately 13 miles north of Rangoon.

(b) *T.R.U. Station* giving all-round R.D.F. cover and height-findings against high-flying aircraft ; also acting as reserve station for Rangoon.

(c) *C.O.L., Mark II, Station* giving all-round R.D.F. cover against low-flying aircraft and aircraft minelayers operating over the Rangoon River. This station will also detect seaborne raiders bombarding Syriam and the harbour.

Moulmein Area.

This area is not ideal for R.D.F. cover, but good results can be expected over certain areas. The main function of the station is to give early warning of the approach of aircraft from the east and to give additional cover over the Gulf of Martabon, which will probably be the interception area for aircraft attacking Rangoon and Syriam from the south-east.

A C.O.L., Mark I, station is proposed for this site.

Lashio Area.

The terrain in this area is unfavourable for R.D.F., but the limited cover provided by a station near the aerodrome is worth while in view of the importance of the target.

A G.C.I. type station is proposed for this area.

Tavoy Area.

This area is not an important target area, but the nature of the terrain is suitable for a G.C.I. set and a limited R.D.F. cover could be provided. The cover would be sufficient to give early warning of attack directed against the aerodrome.

A fair degree of success in interception would be possible should fighter aircraft be stationed there.

Oilfields.

The country in this area is unsuited to R.D.F. and poor results only would be obtained. At present it is not proposed to erect a station in this area.

4. Fighter Operations Block

A fighter operations block incorporating the R.D.F. Filter Room is being erected at R.A.F. H.Q. in the University grounds, Rangoon.

Telephone lines and W/T links will join the R.D.F. stations at Rangoon, Syriam and Moulmein to the Filter Room.

The fighter operations block is similar to that now being erected at Katong, Singapore, but the Filter Room layout is modified to suit local conditions.

APPENDIX No. 17

R.D.F. COVER FOR MALAYA

General

The air defence of Malaya is being and has been considerably strengthened by the construction of fighter and bomber airfields covering the whole of Malaya, and it is apparent that the R.D.F. requirements have increased over the original scheme which allowed only for R.D.F. stations at Singapore and Penang.

Some areas where large bodies of troops are encamped also require early warning of the approach of enemy aircraft though operational airfields are not always on these areas. Most of these encampments are on or near the sea coast, and R.D.F. is the only early warning device applicable.

2.0. Scale of Provision

The original scale of provision was—

2 C.O. stations, Singapore area.
1 C.O. station (split), Penang.
9 C.O.L. stations as satellites of above C.O. stations.

Plus 4 Mobile stations to act as advance C.O. stations and later as Mobile Reserve.

The proposed scale of provision to meet present requirements is as follows :—

3 M.R.U. stations to give initial cover and later to become Mobile Reserve. (Two of these stations to be all-round looking and one single line of shoot.)

5 T.R.U. stations to give initial cover and to remain as operational stations, giving additional cover to the C.O. stations when built, and to provide cover at isolated airfields and defence areas along the coast.

10 C.O.L. stations acting as satellites to C.O. and T.R.U. stations, but also in some cases acting as early warning devices in areas isolated from C.O. and T.R.U. stations.

3 Full-scale C.O. stations. In some cases it may be advisable to split full-scale stations into two half-scale stations, and thus provide greater cover with a given amount of apparatus. Also at some required sites there is insufficient area to build a full-size station.

3.0. Siting and Priority

The proposed sites and priorities are listed below. The sites and priority were approved by the A.O.C. F.E. on 9 April 1941.

M.R.U./T.R.U.

Priority.	*Site No.*	*Location.*	*Remarks.*
1	2	Singapore.	M.R.U. 250 and T.R.U. 243.
2	8	Mersing.	
3	4	Chunang.	
4	20	Penang 1.	
5	24	Penang 2.	
6	12	Kuantan.	
7	16	Kota Bahru.	
8	26	Klang.	

C.O.L.

1	6	Chunang.	11 and 12 C.O.L.
2	34	Johore.	
3	18	Kota Bahru.	
4	22	Penang.	
5	14	Kuantan.	
6	30	Malacca.	
7	19	Alor Star.	
8	28	Klang.	Proposed site for F.A.A. Base.
9	10	Mersing.	
10	32	Pengeram.	

C.O.

1	—	Chunang.
2	—	Mersing—Kuantan.
3	—	Penang—Klang.

4.0. Installation and Material

If the technical apparatus of the stations and the installation material and test instruments can be made available from the U.K. it is considered that the facilities in this Command would allow the installation of the stations to be completed at the rate of one or two stations per month.

Owing to the shortcomings of the 105-foot mast and the possible casualties during local storms which arrive with very little warning, it is proposed that a quantity of 120-foot wooden towers should be constructed and used on some of the T.R.U. stations. A suitable design of 120-foot wooden tower consisting of a standard 90-foot tower with an additional 30-foot bottom section is available. The towers are constructed of hard wood suitable for tropical use, and can be obtained easily and quickly. The delivery period quoted by contractors is two months, and the cost of each tower including erection is approximately 2,000 dollars (£234). It is proposed that five T.R.U. stations should be equipped with these towers, thus requiring ten towers plus two spares for contingencies, making a total of twelve towers.

Some of the sites surveyed for C.O. stations have not sufficient flat area for the erection of steel guyed masts and the associate curtain arrays, and it may be necessary in some cases to use 240-foot towers with intermediate type arrays.

R.D.F. Cover Malaya

M.R.U./T.R.U. Site No.	*Location.*	*L. of S.*	*Covering.*
2	Tanah Merah ..	90	Singapore, Eastern approaches.
4	Chunang ..	40	Singapore, Eastern approaches.
8	Mersing ..	87–32	Mersing and N.E. approaches to Singapore.
12	Kuanton ..	80	Kuanton.
16	Kota Bharu ..	80–11	Kota Bharu.
20	Penang ..	350	Alor Star, Penang and Ipoh.
24	Penang ..	210	Alor Star, Penang and Ipoh.
26	Klang ..	277–187	Western approaches, Malacca and Singapore.
C.O.L.			
6	Bt. Chunang ..	20–270	Eastern approaches to Singapore and surface craft, Eastern approaches.
10	Mersing ..	—	N.E. approaches, Singapore.
14	Kuanton ..	—	Kuanton.
18	Kota Bharu ..	—	Kota Bharu.
19	Alor Star ..	—	Alor Star and Penang.
22	Penang ..	240–10	Penang and surface craft, Penang harbour.
28	Klang ..	—	Naval Base (?)
30	Malacca ..	—	Malacca Army Encampment.
32	Pengeram ..	—	Singapore Eastern approaches.
34	Johore ..	—	Singapore Eastern approaches.

APPENDIX No. 18

RESEARCH ON JAMMING OF R.D.F. STATIONS (1935–1939)

Early Discussions on Jamming (1935–1937)

The possibility and probable effects of deliberate attempts to jam the R.D.F. Chain had been considered almost since the inception of the system. Research on R.D.F. methods had begun at Orfordness in May 1935, and by September of the same year, the scientists were already contemplating the incorporation of anti-jamming designs in the R.D.F. set. When, on 19 October 1935, Mr. Watson Watt was asked by the Committee for Scientific Survey of Air Defence "to consider whether radio location could be defeated by deliberate jamming," he had named the following six conditions which would have to be fulfilled if jamming were to be effective :—[1]

(*a*) The jamming transmitter must produce a certain minimum field strength at the R.D.F. stations.

(*b*) The jamming transmission must be within the frequency band of reception. If this were achieved, it could not be defeated by accurate tuning within a narrow band. The band of frequencies used for reception could, however, be moved ; for example, two wavebands could be available for reception, one for normal operation and the other providing an element of surprise. This arrangement would, however, probably necessitate duplicating the aerial equipment at receiver stations in order to deal with measurement of elevation. (It should be remembered that at this stage, measurement of elevation was expected to be achieved by the use of aerials spaced horizontally, and not, as was finally the case, vertically). Alternately, the waveband of reception could be moved slightly, thus rendering jamming more difficult, but not countering it with certainty.

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[1] Minutes of 12th Meeting of the C.S.S.A.D.

(c) The direction of the electric force in the jamming system must be such that the receiving arrays are affected: for example, it must be known that horizontal electric forces are being used for reception. It would then be open for the R.D.F. stations to change to the reception of vertical forces. This possibility was not an early solution of the jamming problem since, if hostile aircraft were to act as vertical dipoles, the wavelengths would have to be smaller than those so far successfully used.

(d) The jamming signal must be on a bearing where it will be strongly picked up. This condition was fulfilled with the existing "floodlighting" proposals for an R.D.F. scheme. It would not usually be fulfilled if a beam technique were employed. Owing however, to the great advantages associated with "floodlighting," Mr. Watson Watt did not propose that jamming should be countered by this means unless other methods failed.

(e) The jamming transmissions must be received within the sector of acceptance in elevation. With the existing 75-foot masts, this sector excluded only an angle of 3° or 4° from the horizon. With 250-foot masts, however, it was proposed that the maximum response should be to signals of 5° angle of elevation, half signal strength being received at 2° and 8° angle of elevation.

(f) Unless jamming transmissions were extremely powerful, they would need to employ the pulse technique with the same pulse recurrence frequency used at R.D.F. stations. If a different frequency of pulse were employed, the resulting disturbances on an oscillograph would be irritating but would not much reduce the range of detection.

The extent to which the above conditions were likely to be fulfilled, in the case of jamming from hostile territory, was stated by Mr. Watson Watt. He said that for the frequencies contemplated, transmissions from places such as the Belgian coast would not be directly received on the East Coast of England; nor would reflection at the ionosphere usually occur at the angles of incidence involved in reception at the East Coast. Transmissions from greater distances, such as Koenigsberg, would, however, reach the East Coast after reflection from the ionosphere. It appeared certain that no jamming station could emit signals which would be received at the East Coast in the region of 0° to 10° in elevation. It therefore appeared that, by arranging receiving arrays so that they responded only to signals within 0° to 10° in elevation, it was possible to prevent any jamming station in enemy territory from defeating the R.D.F. location scheme. This would not prejudice the location of high-flying aircraft at small distances from the coast, as the inevitable defects in the antenna array would provide that sufficient energy was received at angles greater than 10° to deal with small distances.

In the case of jamming from hostile aircraft, he said that, to be effective, hostile jamming aircraft would have to operate within the region covered by the R.D.F. system. Aircraft patrolling the Belgian coast could not operate at a great enough height to enable them to jam the R.D.F. system. The jamming aircraft would need to fulfil the six conditions previously mentioned, and could be located by ordinary D/F methods. Air Vice Marshal Joubert considered that such jamming aircraft could probably be intercepted by fighter aircraft by day, but that they would probably be able to evade the fighters by night.

Professor Lindemann advocated the provision of a reserve and secret frequency to each R.D.F. station, sufficiently different from the frequency detected by a jamming aircraft to prevent the latter being able to change to the new frequency. Another method of mitigating the effects of jamming was to substitute for "floodlighting," a narrow rotating beam scan which would only be effected by jamming when it was pointing in the direction of the jammer. Mr. Watson Watt, however, was unwilling to substitute for the simplicity of "floodlighting," the operational difficulties of the radio beam technique, and doubted whether personnel could be as readily trained to work with the necessary wavelengths of a few centimetres, as with the pulse technique employing longer wavelengths. It was therefore decided not to alter the existing R.D.F. programme to include this method.

Active Jamming Experiments (1937–1938)

It was realised that the best way to study anti-jamming methods was to do so in realistic conditions, so a Jamming Section was formed at Bawdsey, under Mr. E. C. Williams. The work of this section was to provide various types of jamming, as a service to the Anti-Jamming group, and to conduct experiments to assess the effectiveness, and the probability of use, of these types of jamming.[1] Mr. Williams was allowed a completely free hand in his jamming experiments, and his Jamming Section, in the words of one of the Bawdsey Research Staff " made everyone's life a misery by jamming everything and everyone it could." Its work had the desired result of bringing out many anti-jamming suggestions.

Four types of jamming were thought likely to be effective against the R.D.F. System. These were :—

(*a*) Continuous wave transmissions. (C.W.)
(*b*) Amplitude or frequency modulated C.W.
(*c*) Interrupted (keyed) C.W.
(*d*) Spark transmission.

These types of jamming could be transmitted from three sources :—

(*a*) From a jammer on the ground.
(*b*) From a jammer carried in a ship.
(*c*) From a jammer carried in an aircraft.

In January 1938 a spark jamming generator at Orford, operating on the frequency of the Thames Estuary stations, 22·64 megacyles per second (13·25 metres), succeeded in jamming Bawdsey ; but the stations at Great Bromley and Canewdon were able to read through the interference. In May of the same year, an I.C.W. (interrupted continuous wave) transmitter, installed in a London aircraft, jammed all five stations at ranges between 12 and 50 miles, while circling at 3,000 feet over the Sunk light vessel. Other experiments with airborne spark transmitters and frequency modulated C.W. transmitters were begun, but were discontinued when the officer conducting the experiments was transferred to other work.

In September 1938, trials were held to determine the effective range of ground jamming transmitters.[2] C.W. transmissions on a frequency of 50 megacycles per second (six metres) were radiated from Bawdsey, and the field strengths received from the transmissions were measured continuously in H.M.S. *Fury* as the ship steamed from Bawdsey to Rosyth. These trials gave the following indications on the possibility of jamming :—

(*a*) From ships.

A ship using a transmitter power of 10 kilowatts and radiating on a single frequency (of less than 50 Mc/s.) could jam an R.D.F. station working on that frequency at a maximum distance of 80 miles.

(*b*) From the ground.

The height of aerials required to generate the jamming became prohibitive for stations located at distances greater than 150 miles from the jammer.

Anti-Jamming Devices evolved

The main anti-jamming method, adopted for the mitigation of all types of C.W. jamming, was that of providing stations with a complete change of frequency. By October 1937 an experimental transmitter with provision for this change of frequency was being designed and manufactured at Bawdsey. This transmitter provided for the use of four frequencies, ranging from 21·8 to 37·5 megacycles per second, the change of frequency taking between a half and two minutes.[3] The transmitter, and a corresponding receiver made to development contract, were available early in 1938. It was believed that the ability to use any of four frequencies would afford complete protection against the C.W. types of jamming.

[1] Air Ministry File S.44413, Encl. 9A. [2] *Ibid.*, Encl. 27A.
[3] Minutes of the 35th Meeting of the C.S.S.A.D.

There remained the danger from spark transmissions, which covered a range of frequencies wide enough to interfere with all four of the station's frequencies.[1] Anti-jamming research against spark transmissions fell into three categories :—

(*a*) Aerial attack (including change of frequency).

(*b*) Receiver attack.

(*c*) Cathode Ray Tube attack.

There were also various suggestions for devices which, while not allowing aircraft to be located, would enable their presence to be detected. But it was desirable that anti-jamming equipment should not prevent the determination by the normal R.D.F. methods of the following data on aircraft :—

(*a*) Range.

(*b*) Azimuth.

(*c*) Elevation.

(*d*) Sense (*i.e.*, resolution of the azimuthal ambiguity).

(*e*) Strength of formation.

The " Aerial Attack " was investigated using two methods. As neither of these methods was finally adopted, a detailed description of them is not given here, but the methods may be briefly described. The first, known as the " Three Goniometer " method, involved the use of two extra goniometers. One goniometer could be set to cut out reception over a narrow arc in the azimuthal plane ; the other could be similarly set anywhere in the vertical plane. When these two were set in the direction of the source of jamming, the R.D.F. receiver would be blind to the jamming and to any aircraft on the same bearing (in azimuth or elevation) as the jammer ; but the third goniometer would be capable of locating aircraft outside these bearings.

The second method, known as the " Spaced Aerial " system, involved the setting up of two normal D/F systems at the same elevation, having a central separation of one wavelength. These systems were connected to ganged goniometers, and each goniometer was connected to a receiver through a phase-changing device. The phase-changing device could be used to lay a zero on the source of jamming ; and normal D/F could be performed on aircraft not on the same bearing as the source of jamming.

In the " Receiver Attack " two methods were also tried. The first consisted, in essentials, of employing two accurately balanced receivers, on slightly different frequencies, to feed a cathode ray tube in anti-phase. In these conditions, it was thought that the spark jamming signals would be balanced out, leaving the pulse, upon which all measurements could be made. In the second method, the " Auxiliary Receiver " method, an auxiliary receiver having a wide band width was tuned just off the signal frequency. The output of this receiver was rectified, and the direct voltage produced was used to bias back the main receiver. This enabled advantage to be taken of the gaps in the jamming signal. To prevent the possibility of strong interfering signals overloading the receiver, with consequent loss of receiver " gain " certain modifications were made to the R.F.5 receivers, and these were incorporated in the design of the R.F. 6 model.

The most effective anti-jamming research was made in the third field, the " Cathode Ray Tube Attack." Although the Aerial and Receiver Attacks on jamming were expected to reduce the effectiveness of the jamming, they were not expected to reduce the jamming signals to such proportions that very weak echoes could be accurately studied. The cathode ray tube attack was therefore instituted to enable observations to be readily taken in jamming conditions, and full advantage to be taken of any improvement given by the aerial and receiver attacks. It was designed to take advantage of the recurrent nature of the aircraft responses as compared with the random nature of spark jamming signals. As such, it would be useful only against types of jamming in which there were periods, however small, when no jamming field was present in the receiver.

[1] Air Ministry File S.44413, Encl. 9B.

The main result of the cathode ray tube attack was to produce tubes with types of fluorescent screens having—

(*a*) Afterglow characteristics.
(*b*) Discrimination between Initial and Afterglow responses.
(*c*) Cumulative properties.

As spark recurrence frequencies were not generally locked to the pulse recurrence frequency of the R.D.F. system, the jamming signals appeared to drift past the responses from aircraft, which, as the transmitter pulse frequency and the receiver time-base were locked to each other, appeared stationary on the cathode ray tube.

The property of the afterglow screen was that it reacted more slowly to the bombardment of the electrons than did an ordinary screen, and that the indications produced on it lasted for a longer time. A screen with a very long afterglow would not paint the transients of the drifting interference, but would paint the echoes as black holes in the base line of the time-base. This condition would not allow the echoes to be studied by goniometer methods, so a compromise between infinite afterglow and total lack of afterglow was taken. The requirements first laid down were for 30 per cent. of the initial response to be left at the end of two seconds, but later it was decided that a shorter afterglow was desirable.

The afterglow screen was formed by the use of two separate coatings to the tube face. The coating nearer to the electron gun was of an electron-fluorescent substance, which was excited instantaneously by the bombardment of the electrons, and in its turn, excited the slowly-reacting second coating of a photo-phosphorescent substance. By the use of coloured glass filters, it was possible to vary the amount of afterglow on the tube; the screen viewed through a green filter giving almost purely instantaneous reactions; and viewed through a yellow filter giving strong afterglow reactions.

The research in this field was carried out by Professor Sir Thomas Merton, who had been responsible for designing some of the equipment which had most successfully jammed the stations. The development of the cathode ray tube was contracted to A. C. Cossor and Co., Ltd., but as their progress was slow, the problem was put informally to Dr. Patterson, Chief of the G.E.C. Research Laboratories.[1] Dr. Patterson conducted promising experiments and soon provided four powders for material for the fluorescent screen, which were passed to Cossor's for trial with the tubes they were developing. In October 1938 the General Electric Company, Ltd., were officially appointed to carry out development work and a contract was issued.

By April 1939 Bawdsey Research Station had decided that the only practical protection against the C.W. types of jamming was through change of frequency, but recommended the use of the afterglow cathode ray tube and coloured filters for protection against interference of the spark type. Shortly afterwards, however, it was decided to employ in the receiver, as a means of protection against C.W. interference, a Rejector Unit capable of trapping and absorbing C.W. signals of up to approximately 8 kilocycles bandwidth. This unit, named the Intermediate Frequency Rejector Unit (I.F.R.U.) could be tuned to any part of the received bandwidth.[2] The first model was fitted to the receiver of Stoke Holy Cross R.D.F. station in June 1939. Later receivers were each equipped with two I.F.R.U.s, these being tunable separately so that they could cut out two different sources of interference, or, working together, could cut out one source of interference too strong to be absorbed by one I.F.R.U. alone.

[1] Air Ministry File S.44413, Encl. 9B.

[2] No. 60 Group, F.540.

R.D.F. STATIONS COMMISSIONED BY HEADQUARTERS No. 60 GROUP DURING 1942—1943

C.H. Stations (Chain Home)

Whale Head.
Ringstead.
Downderry (Final).
Castle Rock (Final).
Skaw (Final).
Saligo.
Kilkeel.
Blackpool Tower (dismantled after two months' operational test).
Greystones.
Loth.
Kilkenneth.
Brenish.

C.H. Stations (Buried Reserve)

Rye.
Pevensey.
Stoke Holy Cross.
Staxton Wold.
Danby Beacon.
Great Bromley.
Drone Hill.
Douglas Wood.
Ottercops Moss.
West Beckham.
Bawdsey.

C.H. Station (Remote Reserve)

St. Lawrence.

I.C.H. Station (Intermediate Chain Home)

Broad Bay.

C.H.B. Station (Chain Home Beam) (C.H.L. equipment fulfilling the purpose of a C.H. station where siting difficulties made a full C.H. station impracticable.)

Barrapoll.
Habost.

C.H.L. Stations (Chain Home Low)

Dunwich (Tower station).
Penybryn.
Kilkenneth.
Watsness.
Clett.
Walton Tower.
Worth (duplicate).
Ulbster.
Whitstable.
Kilchiarin.
St. Twynnells (ii) (St. Twynnells (i) released then for Type 9000 use).
Dunnet Head.
Strumble Head.
Downhill.
Skendleby.
Hopton (Tower station).
Bamburgh (Tower station).
Cresswell (Tower station).
Doonies Hill (duplicate).
S. Ronaldshay (duplicate).
Bempton.
Happisburgh (Tower).

M.R.U. Stations (Mobile Receiver Units)

Newtown Butler.
Crossmaglen.

C.D./C.H.L. Stations (Triple Service Coastal Defence C.H.L.)

Bard Hill.
The Needles.
Goldsborough.
North Foreland.
Bolt Tail.
Marsdon.
Oxwich.
Westcliffe.
Westburn.
The Law.
Crannock Hill.
Blackhead.
The Jacka.

C.D. No. 1 Mark V Stations (Coastal Defence)

Downhill.
Saltburn.
Cleadon.
Cresswell.
Doonies Hill.
St. Annes.
Cregneish.
Kendrom.
St. Cyrus.

C.M.H. Stations (Type 13—Centimetre Height)

Happisburgh.
Pen Olver.
Deerness.
Fairlight.
North Foreland } later moved to
Kingswear } Hopton.
Beer Head.

Type 14 Stations (Type 273 Naval Equipment)

Beachy Head.
Ventnor.
Start Point.
The Verne.

Type 271 Stations (10 Centimetre Equipment)

Rosehearty.
The Jacka.
Foreness.
Pen Olver.

Mobile G.C.I. Stations (Ground Controlled Interception)

Dunragit.
Roecliffe.
King Garth.
Blackgang.
Aberleri.
Forth (A.A.).
Sheffield (A.A.).
Plymstock (A.A.).
Tyne (A.A.).
Bristol (A.A.).
Holbeton (A.A.).
Tees (A.A.).
Birmingham (A.A.).

Final G.C.I. Stations

Sopley.
Trimley Heath.

Intermediate Mobile G.C.I. Stations

Hope Cove.
Willesborough.
Fullarton.
Ballydonaghy (used as a C.H.B. station after April 1943).

Transportable G.C.I. Station

Sandwich.

Intermediate Transportable G.C.I. Stations

Newford.
St. Annes.

APPENDIX No. 20

THE AIR AND SURFACE WATCHING CHAIN

31 December 1942

C.H.L. Stations.—Air and Surface Watching

Total number : 122.

6 manned by Navy.
78 manned by R.A.F.
38 remainder of C.D./C.H.L. Army Chain in process of absorption by R.A.F. or dismantling.

Of these :

2 whole-time interception stations	Happisburgh. Foreness.
1 engaged on air reporting	Fairlight.
3 engaged on air reporting or controlled interception	Beachy Head. Kete. Swingate.

27 engaged on air reporting and stand-by surface watching :—

South Ronaldshay (Navy).
Dunnet Head (Navy).
Rosehearty.
Anstruther.
Cleadon.
Bempton.
Skendleby.
Bard Hill.
Happisburgh 11.
Hopton.
Bawdsey.
Dunwich.
N. Foreland.
Truleigh Hill.
The Needles.
Westcliff.
Beer Head.
Rame Head.
The Jacka.
Pen Olver.
Hartland Point.
S. Stack.
Prestatyn.
Cregneish.
Cresswell.
Easington (part-time G.C.I.).
Kingswear (part-time G.C.I.).

51 dual-role stations (air reporting and surface watching) :—

Saxa Vord (Navy).
Clett.
Watsness.
Grutness (Navy).
Fair Isle 1 (Navy).
Fair Isle 11 (Navy).
Crustan.
Deerness.
Ulbster.
Navidale.
St. Twynells.
Strumble Head.
Pen-y-Bryn.
Downhill.
Greian Head.
Islivig.
Sango (Smoo).
Cromarty.
Crannoch Hill.
Westburn.
Doonies Hill.
St. Cyrus.
Cockburnspath.
Bamburgh.
Kinley Hill.
Gt. Orme's Head.
Formby.
Hawcoat.
St. Bees.
Kilchiarin.
Kendrom.
Stoer.
The Law.
Humberston.
Walton.
Whitstable.
Bembridge.
Worth Matravers.
Bolt Tail.
Marks Castle.
Trevose Head.
Oxwich Head.
Ballymartin.
Roddan's Port.
Blackhead.
Glenarm.
Ben Hough.
Rodel Park.
Eorodale.
Cocklaw (part-time G.C.I.).
Goldsborough (part-time G.C.I.).

13 engaged on surface watching only :—

Craster.
Shipsea.
Seaford.
Oldcastle Head.
Dunderhole Point.
Minehead.
Rhossilli Bay.
Ravenscar.
Donna Nook.
Polruan.
Tor Point.
L. Sharpness Point.
Swansea.

C.H.L. Stations.—Air and Surface Watching—*contd.*

5 stand-by surface watching only :—

Saltburn.
Fairlight.
Beach Head C.D./C.H.L.
Barrow Common.
Blood Hill (Winterton).

5 being taken over by R.A.F. for Type 12 stations :—

Ramsgate.
Hythe.
Bexhill.
Brighton.
Highdown Hill.

1 on controlled interception (Surface) :—

Boniface Down.

1 used for tracking mine-laying aircraft and manned by Army :—

Warden Point.

13 redundant :—

Gin Head.
Amble.
Grimston Hill.
Shoreham.
Pakefield Cliffs.
East Cliff.
Trewavas Head.
Spittal.
Harley Crag.
Mablethorpe.
New Hunstanton.
Durlston.
Floors Beacon.

Surface Watching Chain (10 Centimetre Equipment)

(*a*) Operational.
(*b*) Allocated.
(*c*) Stations to which high power transmitters are allocated.

(*a*) *Mark III operating* :—

S. Ronaldshay, Dunnet Head, Gwyspyr — Manned by Navy.

Mark IV operating :—

Kingswear.
Ventnor (stand-by to experimental Mark 6).
Foreness (to become Mark V).
Fairlight (to become Mark V).
Beach Head (to become Mark V).
Highdown Hill (to become Mark V).
The Jacka (to become Mark V).
Hartland Point (to become Mark V).
Capel (manned by Navy).
Bempton (to be Mark VI Tower).
Dimlington (to be Mark VI Tower).
Skendleby (to be Mark VI Tower).
The Verne (to be Mark VI Tower).
Beer Head (to be Mark VI Tower).
Start Point (to be Mark VI Tower).
Rosehearty (to be Mark VI Tower).
Bawdsey (to be erected on C.H. cantilever).

Mark V operating :—

Lydden Spout (manned by Army).
Leathercoats (manned by Army).
Lamberton Moor.
Cresswell.
May Island.
Cleadon.
Saltburn.
The Needles.
Pen Olver.
Carn Brae.
St. David's Head.
South Stack.

Mark VI operating :—

Rame Chapel.
Orford Castle.
Thorpeness (on 200-foot tower).
Blood Hill (on 200-foot tower).
Trimingham (on 200-foot tower).
Dengie (on 200-foot tower).
Ventnor (Experimental).
N. Foreland (on 60-foot tower).
Covehithe (on 200-foot tower).
Hopton.
Barrow Common (on 200-foot tower).

(*b*) *Mark III allocated :—*

Saxa Vord.
Grutness.
Fair Isle I, II.

Mark VI (T) allocated :—

Bamburgh.

Marks IV/V allocated :—

Cregneish.
Kendrom.
Kilchiarin.
Downhill.
St. Agnes Beacon.
Eorodale.
Doonies Hill.
St. Annes's Head.
Truleigh Hill.
Craster.
Rhossilli Bay.
Ravenscar.
Ulbster.
Crannoch Hill.
Glenarm.
The Law.
Gt. Orme's Head.
Dunderhole Point.
Navidale.
St. Cyrus.

(*c*) *High power transmitters allocated to :—*

Blood Hill (Winterton).	Hopton.	Covehithe.
Orford Castle.	Bawdsey.	N. Foreland.
Leathercoates.	Fairlight.	Lydden Spout.
Beachy Head.	The Verne.	Start Point.
St. Anne's Head.	S. Stack.	Pen Olver.
St. David's Head.	Carn Brea.	Hartland Point.
Cregneish.	Ventnor.	Down Hill.
Kilchiarin.	Eorodale.	Saxa Vord.
S. Ronaldshay.	Rosehearty.	Bempton.
Dimlington.	Skendleby.	Barrow Common.

APPENDIX No. 21

REVISED NOMENCLATURE AND SUMMARY OF SURFACE WATCHING R.D.F. STATIONS

On 25 August 1942 a summary of the position with regard to surface watching stations was made by the War Office, confirmed by No. 60 Group.[1] This gave the position to date and a future programme. Modifications which had been continuously carried out in the Army and Naval stations to meet Triple Service requirements were such that existing nomenclature had to be altered, and the following table gives the revised list of equipment :—

Functions.	*Original Nomenclature.*	*Revised Nomenclature.*
Early warning or surface vessels.	C.D./C.H.L. (with transmitter over receiver aerial system).	C.D. No. 1, Mark I.
	C.D./C.H.L. (converted to common transmitter and receiver aerial system).	C.D. No. 1, Mark I*.
	C.D./C.H.L. (converted to common transmitter and receiver aerial system, with C.H.L., Mark V, receiver).	C.D. No. 1, Mark II.
	Naval Type 273	C.D. No. 1, Mark III.
	Naval Type 271 (Mobile)	C.D. No. 1, Mark IV.
	Naval Type 271 (Transportable) ..	C.D. No. 1, Mark V.
	Naval Type 271 (Final, hand-turned)	C.D. No. 1, Mark VI.
	Naval Type 271 (Final, power-turned).	C.D. No. 1, Mark VI.*
	Naval Type 271 (Final, with power-turning and tower).	C.D. No. 1, Mark VI**

[1] A.M. File C.S. 12788, Encls. 92A and 71A.

It was laid down that in future the new nomenclature was to be used when referring to either set of Naval Type 271 or 273, but owing to the confusion arising from such change, the C.D./C.H.L. stations might continue to be referred to as such.

The Mark III was the Naval Type 273 (a modified 271) with the transmitter mounted beneath the 4 ft. 6 in. paraboloid mirror reflectors which were housed in a perspex "lighthouse." Mark IV consisted of a trailer vehicle which was the "Operations Room" containing the transmitter as well as the receiver. The Mark V was a similar set-up, but in a railway container type cabin, the Mark VI was a permanent installation in a Nissen or similar hut. Each set would have its own independent electrical generator for power supply.

APPENDIX No. 22

SOME DETAILS OF TECHNICAL IMPROVEMENTS TO C.H. STATIONS, 1942—1943

Some of the advantages of the improvements embodied in the new equipment installed in C.H. stations can be appreciated from the following brief outline of these developments.

(*a*) *Receiver R.F.*8.—This was a much improved version of the R.F.7. Many minor modifications were made in the lay-out of the operational controls, making the task of the observer speedier and more convenient, whilst an improved sytem of locking the receiver to the transmitter was introduced. The new Electronic Range Marker (E.R.M.) enabled the observer to use at will three time-base speeds, giving ranges on the tube of 70, 130 and 200 miles. Constant search was made in turn on all these range scales, but plotting of an aircraft at short range, for instance, was much easier on the 70-mile scale, where the increased width of the response on the cathode ray tube made it easier for the observer to see, and consequently obtain a truer bearing. The start of the time-base with an E.R.M. was synchronised with the ground ray obtained from the transmitter, thus eliminating the so-called "zero" error of anything up to 4 miles which had occurred with some earlier receiver models. A second time-base, higher than but parallel to the first, was also provided for the display of Mark III I.F.F.[1] linked with a separate receiver and transmitter (the Interrogator and Responsor) working on a special I.F.F. frequency. Other improvements were a single control making possible the simultaneous change of pulse and band width, a new panel A.G.C.4 (Anti-Clutter Gain Control) replacing the existing A.G.C.1, and a Mark II Anti-Jamming Black-out Unit (the A.J.B.O.), a device which assisted the operator to combat enemy Frequency-Modulated Continuous Wave jamming. The receiver was also provided with a simplified crystal controlled calibration marking, ensuring an accuracy in setting up the range of scale of not less than plus or minus one-third of a mile.

(*b*) *Console, Mark III.*—Apart from minor improvements to the display part of the console, the main change was in the radio part—the Tracker Unit. The cathode ray tube on the Tracker was now provided with two time-base speeds, giving alternative range scales of 100 or 200 miles. It was so linked to the tube on the receiver that the Observer, or Tracker Operator, could, by turning a range-control knob, indicate to each other, without speaking, any track to which attention was drawn; this was done by an electronic spot of light appearing on both tubes immediately over the echo in question. This made for very close co-operation between the observers on the two tubes and helped to speed up operations. The Tracker unit was also fitted with independent gain and band-width controls.

The Console, Mark III, was also fitted with an additional panel for the identification of tracks, into which jacks bearing the appropriate letters and figures were plugged by the Teller when identification was received from the Filter Room. Each set of identity jacks had a lamp fitted above it, which lit up when appropriate buttons were pressed by the Tracker Operator. Thus " Track 5 " might be identified

[1] *See* Volume V.

by Filter Room as " Hostile 70." H.70 would be plugged into the jack panel by the Teller ; when the next plot on that track was taken, the Tracker Observer would press her button marked " 5 " and the light would come up in the appropriate place on the jack panel. The Teller would then read to Filter Room the identification from the jack panel display, and follow with the plot and ancillary information read from the display panels operated by the electrical calculator.

(*c*) *The Automatic Message Recorder.*—Both sets of display panels were linked to a teleprinter in the Operations Room, which had been adapted for use as an Automatic Message Recorder. When this unit was switched on all information was automatically recorded on a revolving drum of paper, together with exact times synchronised with the electric clock on the console. The Automatic Message Recorders worked quite well during slight or normal activity, but when operations were intense the observer's plotting speed exceeded the capacity of the Recorder, which sometimes jammed, so that manual recording had to take its place. In addition, ancillary information which did not appear on the display plaques but was told verbally down the line to Filter Room—fade ranges, estimated heights and so on—could not be recorded automatically. A note of such points had to be made at the time by the Teller and entered in writing on the Message Recorder later. For these reasons the Message Recorder did not find favour with Operators, and there was a tendency for it to be disregarded, especially during a busy watch, and for manual recording to be used instead.

APPENDIX No. 23

LIST OF UNITS IN RAID REPORTING SYSTEM IN OPERATION " TORCH "

No. 6000 A.M.E.S. (L.W.S.).
No. 6001 A.M.E.S. (L.W.S.).
No. 6002 A.M.E.S. (L.W.S.).
No. 6005 A.M.E.S. (L.W.S.).
No. 6006 A.M.E.S. (L.W.S.).
No. 6007 A.M.E.S. (L.W.S.).
No. 6008 A.M.E.S. (L.W.S.).
No. 6009 A.M.E.S. (L.W.S.).
No. 6010 A.M.E.S. (L.W.S.).
No. 6011 A.M.E.S. (L.W.S.).
No. 87 W.O.U.
No. 88 W.O.U.
No. 892 A.M.E.S. (G.C.I.).
No. 893 A.M.E.S. (G.C.I.).
No. 894 A.M.E.S. (G.C.I.).
No. 895 A.M.E.S. (G.C.I.).
No. 896 A.M.E.S. (G.C.I.).
No. 897 A.M.E.S. (G.C.I.).
No. 898 A.M.E.S. (G.C.I.).
No. 8002 A.M.E.S. (G.C.I.).
No. 8003 A.M.E.S. (G.C.I.).
No. 8004 A.M.E.S. (G.C.I.).
No. 80005 A.M.E.S. (G.C.I.).
No. 8006 A.M.E.S. (G.C.I.).
No. 301 M.S.S.U.
No. 302 M.S.S.U.
No. 303 M.S.S.U.
No. 304 M.S.S.U.
No. 380 Wireless Unit.
No. 381 Wireless Unit.
No. 226 A.M.E.S. (M.R.U.).
No. 372 A.M.E.S. (M.R.U.).
No. 381 A.M.E.S. (M.R.U.).
No. 387 A.M.E.S. (M.R.U.).
No. 388 A.M.E.S. (M.R.U.).
No. 389 A.M.E.S. (M.R.U.).
No. 392 A.M.E.S. (M.R.U.).

APPENDIX No. 24

DEPLOYMENT OF OPERATIONAL AND NON-OPERATIONAL R.D.F. STATIONS IN NORTH-WEST AFRICA UP TO THE END OF JANUARY 1943

(*a*) *R.A.F. R.D.F. Stations Operational.*

Functions.	*Station No.*	*Locality.*
C.O.L.	895	Cap Takough.
C.O.L.	896	Algiers.
C.O.L.	897	Cap Gros.
C.O.L.	8006	Dellys.
G.C.I.	892	Djidjelli.
G.C.I.	893	Ain Taya.
G.C.I.	894	Morris.
G.C.I.	898	Souk El Arba.
G.C.I.	8003	Phillipeville.
G.C.I.	8009	(On special ops.).
M.R.U.	372	Jemmappes.
M.R.U.	381	Lac Des Oiseaux.
M.R.U.	389	Phillipeville.
L.W.S.	6000	Cap Corbelin.
L.W.S.	6001	Souk El Arba.
L.W.S.	6002	Youks Les Bains.
L.W.S.	6005	Algiers.
L.W.S.	6006	La Calle.
L.W.S.	6007	Phillipeville.
L.W.S.	6008	Youks Les Bains.
L.W.S.	6011	Setif.

(*b*) *R.A.F. R.D.F. Stations Non-operational.*

C.O.L.	8004	Phillipeville ..	Vehicles held up.
C.O.L.	8005	Cap Serrat	Being sited.
G.O.L.	890	Algiers.	
G.C.I.	8010	Port Gueydon ..	Being moved for special ops.
G.C.I.	8011	Cap Corbelin ..	Being sited.
M.R.U.	226	Djidjelli	Gear missing.
M.R.U.	392	Alma Marine.	
M.R.U.	387	Bone Transit ..	Waiting parts in returned ship.
M.R.U.	388	La Calle	Under construction.
L.W.S.	6009	Cap Bougeron.	
L.W.S.	6010	Canrobert.	

(*c*) *R.A.F. R.D.F. Equipment Operational in the Oran area.*

C.O.L.	890	Cap Carbon.
C.O.L.	8001	Cap Falcon.
G.C.I.	899	Fleurus.
M.R.U.	286	Cap Tenes.
M.R.U.	285	N. Colombi (not yet operational).

(*d*) *R.A.F. R.D.F. Equipment Operational in Casablanca area.*

G.C.I.	8000	Fedhala.

(*e*) *American Equipment Cperational in Oran area.*

Function.	*Locality.*
Type 270	Cap Cherchel.
Type 270	Ivi.
Type 270	Cap Carbon.
Type 516	Cap Falcon.
L.W.S.	Cap Tenes.
L.W.S.	Ivi.
L.W.S.	Figale.

(*f*) *American Equipment Operational in Casablanca area.*

Function.	*Locality.*
Type 270	May Bou Selham.
Type 270	Ain Saierni.
Type 270	Marchand.
Type 516	Ben Ahmed.
Type 516	Mecha Bel Ksire.

APPENDIX No. 25

LIST OF A.M.E.S. IN NORTH-WEST AFRICA COASTAL AIR FORCE ON FORMATION OF NORTH-WEST AFRICA AIR FORCES

A.M.E.S. No. 226 (M.R.U.).
A.M.E.S. No. 285 (M.R.U.).
A.M.E.S. No. 286 (M.R.U.).
A.M.E.S. No. 372 (T.R.U.).
A.M.E.S. No. 381 (T.R.U.).
A.M.E.S. No. 387 (T.R.U.).
A.M.E.S. No. 389 (T.R.U.).
A.M.E.S. No. 392 (T.R.U.).
A.M.E.S. No. 892 (C.O.L./G.C.I.).
A.M.E.S. No. 893 (C.O.L./G.C.I.).
A.M.E.S. No. 894 (C.O.L./G.C.I.).
A.M.E.S. No. 895 (C.O.L./G.C.I.).
A.M.E.S. No. 896 (C.O.L./G.C.I.).
A.M.E.S. No. 897 (C.O.L./G.C.I.).
A.M.E.S. No. 8000 (C.O.L./G.C.I.).
A.M.E.S. No. 8001 (C.O.L./G.C.I.).
A.M.E.S. No. 8002 (C.O.L./G.C.I.).
A.M.E.S. No. 8003 (C.O.L./G.C.I.).
A.M.E.S. No. 8006 (C.O.L./G.C.I.).
A.M.E.S. No. 8009 (C.O.L./G.C.I.).
A.M.E.S. No. 8010 (C.O.L./G.C.I.).
A.M.E.S. No. 8020 (C.O.L./G.C.I.).

APPENDIX No. 26

LIST OF A.M.E.S. IN NORTH-WEST AFRICA TACTICAL AIR FORCE ON FORMATION OF NORTH-WEST AFRICA AIR FORCES

A.M.E.S. No. 388 (T.R.U.).
A.M.E.S. No. 890 (C.O.L./G.C.I.).
A.M.E.S. No. 898 (L.W.S.).
A.M.E.S. No. 899 (L.W.S.).
A.M.E.S. No. 8004 (L.W.S.).
A.M.E.S. No. 8005 (L.W.S.).
A.M.E.S. No. 675 (L.W.S.).
A.M.E.S. No. 6000 (L.W.S.).
A.M.E.S. No. 6001 (L.W.S.).
A.M.E.S. No. 6002 (L.W.S.).
A.M.E.S. No. 6003 (L.W.S.).
A.M.E.S. No. 6004 (L.W.S.).
A.M.E.S. No. 6005 (L.W.S.).
A.M.E.S. No. 6006 (L.W.S.).
A.M.E.S. No. 6007 (L.W.S.).
A.M.E.S. No. 6008 (L.W.S.).
A.M.E.S. No. 6009 (L.W.S.).
A.M.E.S. No. 6010 (L.W.S.).
A.M.E.S. No. 6011 (L.W.S.).

ACCOUNT OF EXPERIMENTS TO PROVIDE R.D.F. NAVIGATIONAL AID TO DIRECT SUPPORT AIRCRAFT

(O.R.S. (Middle East) Report No. V.8, dated 8 April, 1943)

1. Introduction

A previous visit to A.H.Q., Western Desert, had shown that there was a case for navigational aids for aircraft engaged in offensive operations over the battle area.

The character of the operations, type of aircraft concerned, and available R.D.F. equipment were considered, and as a result it was decided that the technique most likely to be immediately successful consisted of the use of C.O.L. or G.C.I. equipment in conjunction with a R.D.F. beacon carried in one or more aircraft of a formation; such a beacon could be easily produced by simple modifications to existing Mk. IIG, II N or American I.F.F.

Preliminary tests were held in Egypt using different aircraft, beacons, and R.D.F. stations; after the first series, an interim Memorandum (M.23) was produced. After the final series of tests it was ruled that if A.H.Q.W.D. agreed, the system should be used in present operations. This Headquarters was consequently visited, in conjunction with a member of S.D.6 (the Army Operational Research Group in the Middle East) who had participated in all previous work.

It was ruled that trials in the Western Desert should take place first with a Tac/R Squadron (40 S.A.A.F.) under 285 Wing; after the necessary arrangements had been made with A.H.Q.W.D., 211 Group, 285 Wing, 40 S.A.A.F. Squadron, and 889 A.M.E.S., tests were held as described in Section 3.

2. Procedure

A Hurricane of 40 S.A.A.F. was used for non-operational flights in conjunction with 889 A.M.E.S. which was sited as a G.C.I. (mean aerial height, 10 feet). A modified Mk. IIG I.F.F. was used as a beacon, and a small Morse key was installed in the cockpit of the Hurricane in order to code the beacon by cutting off the R.T. on depression. Since some of the pilots did not know Morse, the following code was finally used: each time the Tac/R pilot wished to have a particular pin-point specially noted, he would send four dots as a warning signal, followed by a pause; the pause was in turn followed by one, two or three dashes. If more than three "key plots" were to be specially noted, the series would be run through again; in this manner sufficient discrimination between key plots was obtained.

At the G.C.I. station the aircraft was continually watched by restricting the aerial sweep to a very small arc. Accurate plots were easily read off the P.P.I. by noting the point of maximum intensity of the "sausage" due to the aircraft beacon, or alternatively by operating the trace brightener switch as the beacon response was observed to pass through maximum on the height tube, which was of the long afterglow pattern. On receipt of the four warning dots, observed on the height tube, the height tube observer stopped the aerial turning in order to observe the number of dashes transmitted. The corresponding plot was found by interpolation between the plots immediately preceding and following the signal. Since the G.C.I. was also used for fighter operations the S.M.E.F.O.G. (Standard Middle East Fighter Operations Grid) latitude–longitude graticule had to be retained on the P.P.I., and an accurate S.M.E.F.O.G/Military Grid 1 : 500,000 conversion map was finally produced, in order to save Tac/R Squadron personnel the trouble of converting plots to the Military Grid Reference normally used. The plots read off in S.M.E.F.O.G. were put down on a large scale perspex covered map, which was also used as a manual converter, and a smoothed or filtered track was produced, showing the key plots. Towards the end of the sortie a sufficient number of plots was selected to give an accurate reproduction of the track, and these were converted into Military Grid, together with the filtered key plots.

These plots were passed (with difficulty) by landline to 40 S.A.A.F. Squadron Operations Room ; in view of the poor landline communications provision was also made for W/T operation on a common frequency, and a simple code was improvised. For security reasons, plots would only have been passed on the completion of a sortie. In view of the relatively small amount of traffic, the use of false grids for additional security could be easily provided for.

The technique employed in setting up the beacon is described in Section 4.

3. Results Obtained in the Western Desert

(*a*) *Non-operational Test Flights.*—A Hurricane of 40 S.A.A.F. Squadron was used for these tests. The first two flights were poor : the aircraft, flying at about 4,000 feet, was seen with difficulty to 40 miles. This result disagreed violently with the predictions made on the strength of the earlier results obtained in Egypt, all of which had been remarkably consistent. In addition, there appeared to be a systematic plan position error, due to faulty conversion, judging by the comparison of the track and the pilot's reports. The A.M.E.S. staff were therefore requested to re-draw the P.P.I. grid and the S.M.E.F.O.G./Military Grid conversion map ; a slightly more linear section of the P.P.I. trace was also used.

At the same time the feeder and aerial system of the Hurricane was investigated and found to be insufficient ; the ground tests used are described in Section 4.

A new and shorter length of feeder was substituted, all plugs and sockets were tested, and a third flight was held ; this was successful. The aircraft was followed continuously round a previously unknown rectangular course, lying partly over hills, and was still visible at over 50 miles at a height of approximately 3,300 feet. Plotting was sufficiently accurate to reproduce an orbit of about 3–4 miles diameter executed when the aircraft was 25–30 miles away. The key plots agreed with the pilot's observations at those points on which he had accurate information.

The performance as regards maximum range was still below that anticipated ; a possible reason is given in Section 4, and it is understood that action is being taken on this point. (It may be mentioned that the same A.M.E.S. would probably not have followed a 3,000 feet aircraft by ordinary R.D.F. to a distance of more than 20 miles.)

In view of the success of the above test flight, it was decided to proceed to operational trials.

(*b*) *Operational Trials.*—One of the Spitfires belonging to 40 S.A.A.F. Squadron was fitted with the same beacon that had previously been used in the Hurricane. It was not possible to fit a Morse key immediately owing to the all-metal construction of the aircraft ; it is understood, however, that the Squadron Signals Officer is installing a key in a suitable position.

The first operational flight failed because the pilot forgot to switch on the beacon (by means of the ordinary I.F.F. switch). The second flight failed because a plug belonging to the existing wiring of the Spitfire proved faulty. The third flight was successful ; the aircraft carried out a sortie in the Gabes–Marath region and was continuously plotted as soon as it had gained sufficient height. Regarding accuracy, the filtered track agreed exactly with the pilot's estimate of the point at which he crossed the coast just south of Gabes.

After this flight it was ruled that no further help in using the above method should be given to R.A.F. personnel until further notice. Before leaving H.Q. 211 Group detailed instructions and information, were drawn up in draft form for approval. A second beacon was installed in another Spitfire, and all the equipment on the charge of O.R.S. was made over to 40 S.A.A.F. Squadron.

It is understood that 285 Wing and 40 S.A.A.F. Squadron will report on the value of the R.D.F./Beacon method of pin-pointing in the particular type of country over which operations are now taking place.

4. Technical Information

(*a*) *The Beacon.*—The particular beacons used were simply produced by removing the drive to the G band of two Mark IIG I.F.F. sets, substituting dials and locking screws and cutting out the H.T. supply to the B band.

The beacons were tested with the appropriate signal generator and output tester in the usual manner ; detonator drill was also normal.

A Yagi aerial (four directors, folded dipole reflector, and 100-ohm feeder) cut to 200 Mc/s was used to pick up the transmission from the R.D.F. station, which was requested to " look " in the direction of the L.G. when necessary. A mast was unnecessary for the short period for which reception was needed ; the beacon was easily turned to the R.D.F. station, and showed no signs of being off tune on subsequent days. Ranges at which the beacon could be triggered, using a Yagi aerial about 12 feet high are as follows : 110-foot C.O.L., V.T. 58 transmitting valves, 35 miles (approximate maximum) ; 10-foot G.C.I., V.T. 98 valves, not less than 12 miles.

(*b*) *The G.C.I. Station.*—The factors limiting range (for aircraft and aerial at given heights) are the output of the beacon, the feeder system between beacon and aerial, the polar diagram of the aircraft aerial, the power gain of the R.D.F. receiver aerial, the feeder and coupling system between this aerial and the receiver, and the Noise Factor of the latter. There is ample power in the case of C.O.L./G.C.I. equipment to trigger the beacon at all ranges at which it can still be seen.

In the case of the particular G.C.I. station used (889 A.M.E.S.), the receiver inductive coupling was suspected as the cause of the comparatively poor ranges obtained. It was discovered on returning to H.Q., R.A.F., M.E., that this fact had already been reported by a member of Sigs 6, H.Q., R.A.F., M.E. It is understood that this Branch is taking action in the matter.

Preliminary experiments on the possibility of plotting beacon-equipped aircraft over hilly country were carried out when 889 A.M.E.S. moved to a C.O.L. type site ; a reduction of the H.T. to a safe value, combined with slight detuning, should in general remove all but saturation permanent echoes.

(*c*) *Beacon Ground Tests.*—A crude comparison of different feeder systems was carried out by triggering the beacon in the aircraft by means of the signal generator, and removing the output tester till the beacon signal could only just be heard ; the distance between the tester and the tail plane was then paced out. Care has to be exercised in the placing of the body, which acts as a re-radiator.

5. Further Investigations

Pending decisions as to the use of the R.D.F./Beacon method as an aid to navigation, further technical investigations in co-operation with D.C.D., H.Q., R.A.F., M.E., are being undertaken along two lines.

(*a*) *Ground Tests of Beacons and Aerial Systems.*—Beacons with variable aerial couplings are now known to be available. It is proposed to carry out comparative ground tests, using a field strength meter, to determine optimum coupling and feeder data for various operationally important aircraft ; it is anticipated that allowance for airborne aircraft will be obtainable from extrapolation of ground data.

(*b*) *Modification of Type 6 Equipment.*—The chief drawback to the use of Type 6 (Light Warning) equipment in conjunction with beacons is the poor bearing accuracy obtainable. A further disadvantage is the low power gain of the receiver aerial array (Yagi) compared with a C.O.L. 52 element array.

It has consequently been suggested to D.C.D. that it would be operationally valuable to fit a split system using two Yagis and modelled on the existing S.L.C. azimuth-finding system ; display, however, should involve the comparison of two echo amplitudes, as in A.S.V. A greater receiver aerial power gain would also be provided. Such a modification would also be provided. Such a modification would be valuable both for normal R.D.F. plotting and for following beacon-equipped aircraft.

6. Conclusions and Recommendations

(*a*) If it is accepted that there is a general need for navigational aids to aircraft employed on offensive operations over the battle area, then it would be advisable to obtain operational experience of the small-scale use of such aids during the present campaign, in order that the lessons learnt may be correctly applied in the planning and execution of future operations.

(*b*) To this end, the use of one or other of the present available aids is recommended in the case of offensive fighter, fighter bomber, and light bomber sorties.

(*c*) In the case of the latter, the present R.D.F. system could in general be used, even without the use of beacons, since the heights at which the formations usually fly in day-time are sufficient, provided suitable sites can be chosen for the R.D.F. stations. Direct R/T communication between the appropriate R.D.F. station and the formation leader would be necessary.

(*d*) In the case of single-seater fighters and fighter-bombers, the present R.D.F./Beacon method should be adequate : if the pin-point of any target is known the formation can be vectored on to the target area by R/T. A further aid is available to bombers and all but single-seater aircraft ; the Rebecca-Eureka combination, which was fully described in O.R.S. (M.E.) Report R.7 in April 1942. A small number of sets are available in the Middle East, and it is suggested that a fraction of this number should be put to the use recommended above, after sufficient personnel have been trained in the operation of the apparatus, and satisfactory tests have been held.

It is perhaps also advisable to mention that none of the existing aids recommended above are suitable for " blind bombing " of direct support targets ; they are only capable of directing aircraft to what is loosely called the " target area " ; for individual bombing visual indication is still essential.

APPENDIX No. 28

THE MEDITERRANEAN AREA FIGHTER OPERATIONS GRID (MAFOG)

Instructions for Use

Description

The Mediterranean Area Fighter Operations Grid (MAFOG) is simply a system of letters and figures used to identify divisions of the latitude and longitude graticule.

The system of lettering is built up from the point of intersection of the equator with the meridian through Greenwich and can be easily calculated for anywhere in the world provided a map marked with latitude and longitude on the British system is available.

(*Warning.*—French maps often have the zero meridian drawn through Paris, Greek through Athens, Italian through Rome, Turkish through Ankara, etc.)

The grid is suitable for use everywhere in the world except where the lines of longitude converge too rapidly towards the poles.

The basis of the grid is a section bounded by lines of latitude and longitude five degrees apart. These sections are lettered in blocks four sections east and west by four sections north and south, using the letters A to P.

The five-degree sections are divided into 25 one-degree divisions lettered from A to Y.

Each one-degree division is divided into 36 ten-minute divisions. Thus the smallest division drawn is an area ten minutes of latitude by ten minutes of longitude.

For readings inside these ten-minute divisions tenths are estimated by eye. Thus a grid reference can be given accurate to within one minute either way.

(*Note.*—For special purposes further divisions can be made in tenths giving any required accuracy.)

Instructions for Use

References are given by reading the letter of the appropriate five-degree section, followed by the letter of the one-degree division and four figures indicating the pin-point.

The figures are given READING NORTH THEN EAST in the following way :—

Count the number of ten-minute divisions UP from the bottom of the one-degree division, and then estimate the number of minutes above this by eye. This will give two figures. Then do the same ACROSS from left to right, giving two more figures.

A pin-point would then be given in the following form :—

GN 5138 or AS 3909

Note that no pin-point can exceed 5959.

When working locally and there is no danger of ambiguity, the first letter (referring to the five-degree section) may be omitted. The pin-point would then be in the form N 5138 or S 3909.

Examples

The following references are given as examples :—

Place.	*Reference.*
Sousse	CU 4939
Bizerta	BO 1751
Algiers	AS 4504
Benghazi	EK 0504
Tripoli	GN 5511
Oran	DY 4121
Casablanca	GH 3522
Rabat (Morocco)	GD 0011
Beni Ulid	GT 4400

Security

To achieve any measure of security with regard to a grid it is necessary to change it very frequently. A change, however, involves considerable work and liability to error, and for fighter defence purposes it is considered better to risk the loss of security and retain a constant lettering. Great care, however, should be taken to avoid danger of compromisation of similar systems such as the Naval lettered co-ordinate system.

APPENDIX No. 29

STANDARD AIR WARNING CODE

Method of Reporting

(*a*) The first report from any station after a period of silence is to be made using full procedure.

(*b*) Subsequent reports are to be broadcast without call signs or address, and are to be identified by their raid letters and numbers. The raid letter will normally be T except where two or more stations are working on a common frequency, in which case each is to be allotted a different raid letter.

(*c*) Noughts (zeros) are to be sent in full.

(*d*) The speed of morse is not to exceed 15 words per minute.

(*Note.*—It is necessary that raid letters and call signs of all stations (and ships) should be promulgated in Communications Orders and known to all authorities concerned.)

Form of Message

Information is to be reported in the following order :—

(*a*) One or two raid letters followed by track numbers from 1 to 99 for the station concerned (*e.g.*, T24, or, in the case of two stations working on a common frequency, B24, S9, etc.).

(*b*) One or two letters indicating the direction of flight. For letters to be used see below. (This will usually be omitted when plots are being passed by R.D.F. stations.)

(*c*) The position of the aircraft expressed either in MAFOG or in lettered co-ordinates (latitude and longitude). Filter plots must be capable of using either system.

(i) A grid reference may, if necessary, be followed by the letter K and either A, B or C, indicating the class of reading, where A represents "reliable," B represents "approximate," and C represents "unreliable." This should rarely be necessary.

(ii) If no definite plot can be given it may be possible to pass a range and rough indication of the direction of the aircraft from the station. In this case the letter G is to be used followed by the letter B or one or two letters indicating the rough bearing of the aircraft from the station or observer post.

(*d*) A letter indicating identity or whether I.F.F. is being received or a plain language word in special cases (*e.g.*, Y Z F H X Gliders, etc.).

(*e*) The letter W, followed by the number of aircraft in figures (*e.g.*, W12).

(*f*) The letter A, followed by one or two figures indicating the height in thousands of feet (*e.g.*, A18 indicates " Height of aircraft is estimated at 18,000 ft."). This may be followed by KA, KB or KC to indicate the class of reading.

(*g*) Authentication, if pre-arranged or brought into force by control signal.

(*Note.*—Short breaks are used to separate components of the report.)

Codes to be used

A	Height.
B	Bearing.
C	Affirmative ; Correct.
CT	Keep all-round sweep and report once only any new echo, giving estimate of number and height.
D	Serviceable.
DB	Beacon, switch on beacon.
DC	Emergency recall from maintenance.
F	Friendly.
G	Range.
GI	Range increasing.
GNI	Range decreasing.
GG	Range constant.
H	Hostile.
I	Plus.
J	Faded.
K	Class of plot or height.
L	Maintenance.
M	Visual.
N	Negative.
NI	Minus.
NT	Cease passing reports on raid.
O	Orbiting ; Circling.
P	North.
Q	South.
R	East.
S	West.
T	Track.
TT	Concentrate on track ; or take over reporting on track.
U	Unserviceable.
UT	Authenticate.
V	Vessel ; Shipping plot.
W	Number of aircraft.
X	Unidentified.
Y	Showing I.F.F.
Z	Showing broad I.F.F.
INT	Interrogative.

Intense Activity

(*a*) In conditions of intense activity when individual tracks cannot be handled the letters WW are to be used followed by a figure denoting the approximate number of aircraft and any other information which can be supplied.

(*b*) *Example :* B18 – WW100 – S4823 – GNI – A12.

Meaning : B18—Track No. 18 from ship or station allocated raid letter B; WW100—Intense activity involving about 100 aircraft at Grid Reference S.4823; GNI—Range from ship or station decreasing; A12—Approximate height 12,000 feet.

Control Signals

When it is necessary for the Control Centre (if any) to interrogate stations, or to pass them operating instructions, these signals will be passed in accordance with the above code.

Examples of the Use of the Code

(*a*) *From a Wireless Unit or Observation Post.*

Example : P6 – QR – H – W6 – A7.

Meaning : P6—Report No. 6 from post P; QR—Direction of flight of aircraft, south-east; H—Hostile; W6—Six aircraft; A7—Height 7,000 feet.

(*b*) *From an R.D.F. Station working on an Individual Frequency.*

(i) *Example :* 5VU v G6C – T4 – GI12345 – KB – Y – W8.

Meaning : Signal after period of silence 5VU—Control station call sign (from); G6C—R.D.F. station call sign; T4—Track No. 4; GI12345—Position of aircraft; KB—Approximate bearing; Y—Showing I.F.F. W8—Number of aircraft 8.

(ii) Subsequent information on this track might be :—

Example : T4 – GI 1728 – W6 – A8.

Meaning : Track 4 is now at GI 1728, and is now estimated to be 6 aircraft at 8,000 feet.

(iii) *Example :* T6 – G42 – BPS – Z.

Meaning : I have an echo which I am calling T6 at a range of 42 miles north-west of me showing Broad I.F.F.

(iv) *Example :* INT – L – 0900 – 1000.

Meaning : Can I go off the air for maintenance from 0900 to 1000 hours? (*Note.*—If the above station was working on a group frequency K4 would replace T4 in all cases, assuming K to be the raid letter allotted to that station.)

(*c*) *From a Ship having a previous Report.*

(i) *Example :* B18 – ABCD1234 – X – W2 – A6 – KC.

Meaning : B18—Track 18 from ship allocated raid letter B; ABCD1234—Position of aircraft in latitude and longitude co-ordinates; X—Unidentified; W2—Two aircraft; A6 – KC—Unreliable height 6,000 feet.

(ii) *Example :* B12C6 – ABCD1234 – A18.

Meaning : The ship allocated raid letter C has discovered that her track 6 is the same as track 12 of the ship allocated raid letter B. The position of the raid is now ABCD1234 and its height is 18,000 feet.

Examples of the Use of the Code—*contd.*

(*d*) *From a Control Centre* (e.g., *a Filter Room*).

(i) *Example :* INT – G – T2.
Meaning : What is the range from you now of your track No. 2 ?

(ii) *Example :* TT3.
Meaning : Concentrate on your track No. 3.

(iii) *Example :* INT – M – T2.
Meaning : Can you obtain a visual observation of the aircraft in your track No. 2 ?

(iv) *Example :* INT – A.
Meaning : What height ? Or check height. (The answer to this might be " N – A," meaning " Cannot give you a height.")

(v) *Example :* UT.
Meaning : Authenticate your reports.

(vi) *Example :* NT3.
Meaning : Cease passing plots on your track 3.

Procedure Adopted by the Royal Navy

Note 1

When this code is being used by H.M. ships (*e.g.*, during Combined Operations) the following additional procedure is adopted :—

(*a*) In the event of one ship finding that a raid which she is reporting is the same as one which another ship is already reporting, and in the absence of an instruction from the Control Centre, she is to add the raid letter and number of the other ship before her own raid letter and is to cease reporting that raid *after two such reports.* (*See* Example (ii) (*c*).)

(*b*) A ship detailed to take over a raid is to use her own raid letter and number AFTER that of the ship previously reporting this raid *For the First Two Reports* and then her own raid letter and number only.

Use of R/T in Combined Operations

Note 2

When information is passed by R/T during combined operations, the same code procedure is to be used and the standard phonetic alphabet employed.

APPENDIX No. 30

G.C.I. EQUIPMENT FITTED IN L.S.T. 305

Brief History and Introduction

On 9 June 1943 the installation of the G.C.I. on H.M.S. L.S.T. 305 was completed, and on 11 and 12 June, calibration and V.H.F. tests were carried out in Liverpool Bay, and northwards to the Clyde.[1]

The R/T range on T.R.1143 was found to be inadequate at low altitudes. Twin channel mobile equipment, T.1131 and R.1132A, was installed later at Greenock.

Without any further calibration or V.H.F. tests, and also without, to the best of our knowledge, our secret documents or operational details, the ship sailed on 19 June.

Further tests were impossible during the passage, by order of the Convoy Commodore.

At Gibraltar, tests were arranged, and it was found that mutual interference between the V.H.F. and the G.C.I. was such that on certain frequencies operations were impossible on all bearings ; on most frequencies the G.C.I. receiver was entirely paralysed for 180 degrees of rotation.

[1] A.M. File S.20034, Encl. 2A.

At Algiers, further enquiries resulted in the inclusion into the G.C.I. input circuit of a V.H.F. interference rejector unit which unfortunately we had no opportunity of testing conclusively. But as we saw a number of aircraft on the " bowl," and no interference, we assumed this unit to be a success.

On D — 2 day the Army on board opened their sealed documents, and with these there were some details referring to A.M.E.S. 15076.

On arrival at Cap Passero on D-day, we were furnished with our call sign and the call signs of the H.Q. ships and Malta, by H.M.S. *Hilary*, but still had no complete picture of our part in the operation, nor of the call signs, A.I. patrol lines, etc., of the aircraft we were to control.

Owing to the comparatively small amount of enemy opposition encountered in the early stages, another G.C.I. was landed and was operating on the same V.H.F. frequency that night, which resulted in far too much traffic on the one channel.

At 2100 hours we attempted to take over an aircraft, but owing to excessive fading it was found impossible. Therefore, when the first raiders appeared at 2200 hours we had no fighter under control.

The Technical Officer removed the V.H.F. interference rejector unit and we operated in the 180 degrees of the " bowl," which was free of V.H.F. interference, during the second raid.

The first fighter taken over requested to return to base with " a bent weapon " ;[1] we finally got an aircraft and patrolled it about 50 miles north of us, off Augusta.

At 0430 hours some unidentified raids were engaged, and in the two attempts at interception, made at 60 and 70 miles range, one Ju.88 was destroyed and one was damaged. Another fighter was taken over, but unfortunately with his " weapon bent " ; the interception, although persevered with, was unsuccessful.

On the night of D plus 1-day two controllers working from the one P.P.I, carried out four interceptions, resulting in one Ju.88 destroyed, one damaged, one combat result unknown, and one identified—a Hurricane.

On D plus 2-day were given instructions to land, but after explaining that we were not completely mobile, were told to remain on board.

During this day we arranged with H.M.S. *Hilary* to carry out R.D.F. plotting, and that night to act as stand-by to another G.C.I. which had been landed.

On D plus 3-night we operated as a G.C.I. from 2100 hours, patrolling aircraft and carrying out practice interceptions until 0249 hours, when our G.C.I. transmitter became unserviceable, and we missed the only hostile activity of the night, coming back on the air at 0505 hours.

On the fourth day, in the absence of any further orders from our controlling ship, H.M.S. *Largs*, we suggested that we return to Malta to obtain badly needed P.P.I. tubes. (Our two spares, said to be new, was found to be almost U/S.)

On this and the following days, continued representations were made to the Naval Commander, Force V, for permission to proceed, and finally we reached Malta on 22 July.

The S.A.S.O., Malta, reported our whereabouts to A.H.Q., Desert Air Force, and then with the excellent assistance of the Signals, Operations, and R.D.F. staffs, we completely recalibrated and re-equipped the unit. The installation of a Hallicrafter S.27 V.H.F. receiver completely overcame all our local oscillator interference.

A.H.Q., Malta, were making arrangements to use the unit as a sea-borne G.C.I. some 10–15 miles off the island, when they were rushed back to Sicily to operate off Avola.

On arrival, the Senior Officer of H.M.S. *Delhi* was contacted for instructions, and it was found that the unit was required to give R.D.F. cover to the landing beaches. On explaining our capabilities, it was realised that the function of the unit had not been fully understood. However, we moved 15 miles south and became an R.D.F. teller to H.M.S. *Ulster Queen* and *Delhi*, who were giving A.A. protection to the shipping.

[1] The code for indicating that A.I. was unserviceable was " My weapon is bent."

The coverage we gave was satisfactory from the naval point of view, and our identification of night fighters (Mark II-G I.F.F.) was invaluable to them.

We contacted No. 1 M.O.R.U. at Melilli, and found that there was a W/T frequency in operation, giving a broadcast of general situation filtered plots. This frequency was passed to H.M.S. *Delhi* and *Ulster Queen*, who thus obtained a far more comprehensive picture than we could provide. The Navy should have been advised of this facility by the Signals planning organisation.

On 5 August we returned to Malta.

Installation

The G.C.I. equipment was fitted in the U.K., and only minor modifications to the original work have been carried out since. The equipment consists of transmitter, type T.3079; receiver, type R.3101, and Mark IV B.T.H. power-tuned aerial trailer. Power supplies consist of two Lister, Mark 11 20 KVA Diesel sets. The aerial is installed in a platform 7 ft. 6 in. above the main deck level, giving an effective height above sea-level of 33 ft. Tx. and Rx. vehicles are installed in the tank space, port side forward ; both Diesels are in the extreme after end of the tank deck. In connection with the installation of vehicles in an L.S.T. tank deck, it should be noted that the standard Crossley radio vehicles are too high to be manœuvred into position easily, and partial tyre deflation had to be resorted to.

All gear was set up for operation on 209 megacycles, the aerial being C.H.L. connected (no G.C.I. " Split "). The Tx. feeder is strained open-wire, the Rx. feeder AS.26 coax. Considerable care was taken with inter-connecting cabling, and it was necessary to keep it slung above the deck levels, so as to prevent damage due to tanks, M., etc. Insulation is important, due to the steel hull at all points.

A special feature of the installation is the provision of P.P.I. bearing correction to allow for the ship swinging. This is achieved by the use of a gyro compass repeated, and a differential Selsyn connected in circuit between the rotors of the aerial and P.P.I. Selsyns. Manual adjustment of the differential Selsyn dial, to correspond with the gyro repeated reading, serves at all times to maintain the P.P.I. trace correct to the reading on the fixed compass rose.

Interference

Interference between G.C.I. and V.H.F. has been the largest single technical problem.

Operational Performance

(a) General

The station operates as a C.H.L./G.C.I., and results are comparable with those of Happisburgh 1, in U.K. The signal strength varies slightly with the pitch and roll of the ship, but in the seas in which we have carried out interception, this has not hampered operation or height-finding seriously. The L.S.T. superstructure offers no really effective screening, and 360-degree cover is available. V.H.F. interference referred to below is a problem.

In practice it has been found that the P.P.I. bearing correction device works very satisfactorily ; however, a means of maintaining this correction automatically would be very desirable, and it would reduce by one the number needed to make up an operational watch. It is believed that some such device is in use in Naval R.D.F.

On the whole, the gear stood up very well to sea-borne operation, the only trouble being the expected ones of—

(i) Slipping of adjustments, due to shock and vibration.

(ii) Necessity for careful precautions against salt corrosion.

One serious difficulty did show up, namely that of a defective slipping unit. This was due to lack of time for thorough checking of gear before hasty departure, and full details are set down in Monthly Technical Report of 30 June.

The aerial turning gear has performed very well under the adverse conditions, maintaining its speed of rotation fairly constant despite the rolling of the ship, etc.

(*b*) *Height-finding*

The height-finding was good, but only one operator in the crew had any experience, and in future all crews should be trained in the C.H.L. height-finding technique.

(*c*) *Calibration*

Calibration should be completed before the unit leaves its home base. Care must be taken that the ship's draught, forward, is the same during operations as when calibrations are carried out. An additional calibration in the operational area is useful, owing to the effects of temperature inversion. Under tropical conditions, extra low-angle cover is available.

Operational Control

(*a*) *Identification of Aircraft*

Extreme difficulty was experienced in identifying aircraft. In fact, there was no identification, except of night fighters. A Mark III interrogator would be of value. It is essential that in future operations, advance information regarding friendly bomber activity and courses, be passed to the G.C.I.s.

(*b*) *Problem of Rendezvous*

This problem could be overcome by the full use of Marks IV and VIII beacons. During this operation the Mark VIII beacon installed was inoperative, due to advice received from Malta R.D.F. (Air) to the effect that, at present, use of the Mark VIII beacon would seriously damage the modulator units of the A.I. sets in the aircraft. A Mark IV beacon (consisting simply of a modified aircraft I.F.F. set) was supplied to us by A.H.Q., Malta. This unit, working on 193 mc/s., causes serious interference with the G.C.I., and means must be found for remedying this before the unit can be of practical value. Aircraft with Marks IV, VII and VIII A.I., were used in this operation.

Failing the use of the beacon method of fixing, patrolling by the aircraft off some known position is essential.

Neither of these methods are of the slightest use whatsoever, unless pilots and controllers are well briefed in regard to beacon coding and/or patrol lines, which was not the case.

Suggested Improvements—Operational

In future operations the sea-borne G.C.I. should have a clear picture of its expected duties, well before the operation (with due regard to security).

When the initial L.S.T. cargo has been discharged, it is essential within reason that the G.C.I. unit has control of its own movements.

If the unit is giving cover to a particular area, it should not be placed directly in that area. Radio interference from H.Q. and Naval ships (flagship, etc.), which was considerable, could then be avoided.

The anchorage authority controlling Naval flagships should be informed of the frequency used for passing the general situation information from the H.Q. ship and/or M.O.R.U.

A "Sea-Jeep," carried in the L.S.T., on the G.C.I.M.T. establishment, would be an asset. Transport for liaison purposes is totally inadequate.

Day interceptions while en route, for convoy protection, and using Mediterranean land-based fighters, could have been carried out; but experiments should be made in heavier seas to ascertain operational efficiency.

Suggested Improvements—Technical and General

Vehicles

The present "roll-out" fitting of R.3101 has been a source of much trouble. There is no provision for locking the receiver in its "out" position, and it tends to be very unmanageable during rough weather. The shocks and vibration encountered necessitate frequent readjustment to the set, also the unavoidable jar to which it is subjected each time it is rolled back in operating position after adjustment, does not contribute to maintaining accuracy of set-up. Furthermore, under the existing arrangements, it is impossible to make rapid adjustments such as are occasionally required during operations. The obvious remedy is to provide a let down flap on the left-hand side of the vehicle, such as is already provided on the right-hand side.

Floor level ventilator louvres in the aerial cabin should be sealed. All cable entry boxes should be so designed that they could be waterproofed with the cables connected in position. A very important point is that of waterproofing beneath the aerial cabin, where salt spray enters around the rotation track.

All vehicles should be provided with stout eyes at the corners, for lashing-down purposes ; also steadying jacks should be provided in all cases, to prevent swaying.

All tall units such as Transmitter T.3079, and the Mark VIII beacon units, should definitely be supported at the top, to prevent damage during violent rolling of the ship. There is a distinct possibility of these units tearing themselves loose from their base mountings, if not so supported. The type of top mounting provided on V.H.F. Tx. type T.1131 is ideal. It has been found that even a moderate role will break the internal G.C.I. feeder run, unless the top of the Tx. is supported. The flimsy superstructure of the vehicle cannot be depended upon to support this massive unit, so it was found necessary to secure the top of the transmitter to the floor of the vehicle.

Fittings, Internal

Internal ventilation of the operations room is still inadequate, despite the air-conditioning system.

There is a need for compartmentation of stores cupboards, also provision of numerous screw-eyes, so that gear can be securely stowed and lashed into position. Floor cleats should be provided so that large items, such as tool-boxes, can be lashed to the floor of the Tx. van. A work-bench of reasonable size is definitely needed.

Feeders and Cabling

All feeder joints must be bound with tinned wire before soldering. Solder alone is useless in view of the stresses to which the feeders are subjected.

All external feeder runs, straining springs, tapping points and shorting bars, should be given a heavy coat of Distrene varnish, to prevent salt spray corrosion. Soldered joints need particular attention due to the tendency towards electro-chemical action of the dissimilar metals in the presence of salt electrolyte. A stronger type of power cable is needed on ship-borne units to stand up to the inevitable extra abuse. Cables should be armoured with metal sheath, or at least strong braid.

P.P.I. Mounting Modification

It has been found that the P.P.I. tube is prone to slip slightly out of its correct position, due to vibration of the ship ; also the frequent need for grid mask readjustment, as the unit moves from site to site, loosens the tube in its rubber holder. A very satisfactory solution has been found for this difficulty—simply the provision of a canvas belt for the tube, as is used on the H/R tube. This can be made from the mounting fitted in the P.P.I. transit case.

Aerial Positioning

Care should be taken upon installation to mount the aerial trailer so that its connection box faces aft, for protection from salt spray. This was not done in the case of the present unit.

Positioning of Diesel engines on the upper deck would be an improvement from the standpoint of both ventilation and cooling ; also they would be more accessible for maintenance.

Extra Material Required

A good stock of P.P.I. tubes is most important ; at least six spares should be carried as a good percentage were found to be unsatisfactory upon test. Several spare G.C.I. dipoles and matching transformers should be provided in case of mechanical damage to the aerial. A long-nosed water can is needed for topping up Diesel radiators which are very inaccessible. A good stock of " raw materials " should be included with the spares for these self-contained units—such items as nuts and bolts, sheet brass, perspex, concentric plugs and sockets, assorted small bulbs and bulb holders. Such items are very necessary to carry out the inevitable small improvisations which have to be made by unit mechanics. A good quantity of light cord is essential for cabling together inter-vehicle leads and not less than three dozen rolls of black friction tape.

A complete set of valve characteristics should be issued covering all R.D.F. and V.H.F. types. This should give the manufacturer's type number as well as the R.A.F. type, and should show if possible the valves' characteristic curves. Such a chart would be particularly useful when valve spares run short to facilitate intelligent substitution.

It is strongly recommended that every technical officer on a unit of this type should be given an intensive course on V.H.F. gear as a part of his training; he is not usually in a position to obtain the help of a Signals specialist, and is responsible for the efficiency of the V.H.F. gear as well as the G.C.I.

V.H.F. EQUIPMENT

Installation

R/T equipment consists of a twin-channel mobile set, employing T.1131.s and R.1132A.s; also two pack-sets, type T.R.1143 for H.Q. ship intercommunication, and one Hallicrafter, type S.27 V.H.F. receiver. Two J-matched dipoles are mounted on the mast for transmitters, and two half-wave centre-fed dipoles on the yard-arms for receivers and pack-sets. All R/T transmitters and receivers are fitted in two vehicles, type 100 and 150, on the top deck.

Interference

Heavy mutual interference between G.C.I. and R/T has been a very great problem. This interference may be classified as follows :—

(*a*) Interference by the second harmonic of the V.H.F. transmitter with the G.C.I. receiver. This results in complete paralysis of the G.C.I. receiver when the aerial faces the R/T, and for some distance on either side of this point; the size of the interference sector depends upon the R/T frequency and extends up to 360 degrees in the worst cases. The use of any V.H.F. whose second harmonic approaches 209 m/cs. should be avoided; in general, it may be said that crystal frequencies above 6,000 kc/s are satisfactory; those below this are not.

(*b*) Paralysis of R/T receiver by G.C.I. radiator, the sensitivity of the G.C.I. receiver, seems to be very adversely affected when the G.C.I. aerial faces it; also background noise is excessive due to the G.C.I. 400 cycle note.

(*c*) Interference from the local oscillator of R.1132A with G.C.I. receiver. This caused serious trouble over a G.C.I. sector of about 130 degrees, and was the most serious type of interference encountered, due to its continuous nature. The solution found (after the operation) was the installation of a Hallicrafter S.27 receiver.

Operation

Arrangements have been made whereby both controllers can operate simultaneously on the same channel; a separate line is provided for the passing of plots and general information to and from H.Q. ship or M.O.R.U. via pack-set T.R.1143. No arrangements had been made, however, in the H.Q. ship for this obvious necessary liaison.

All transmitters are switched by remote control, *i.e.*, no carrier-wave is radiated when not actually transmitting. The intercom pack-set control panel is at present operated in the R/T cabin. In all cases, signal to " Transmit " is given by push-button in the operations room to indicator light in the R/T cabin; this seems to be the most trouble-free system.

Suggested Improvements—Operational

In future operations communication with H.Q. ship and/or M.O.R.U. should be arranged as outlined above.

If possible, crystal frequencies allotted should be 6,000 kc/s or over for interference reasons.

Suggested Improvements—Technical and General

R/T vehicles should be situated in the tank space for air raid protection.

Receivers type 1132A should definitely be eliminated in favour of Hallicrafter type S.27. Not only does the latter overcome the problem of local oscillator interference, it also provided a lower level of background noise, according to tests carried out.

Tuning dial locks should be provided for receivers, to avoid frequency drift due to vibration.

Transmitters type T.1131 are prone to overheating and fuse-blowing under tropical conditions. A forced air ventilating system is indicated.

A power pack suitable for operating T.R.1143 directly from the mains is essential, to avoid use of accumulators.

Dipoles of the ·75 wavelength J-matched type have been found to snap due to vibration ; they have considerable length and mass, and even when supported with guying cords sway about considerably. Would recommend use of the ½-wave centre-fed type such as are fitted on the yard-arms of L.S.T. 305. These are rugged, and also appear to have greater efficiency according to receiving tests carried out.

Test set type 5A is necessary for line-up of T.R.1143—none was provided for this unit.

To save R.T.C. personnel, press-button control unit for T.R.1143 should be set up in operations room.

Personnel

The C.O.L. establishment of A.M.E.S. 15076 is inadequate. Establishment should be made up as follows :—

2 Controllers.
1 Technical Officer.
R.D.F. Operators : 1 Sgt., 3 Cpls., 18 A.C.s. The following positions have to be manned :—

Height/Range Reader.
H.Q. Ship or M.O.R.U.
Liaison (able to use R/T).
Turning Gear Operator.
Bearing Correction Operator.
P.P.I. Reader.
Telephone Operator.

R.D.F. Mechanics : 1 F/Sgt., 1 Cpl., 2 A.C.s.
R/T Personnel : 1 Cpl. W/Mech., 1 A.C. R.O.M., 5 A.C.s R.T.O.s (in future 2 R.T.O.s. (Refer paragraph 74)).
1 M.T.M., 1 D.M.T., 2 A.C.H./G.D.s.

Consideration *must* be given to seasickness ; 90 per cent. of the personnel were affected and operational efficiency jeopardised.

Conclusion

If all the aforementioned points, operational and technical, are given due consideration, the results obtained by this station in two hours of actual operation (*i.e.*, two destroyed, two damaged, one combat result unknown) prove that, with further experiment, sea-borne units offer great possibilities.

Headquarters, Mediterranean Air Command.
S.8578/Signals.

3 August 1943.

GROUND SEARCH R.D.F. UNITS TAKING PART IN OPERATION " HUSKY"[1]

In order to provide shore-based R.D.F. cover over ports and beaches as early as possible in the operation, and to provide facilities for the control of fighters, the Air Plan made provision for landing air warning and C.O.L./G.C.I. units as follows :—

1. Twelth Army

Acid (for defence of Syracusa and Augusta).

D-day ..	.. 1 G.C.I. (nucleus), 2 L.W.S.
D plus 3 ..	.. 1 C.O.L., 2 L.W.S.
D plus 14 ..	.. 1 G.C.I. (balance), 1 M.R.U.

Bark (South).

D-day plus 1	.. 1 G.C.I. (nucleus), 2 L.W.S.
D plus 3 ..	.. 1 C.O.L., 2 L.W.S.
D plus 14 ..	.. 1 C.O.L. (balance), 2 G.C.I. (balance).

Bark (East).

D-day ..	.. 1 G.C.I. (nucleus), 2 L.W.S.
D plus 3 ..	.. 1 C.O.L. (nucleus), 1 G.C.I. (nucleus).
D plus 14 ..	.. 1 G.C.I. (balance), 1 M.R.U.

Bark (West).

D-day ..	.. 1 G.C.I.

Cent.

D-day ..	.. 1 G.C.I., 2 L.W.S.
D plus 4 ..	.. 1 G.C.I., 2 L.W.S., 1 G.C.I. (balance).
D plus 8 ..	.. 1 C.O.L.

Fustian Area.

D plus 5 ..	.. 4 L.W.S., 1 G.C.I. (nucleus).
D plus 7 ..	.. 1 G.C.I., 1 C.O.L., 1 M.R.U.

2. Force 343

Dime.

D-day ..	.. 1 G.C.I.
D plus 3 ..	.. 2 G.C.I. or C.O.L., 2 L.W.S.
D plus 14 ..	.. 1 M.R.U.

Joss.

D-day ..	.. 1 G.C.I. or C.O.L., 2 L.W.S.

This provision was to be made from the following R.A.F. Units :—

From the Middle East :—

A.M.E.S. No. 871 (G.C.I.).
A.M.E.S. No. 873 (G.C.I.).
A.M.E.S. No. 887 (G.C I)
A M.E.S. No. 8028 (G.C.I.).
A.M.E.S. No. 628 (L.W.S.).
A.M.E.S. No. 6037 (L.W.S.).
A.M.E.S. No. 6038 (L.W.S.).
A.M.E.S. No. 6039 (L.W.S.).
A.M.E.S. No. 6040 (L.W.S.).
A.M.E.S. No. 6041 (L.W.S.).
A.M.E.S. No. 6042 (L.W.S.).
A.M.E.S. No. 6043 (L.W.S.).
A.M.E.S. No. 6044 (L.W.S.).
A.M.E.S. No. 6045 (L.W.S.).
A.M.E.S. No. 886 (C.O.L.).
A.M.E.S. No. 8016 (C.O.L.).
A.M.E.S. No. 267 (M.R.U.).
A.M.E.S. No. 374 (M.R.U.).

[1] A.H.B./IIA1/73, Encl. 95A.

2. Force 343—*contd.*

Flying Rescue :—

A.M.E.S. No. 605 (L.W.S.).
A.M.E.S. No. 621 (L.W.S.).
A.M.E.S. No. 622 (L.W.S.).
A.M.E.S. No. 623 (L.W.S.).
A.M.E.S. No. 630 (L.W.S.).
A.M.E.S. No. 631 (L.W.S.).

From the United Kingdom :—

A.M.E.S. No. 8033 (G.C.I.).
A.M.E.S. No. 15052 (G.C.I.).
A.M.E.S. No. 15076 (G.C.I.).
A.M.E.S. No. 6109 (L.W.S.).
A.M.E.S. No. 6060 (L.W.S.).
A.M.E.S. No. 6061 (L.W.S.).
A.M.E.S. No. 6069 (L.W.S.).
A.M.E.S. No. 332 (M.R.U.).
A.M.E.S. No. 8042 (C.O.L.).

From North-West Africa :—

A.M.E.S. No. 8043 (G.C.I.).
A.M.E.S. No. 8035 (G.C.I.).
A.M.E.S. No. 6003 (L.W.S.).
A.M.E.S. No. 6004 (L.W.S.).
A.M.E.S. No. 6008 (L.W.S.).
A.M.E.S. No. 6011 (L.W.S.).
A.M.E.S. No. 8023 (C.O.L.).

APPENDIX No. 32

DETAILS OF RADAR UNITS TAKING PART IN THE LANDING ON THE ITALIAN MAINLAND, SEPTEMBER 1943

Tactical Units under M.A.T.A.F. Control—Salerno–Naples Area

D-day.	887 G.C.I. Station.	Plotting to 64th Fighter Wing (U.S.A.A.F.).
	871 G.C.I. Station.	
	6037 L.W.S.	
	6043 L.W.S.	
D plus 4.	329 M.R.U.	
	8035 G.C.I. Station.	
	6041 L.W.S.	
	6038 L.W.S.	
D plus 7.	8043 C.O.L. Station.	
	8015 G.C.I. Station.	
D plus 11.	8020 C.O.L. Station.	
D plus 15.	332 M.R.U.	
	886 C.O.L. Station.	

Base Defence Units under M.A.T.A.F. and M.A.C.A.F.—Messina–Calabria–East Coast of Italy

873 C.O.L./G.C.I. Station.	Plotting to No. 1 M.O.R.U. and No. 1 F.F.C.U. (Desert Air Force).
890 C.O.L./G.C.I. Station.	
8028 C.O.L./G.C.I. Station.	
8033 C.O.L./G.C.I. Station.	
8036 C.O.L./G.C.I. Station.	
628 L.W.S.	
629 L.W.S.	
6003 L.W.S.	
6004 L.W.S.	
6039 L.W.S.	
6040 L.W.S.	
6042 L.W.S.	
6044 L.W.S.	
6045 L.W.S.	
6060 L.W.S.	
6061 L.W.S.	

APPENDIX No. 33

CONSTITUTION AND TERMS OF REFERENCE OF THE SEABORNE FIGHTER CONTROL BOARD

Constitution of the Board

One Operational Staff and one Signals representative from each of the following authorities :—

Commander-in-Chief, Mediterranean.
Commander, United States Naval Forces, Northwest African Waters.
Air Commander-in-Chief, Mediterranean Allied Air Forces.
Mediterranean Allied Coastal Air Force.
Mediterranean Allied Tactical Air Force.
Headquarters, Royal Air Force, Middle East.

Terms of Reference

The function of the Board will be—

(*a*) To co-ordinate all matters relating to sea-borne fighter control in the Mediterranean, including the co-ordination of the provision and fitting of equipment and the provision and training of the necessary personnel.
(*b*) To advise on requirements of sea-borne fighter control in the Mediterranean.
(*c*) To advise on the equipment required in any ship which may perform duties relating to sea-borne fighter control.
(*d*) To recommend modifications necessary to existing equipment for future employment in ships carrying facilities for fighter control.
(*e*) To recommend and co-ordinate any tests or developments considered necessary.
(*f*) To collate and distribute to interested parties information on sea-borne fighter control.
(*g*) To suggest recommendations for transmission to Admiralty ; Chief of Naval Operations ; United States Navy ; Air Ministry, London ; and Commanding General, Army Air Forces, Washington, United States.

In carrying out the above the Board will act in an advisory capacity to Commander-in-Chief, Mediterranean, and Air Commander-in-Chief, Mediterranean Allied Air Forces, and is empowered to co-opt such additional members as may be required from time to time, to deal with particular problems.

RADAR UNITS IN THE NORTH AFRICA COASTAL AIR FORCE BASE DEFENCE SECTORS, 1 NOVEMBER 1943[1]

Sector.	*A.M.E.S. No.*	*Type.*	*Location.*
1. Taranto	274	M.R.U.	S. Cataldo.
No. 242 Group (Desert Air Force).	8010	G.C.I.	Bari.
	8032	G.C.I.	Brindisi. Leuca
	8041	C.O.L.	C.S. Maria di Levea.
	624	L.W.S.	Brindisi.
	14027	Type 14	Bari.
	14028	Type 14	Brindisi.
2. Naples	330	M.R.U.	Acciarolli.
62nd Fighter Wing (XII Air Support Command, U.S.A.A.F.).	256	M.R.U.	St. Felice Circeo.
	15051	G.C.L.	Ischia.
	8009	C.O.L.	Pisciatta.
	8044	C.O.L.	Naples.
	8029	C.O.L.	Maddaloni.
	623	L.W.S.	Ischia.
3. Foggia	214	M.R.U.	Vieste.
No. 242 Group (Desert Air Force).	899	G.C.I.	Lake Lesina.
	8016	C.O.L.	Peschisi.
	890	C.O.L.	Rossa Point.
4. Corsica	372	M.R.U.	Calvi.
63rd Fighter Wing (XII Air Support Command, U.S.A.A.F.).	392	M.R.U.	Ajaccio.
	295	M.R.U.	Ghissonnacia.
Borgo Sector	8003	G.C.I.	Algajola.
Ajaccio Sector	892	G.C.I.	Bastia.
	8001	C.O.L.	Oristano.
	889	C.O.L.	Ghissonnacia.
	6005	L.W.S.	North Bastia.
		Type 11	Maccinagio.
		Type 11	N. Bastia.
		Type 16	Lumio.
5. Sardinia	275	M.R.U.	C. Falcone.
63rd Fighter Wing (XII Air Support Command, U.S.A.A.F.).	294	M.R.U.	C. Mannu.
	898	G.C.I.	Porto Torres.
Alghero Sector,	8005	G.C.I.	Giovanni.
Cagliari Sector.	880	C.O.L.	C. Ferro.
	881	C.O.L.	C. Marco.
	6010	L.W.S.	Pula.
	622	L.W.S.	Decimomannu.
	6007	L.W.S.	Decimomannu.
	631	L.W.S.	Pula.

[1] A.M. File C.S. 18822, Encl. 63A.

APPENDIX No. 35

M.A.A.F. RADAR STATION STATUS
1 March 1945

CO = Corsica.
CY = Cyrenaica.
E = Egypt.
F = France.
P = Palestine.
M = Malta.
I = Italy.
T = Turkey.

PART I
Royal Air Force Stations

Type No.		Present Location.	MAFOG Grid.	Status.	Admin. Control.	Ops. Control.	Sector.	Remarks.
9T	239	Mondalfo (I)	OH 4157	N/Op.	D.A.F. ..	1 M.O.R.U. ..	—	
	256	Varcature, L. Patria (I)	OY 5403	Op.	335 Wing ..	335 Wing ..	Naples	
	267	Cattolica (I)	OH 5843	Op.	D.A.F. ..	287 Wing ..	Ancona	
	278	Derna (CY)	EH 4738	Op.	212 Group ..	212 Group ..	16 S.O.R.	Two-watch basis.
	329	Hyeres (F)	NG 0710	Op.	340 Wing ..	340 Wing ..	Aix	
	330	Rosignano (I)	OF 2326	Op.	338 Wing ..	338 Wing ..	Leghorn	
	331	Pianta di Piscara (I) ..	OO 2418	Op.	323 Wing ..	323 Wing ..	Foggia	
	372	Ile Ruusse (I) ..	NF 3853	Op.	No. 301 A.S.P. Cert. Unit.	338 Wing ..	Leghorn	
	374	Bullaria (I)	OC 0825	Op.	D.A.F. ..	1 M.O.R.U. ..	—	
	388	Marz Ecca (I) ..	OI 3919	Op.	287 Wing ..	287 Wing ..	Ancona	
	397	Berra L'Etang (F) ..	NF 2909	Op.	340 Wing ..	340 Wing ..	Aix	
4	401	Ikingi (E)	FY 5844	Op.	A.H.Q., E. Med.	A.H.Q., E. Med.	13 S.O.R.	Being reduced to C. and M. basis.
	402	Damietta (E) ..	GQ 3251	Op.	A.H.Q., E. Med.	A.H.Q., E. Med.	12 S.O.R.	Two-watch basis.
3	501	Fort ta Silch (M) ..	CY 5033	Op.	137 M.U. ..	Halfar ..	Malta	
	502	Madalena (M)	GY 5628	Op.	Halfar ..	Halfar ..	Malta	
	531	Port Said (E) ..	GR 1517	Op.	A.H.Q., E. Med.	A.H.Q., E. Med.	12 S.O.R.	
8 G.C.I.	826	Tel el Kebir (E) ..	GY 3554	When wanted.	A.H.Q., E. Med.	A.H.Q., E. Med.	12 S.O.R.	
G.C.I.	871	La Grette (F)	NF 3700	Op.	340 Wing ..	340 Wing ..	Aix	
G.C.I.	892	Gorgona Island (I) ..	NJ 2553	Op.	301 A.S.R.O.U.	338 Wing ..	Leghorn	
C.O.L.	897	Torre Gaveta (I) ..	OY 4802	Op.	335 Wing ..	335 Wing ..	Naples	
G.C.I.	899	Gabicoe Marina (I) ..	PQ 2007	Op.	323 Wing ..	323 Wing ..	Foggia	S.A.A.F. personnel.

	C.O.L.	8003	Lumio (CO)	NN	3549	Op.	301 A.S.R.O.U.	338 Wing ..	Leghorn	
8	C.O.L.	8005	Populonia (I) ..	OK	5830	Op.	338 Wing ..	338 Wing ..	Leghorn	
	G.C.I.	8009	Guasticce (I)	OF	3622	Op.	338 Wing ..	338 Wing ..	Leghorn	
	C.O.L.	8010	Mola di Bari (I) ..	PR	0207	Op.	323 Wing ..	323 Wing ..	Foggia	
	G.C.I.	8015	La Londe (F) ..	NG	0814	Op.	340 Wing ..	340 Wing ..	Aix	
	C.O.L.	8016	Peschici (I)	PQ	5702	Op.	323 Wing ..	323 Wing ..	Foggia	
	G.C.I.	8017	Port Said (E) ..	GR	1715	When wanted.	A.H.Q., E. Med.	A.H.Q., E. Med.	12 S.O.R.	
	G.C.I.	8020	Pomigliano (I) ..	OY	5523	Op.	335 Wing ..	335 Wing ..	Naples	
	C.O.L.	8023	Ancona (Lighthouse) ..	OI	3731	Op.	287 Wing ..	287 Wing ..	Ancona	
	G.C.I.	8028	Rimini (I)	OC	0335	Op.	D.A.F. ..	1 M.O.R.U.	—	
	G.C.I.	8029	Yesilkoy (T)	NX	5849	Op.	B.R.C. ..	B.R.C. ..	29 Radar Det.	
	C.O.L.	8031	Lanciano (I)	OO	1630	Op.	323 Wing ..	323 Wing ..	Foggia	
		8032	Staging prior to transfer to B.A.F.							
	G.C.I.	8033	Bellaria (I)	OC	0825	Op.	D.A.F. ..	1 M.O.R.U.	—	
	C.O.L.	8035	Ledramont, Agay (F) ..	NG	2552	Op.	340 Wing ..	340 Wing ..	Aix	
	G.C.I.	8036	Ospedalleto, nr. Forli (I)	OC	1503	Op.	D.A.F. ..	1 M.O.R.U.	—	
	G.C.I.	8043	Chiaravalle (I) ..	OI	3720	Op.	287 Wing ..	287 Wing ..	Ancona	
	GCI	8044	Ripalta (I)	PP	5318	Op.	323 Wing ..	323 Wing ..	Foggia	S.A.A.F. personnel.
		8503	Amriya (E)	FT	0651	When wanted.	A.H.Q., E. Med.	A.H.Q., E. Med.	13 S.O.R.	
15	C.O.L.	15051	Sete (F)	MI	2441	Op.	340 Wing ..	340 Wing ..	Aix	
		15052	Ravenna (I)	OC	2811	Op.	D.A.F. ..	1 M.O.R.U.	—	
		15057	Cesena (I)	OC	0713	Op.	D.A.F. ..	1 M.O.R.U.	—	
6			Yesilkoy (T)	NX	5849	Op.	B.R.C. ..	B.R.C. ..	29 Radar Det.	
			Yaluva (T)	NY	3917	Op.	B.R.C. ..	B.R.C. ..	29 Radar Det.	
		6004	Ravenna (I)	OC	2711	Op.	2 L.W. H.Q. ..	D.A.F. ..	—	
		6038	Gracciano, nr. Colle (I)	OG	2308	Op.	338 Wing ..	338 Wing ..	—	
		6041	Ravenna (I)	OC	2711	N/Op.	1 L.W. H.Q. ..	8 Army ..	—	Shell tracking.
		6042	Faenza (I)	OB	1754	Op.	2 L.W. H.Q. ..	D.A.F. ..	—	
		6043	Ravenna (I)	OC	2711	N/Op.	1 L.W. H.Q. ..	8 Army ..	—	Shell tracking.
		6060	Rimini (I)	OC	0430	Op.	2 L.W. H.Q. ..	D.A.F. ..	—	

M.A.A.F. RADAR STATION STATUS
1 March 1945

CO = Corsica.
CY = Cyrenaica.
E = Egypt.
F = France.
P = Palestine.
M = Malta.
I = Italy.
T = Turkey.

PART I—*continued*

Royal Air Force Stations—*continued*

Type No.	Present Location.	MAFOG Grid.	Status.	Admin. Control.	Ops. Control.	Sector.	Remarks.
6 C.O.L. 6061	Rimini (I)	OC 0430	Op.	2 L.W. H.Q. ..	D.A.F. ..	—	
6062	Pisa (I)	OF 4321	Op.	338 Wing ..	338 Wing ..	Leghorn	
6075	Bellaria (I)	OC 0727	N/Op.	D.A.F. ..	1 M.O.R.U. ..	—	
6076	Bellaria (I)	OC 0727	N/Op.	D.A.F. ..	1 M.O.R.U. ..	—	
6109	Staging prior to transfer to B.A.F.						
67 S.C.R. 67005	Ravenna (I)	OC 2711	Op.	R.H.Q., D.A.F.	1 M.O.R.U. ..	—	Mobile Radar Control Unit.
584 US7277	Faenza (I)	OB 1754	Op.	582 Sig. A.W. Bn.	1 M.O.R.U. ..	—	Mobile Radar Control Unit.
14 14019	R.I. and M.U. (M.E.) ..	—	Training	—	—	—	
14020	Cap Ferrat (F) ..	NG 4120	Op.	340 Wing ..	340 Wing ..	Aix	
14021	Cap Corse (CO) ..	NJ 0127	Op.	301 S.R.C.U. ..	338 Wing ..	Leghorn	
14023	Antignano (I) ..	OF 2920	Op.	338 Wing ..	338 Wing ..	Leghorn	
14024	Ancona Lighthouse (I)	OI 3731	Op.	287 Wing ..	287 Wing ..	Ancona	
14025	Ravenna (I)	OC 2811	Op.	D.A.F. ..	1 M.O.R.U. ..	—	
14027	Bellaria	OC 0825	Op.	D.A.F. ..	1 M.O.R.U. ..	—	
14028	Peschici (I)	PQ 5702	N/Op.	286 Wing ..	—	—	To move.
14034	Giens (F)	NG 0306	N/Op.	340 Wing ..	340 Wing ..	Aix	
14035	Grottamare Alto (I) ..	ON 5952	Op.	287 Wing ..	287 Wing ..	Ancona	
14036	Castel de Mezzo (I) ..	OH 5748	Op.	287 Wing ..	287 Wing ..	Ancona	
14073	Riccione	OC 0238	N/Op.	D.A.F. ..	M.A.T.A.F. ..	—	Awaiting Radar equipment.
14074	*En route* Middle East						

	14075	*En route* Middle East						
	14076	Reserve						
	14077	Expected from U.K. ..						
23	23001	Cap Bizerta (NA) ..	BO 1951	Op.	Malta	Air Ministry ..	—	
	23002	Cap Bizerta (NA) ..	DY 5339	Op.	Malta	Air Ministry ..	—	
	23003	Apollonia (CY) ..	EL 5459	Op.	212 Group ..	Air Ministry ..	—	

A.M.E.S. Disbanded or Non-Operational since August 1944

Western Mediterranean R. to N.B.

214	332	893	8038
216	381	894	8041
226	387	895	11000
232	392	896	11001
264	841	898	16004
274	873	8000	6005
275	880	8001	6006
283	881	8002	6007
285	886	8004	6008
286	887	8006	6010
294	889	8011	6011
295	890	8012	6009
		8018	6016
			6019
			6037
			6044
			6045
			6071
			6072
			6073
			6074

Middle East R. to N.B.

205	277	536
218	278	537
220	280	577
233	282	578
237	287	579
249	337	5020
253	503	5021
255	508	5104
257	523	845
259	525	846
266	533	833

Middle East C. and M.

403	540
404	407
405	505
582	531
5012	532

Turkey R. to N.B.

398	637
515	638
516	6018
633	6322
634	842
636	8037

R. to N.B. = Reduced to Number only Basis.
C. and M. = Care and Maintenance Basis.

M.A.A.F. RADAR STATION STATUS
1 March 1945

CO = Corsica.
CY = Cyrenaica.
E = Egypt.
F = France.
P = Palestine.
M = Malta.
I = Italy.
T = Turkey.

PART II

U.S.A.A.F. Stations, M.A.T.A.F.

Type.	No.	Present Location.	MAFOG/ Grid.	Status.	Admin. Control.	Ops. Control.	Sector.	Remarks.
S.C.R.270-DA	1015	Mt. Meto (I) ..	OF 5317	Op.	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	C.O.L.
	1026	Altopascio (I) ..	OF 4944	Op.	561st S.A.W. Bn., Co. E	62nd F.W.	Blue ..	C.O.L.
	1028	Castelveccio (I)	OF 4637	Op.	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	C.O.L.
S.C.R. 527	2099	Piscetto (I) ..	OG 4509	Op.	594th S.A.W. Bn., Co. B	62nd F.W.	White ..	G.C.I.
	2144	Perignano (I) ..	OF 3635	Op.	594th S.A.W. Bn., Co. A	62nd F.W.	Blue ..	C.G.I.
	2115	Antignano (I) ..	OF 3020	Op.	594th S.A.W. Bn., Co. A	62nd F.W.	Blue ..	C.O.L.
	2116	Marine di Pisa (I)	OF 3918	Op.	594th S.A.W. Bn., Co. A	62nd F.W.	Blue ..	G.C.I.
	2117	La Cava (I) ..	OF 5120	Op.	594th S.A.W. Bn., Co. A	62nd F.W.	Blue ..	G.C.I.
	2119	Pisa (I) ..	OF 3721	Training	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	Training with A.N./G.P.S.-T.1 equipment.
	2120	Lucca (I) ..	OF 4934	Op.	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	G.C.I.
S.C.R. 584A	7232	Piamaggio (I) ..	OB 1219	Op.	561st S.A.W. Bn., Co. E	XXII T.A.C.	White ..	Offensive control.
	7251	Operational Pool	—	N/Op.	562nd S.A.W. Bn., Co. A	62nd F.W.	White ..	Being converted for C.S.B. and O.C.
	7254	Pisa (I) ..	OF 4124	Op.	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	G.C.A.
	7277	—	—	Op.	180 S.S.W.P.	D.A.F. ..	1 M.O.R.U.	Close support.
	7320	—	—	Op.	180 S.S.W.P.	D.A.F. ..	1 M.O.R.U.	Close support.
S.C.R. 588	537M	Piamaggio (I) ..	OB 1219	Op.	561st S.A.W. Bn., Co. E	62nd F.W.	White ..	C.O.L.
S.C.R. 615	329	Operational Pool	—	N/Op	561st S.A.W. Bn., Co. E	62nd F.W.	White ..	To be made mobile.
	388	Operational Pool	—	N/Op.	561st S.A.W. Bn., Co. C	62nd F.W.	White ..	To be made mobile.
A.N./C.P.S.-1	3001	Bertinore (I) ..	OG 0908	Op. .	561st S.A.W. Bn., Co. C	XXII T.A.C.	White ..	Offensive control.
A.N./M.P.S.-2	403	Piamaggio (I) ..	OB 1219	Op.	561st S.A.W. Bn., Co. E	62nd F.W.	White ..	C.M.H.
A.N./T.P.S.-1	5003	Operational Pool	—	N/Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.

	5011M	Mt. Canda (I) ..	OB 1121	Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.
	5013M	Piamaggio (I) ..	OB 1219	Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	
	5014	Mt. Meto (I) ..	OF 5317	Training	594th S.A.W. Bn., Co. B	62nd F.W.	Blue ..	L.W.
	5022	Castelveccio (I)	OF 4637	Training	593rd S.A.W. Bn., Co. B	62nd F.W.	Blue ..	
	5025M	Rocco di Sotto (I)	OB 1225	Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.
	5090	Operational Pool		N/Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.
	5092M	Monghidore ..	OB 1319	Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.
A.N./T.P.S.2	12077	Florence ..	—	N/Op.	561st S.A.W. Bn., Co. D	62nd F.W.	White ..	L.W.
A.N./T.P.S.-10	105	Leghorn ..	—	N/Op.	594th S.A.W. Bn. ..	62nd F.W.	—	To be vehicle mounted
T.R.U.	111	Operational Pool	—	N/Op.	594th S.A.W. Bn., Co. A	62nd F.W.	Blue	

U.S.A.A.F. Stations, Special Applications

Type.	*No.*	*Ops. Control.*	*Remarks.*
S.C.R. 584	7041	12th Weather Sq. ..	Weather Observation.
	7099	Fifteenth Air Force ..	Bombardier Training.
	7260	12th Weather Sq. ..	Weather Observation.
	7397	Fifteenth Air Force ..	Bombardier Training.

U.S.A.A.F. Stations, 562nd SAW Bn (Non-operational)

S.C.R. 270-DA.		*S.C.R.* 584-A.	*S.C.R.* 588.	*A.N./M.P.S.*-2
1014 Co. A	1121 Co. B	7236 Co. B	579M Co. B	404 Co. B
1031 Co. B	1122 Co. A	7236 Co. B	600M Co. B	405 Co. A.
1037 Co. A	1124 Co. A			
1038 Co. A	1125 Co. B			
	1126 Co. A			

M.A.A.F. RADAR STATION STATUS
1 March 1945

CO = Corsica.	P = Palestine
CY = Cyrenaica.	M = Malta.
E = Egypt.	I = Italy.
F = France.	T = Turkey.

PART III

U.S.A.A.F. Equipments in Depots or Pools

S.C.R. 270-DA	*S.C.R.* 582*.		*S.C.R.* 584.	*S.C.R.* 588.	*A.N./M.P.S.* 2.	*A.N./T.P.S.* 1
1010	21	176	7054	530	402	5007
1013	22	177	7238	538		5012
1029	23	179	7256			5027
1030	24	180	7280	*Salvaged.*		5061
	42	181	7315			5091
	43	182M		542		
	44	183		576M		
	45	184M		577M		
	46	185				
	47	186M				
	48	187M				
	49	188				
	50	189				

PART IV

U.S.A.A.F. Equipments in North Africa

With R.N.	*With French Air Force.*		
S.C.R. 582*.	*S.C.R.* 588.	*S.C.R.* 602.	*S.C.R.* 270.
20	531	4240	1170
	532	4260	1172
	534	4262	
	535	4364	
	536		
	547		
	578		

* Set serial numbers appear in place of platoon numbers used on previous status reports.

A.M.E.S. OPERATIONAL IN INDIA AND CEYLON, MARCH 1942–SEPTEMBER 1943

Date Operational.	*A.M.E.S. No.*	*Location.*	*Type.*	*Group Area.*
1942. 28 March ..	254	Ridgeway, Colombo ..	T.R.U. ..	222
31 ,, ..	272	Elizabeth Point	M.R.U. ..	222
27 May ..	290	Ridgeway	T.R.U. ..	222
25 June ..	258	Mathurapur	M.R.U. ..	221
5 ,, ..	849	Nanunkula	G.C.I. ..	222
15 ,, ..	524	Mt. Lavinia	C.O.L. ..	224
21 ,, ..	681	Dinjan	Portable ..	224
21 ,, ..	682	Tezpur	Portable ..	224
21 ,, ..	4	Bona Vista	Naval 279 ..	222
24 ,, ..	851	Deganga	Naval 279 ..	222
13 August ..	2	Kodipotumalai	C.D./C.H.L.	222
16 ,, ..	538	Mitwal	C.O.L. ..	222
	248	Kharagpur	M.R.U. ..	224
24 ,, ..	848	Gidni	G.C.I. ..	224
25 ,, ..	678	Port Canning (transferred from Diamond Harbour).	Portable.	—
	554	Malabar	C.O.L. ..	225
	539	Dutch Tower	C.O.L. ..	222
4 September	542	Pallavaram	C.O.L. ..	225
6 ,,	292	Elizabeth Point	T.R.U. ..	222
15 ,,	288	Amghata	T.R.U. ..	224
18 ,,	858	Manning Town, Colombo	G.C.I. ..	222
24 ,,	859	Pular, Madras	G.C.I. ..	225
28 ,,	289	Worli	T.R.U. ..	225
5 October ..	864	Noa Hat, Chittagong ..	G.C.I. ..	224
10 ,, ..	284	Jalaripeta (non-op., Nov.)	—	224
13 ,, ..	247	Elliotganj	M.R.U. ..	224
22 ,, ..	869	Hathipara	G.C.I. ..	224
November	209	Galle.		
	254	Transferred from Galle to to 290 H.A.M.E.S.		
8 ,,	268	Pondicherry	M.R.U.	—
10 ,,	870	Surma	G.C.I.	—
27 ,,	2000	Waltair	H.A.M.E.S.	—
28 ,,	225	Nellore	M.R.U. ..	225
8 December	546	Namunkula	C.O.L. ..	222
25 ,,	296	Kilinocheli	T.R.U.	—
25 ,,	370	Negapatam	M.R.U. ..	225
1943. 7 January ..	848	Transferred from Gidni to Mathurapur.	G.C.I.	—
16 ,, ..	4	Transferred from Buno Vista to Horton Plains.	Naval 279	222
19 ,, ..	884	Nonya (Cox's Bazar) ..	G.C.I. ..	224
19 ,, ..	567	Basirhat	C.O.L. ..	293 Wing.
1 February	284	Pagdalapeta	M.R.U. ..	225
3 ,,	859	Maungdaw	G.C.I. ..	224
5 ,, ..	228	Ongole	M.R.U. ..	225
	574	Navalur	C.O.L. ..	225
9 ,,	553	Hambantota	C.O.L. ..	222
11 ,,	373	Char Chapli	M.R.U. ..	293 Wing.
19 ,,	849	Amarda Road	G.C.I. ..	293
26 ,,	2016	Panadure	T.R.U. ..	222 Gp.
2 March ..	879	Chittagong	G.C.I. ..	224
	884	Nonya (Ramu)	G.C.I. ..	224

Date Operational.	A.M.E.S. No.	Location.	Type.	Group Area.
1943. 13 March	378	Kattali (Chittagong)	M.R.U.	224
	376	Fazilpur	M.R.U.	224
17 ,,	590	Chandipur (Balasore)	C.O.L.	—
29 ,,	568	Manchapur	C.O.L.	—
10 April	5042	Signal Hill (Cox's Bazar)	C.O.L.	224
11 ,,	377	Challitura	M.R.U.	222
17 ,,	210	Samader (Cox's Bazar)	M.R.U.	224
	5028	Ennor Road., Madras	C.O.L.	225
	858	Nilaveli, Trincomalee, moved from Colombo.	G.C.I.	222
6 May	859	Teknaf	G.C.I.	224
14 ,,	5019	Edappalli	C.O.L.	225
20 ,,	5029	Chittagong	C.O.L.	224
11 June	296	Periyan	M.R.U.	222
17 ,,	319	Bankura	T.R.U.	
22 ,,	290	Negombo	M.R.U.	222
1 July	272	—	—	222
	2001	Heratera, Addu Atoll	—	222
4 ,,	570	Rendugullapalem	C.O.L.	225
8 ,,	552	Kanbaloya	C.O.L.	222
14 ,,	5010	—	—	222
10 August	5043	Batticaloa	C.O.L.	222
12 ,,	8513	Manning Town, Colombo	—	222
17 ,,	5059	Honeymoon Lodge, Karachi	C.O.L.	223
12 September	5054	Narayanpur	—	181 Wing.
15 ,,	589	Palavakki	C.O.L.	222 Gp.

APPENDIX No. 37

SIGNALS PLAN (2) FOR INDIA, JUNE 1943

R.D.F. Cover Required

Detection of high-flying aircraft is required in the following areas :—

(*a*) Maungdaw to Cuttack, with cover in depth at Calcutta.
(*b*) Imphal.
(*c*) Mauripur Road.
(*d*) Silchar.
(*e*) Sylhet.
(*f*) 100 miles on either side of Vizagapatam, with particular reference to the easterly direction.
(*g*) 200 miles on either side of Madras, with particular reference to the easterly direction.
(*h*) Pamban.
(*j*) Coastline of Ceylon.
(*k*) Cochin.
(*l*) Bombay.
(*m*) Addu Atoll.
(*n*) Akyab. (Details will be submitted at a later date.)
(*o*) Burma and Far East. (Details will be submitted at a later date.)

Detection of low-flying aircraft is required in the following areas :—

(*a*) Maungdaw to Chittagong.
(*b*) A belt round Calcutta from Jessore to Balasore.
(*c*) Vizagapatam.
(*d*) Madras.
(*e*) Point Calimere.
(*f*) Pamban.
(*g*) Coastline of Ceylon.
(*h*) Cochin.
(*j*) Bombay.
(*k*) Karachi.
(*l*) Addu Atoll.
(*m*) Akyab. (Details will be submitted at a later date.)
(*n*) Burma and Far East. (Details will be submitted at a later date.)

Owing to the decrease of the threat to India certain A.M.E. stations are to be put on a care and maintenance basis, and as the strategical situation becomes more favourable they are to be withdrawn for use in other areas.

There is an R.D.F. School in India which requires equipment for instructional purposes until such time as training equipment is received from the U.K.

The following A.M.E. stations are required to implement the plan :—

	M.R.U.	T.R.U.	20-ft. C.O.L.	184-ft. C.O.L.	G.C.I. (M)	G.C.I. (I)	Portable.	Light Warning.
(*a*) India	21	5	13	10	12	—	16	10
(*b*) R.D.F. School ..	6	2	6	—	2	—	6	5
(*c*) Ceylon and Addu Atoll.	7	5	10	4	2	—	—	5
(*d*) Burma and Far East	25	7	6	7	10	14	—	35
(*e*) Pool Reserve ..	4	—	2	2	8	—	—	15
Total ..	63	19	37	23	34	14	22	70

Note.—Two 20-foot C.O.L. are ex-Army equipment already in India.

It is estimated that six 20-foot C.O.L. and seven 184-foot C.O.L. will be required for future operations.

There will be one Combined Sector Operations/Filter Room, seven Sector Operations Rooms, five Combined Mobile Operations/Filter Rooms, six Filter Rooms (large) and four Wing Operations Rooms.

Reserve Transportable Filter Rooms (not to be manned) :—

(*a*) 222 Group 1
(*b*) 225 Group 2
(*c*) A.H.Q., Bengal 2

Estimated requirement for Filter Rooms in the Far East area :—

(*a*) Filter Rooms, Type " F " 3
(*b*) Filter Rooms, Type " E " (Mobile) 4
(*c*) Reserve Transportable Filter Rooms 3

A Radio Installation and Maintenance Unit (R.I.M.U.) has been formed at Bombay whose functions are :—

(a) The receipt from overseas, unpacking and bringing on charge of all equipment for A.M.E. stations in India, Ceylon and Indian Ocean bases.

(b) The testing and, if necessary, the modification of all such equipment.

(c) The despatch when tested of repaired and modified equipment to the site on which it will be used.

(d) The demanding on the Master Provision Officer for provisioning action for all ground R.D.F. spares and test equipment, and the holding and distribution to A.M.E. stations of all technical ground R.D.F. equipment.

(e) The checking of all Forms 1022 rendered by A.M.E. stations in respect of R.D.F. ground equipment.

(f) Accommodation of A.M.E. station personnel awaiting the arrival of their equipment in India.

As certain equipment is unloaded at Calcutta, a R.I.M.U. has also been formed there. Its functions are as in paragraph 10, sub-paragraphs (a), (b), (c) and (e), of this appendix.

Signals Wings are being formed, which are to be responsible for administration, accounting and demanding of technical spares, etc., for the A.M.E. stations under their jurisdiction.

APPENDIX No. 38

RADAR STATE IN A.C.S.E.A., JANUARY 1944

A.M.E.S. No.	*Type.*	*Site.*	*Remarks.*
Bengal Area			
No. 180 Signals Wing			
Operational Stations.			
(Filter Room, Calcutta.)			
211	M.R.U.	Khulna.	
224	M.R.U.	Bhadrack.	
248	M.R.U.	Egra I.	
258	M.R.U.	Mathurapur.	
281	M.R.U.	Jagatsingpur.	
288	T.R.U.	Amghata.	
319	T.R.U.	Bankura.	
373	M.R.U.	Char Chapli.	
543	C.O.L.	Egra II	184-foot tower.
544	C.O.L.	Diamond Harbour	184-foot tower.
567	C.O.L.	Basirhat	184-foot tower.
568	C.O.L.	Manchapur (Jessore)	184-foot tower.
590	C.O.L.	Chandipur (Balasore)	184-foot tower.
848	G.C.I.	Jaynagar	Operating G.C.I.
849	G.C.I.	Kharagpur	Operating. Used as G.C.I. Controllers Training Unit.
851	G.C.I.	Deganga	Operating G.C.I.
1581	Calibration Flight (Alipore).		

A.M.E.S. No.	*Type.*	*Site.*	*Remarks.*

Bengal Area—*contd.*

No. 181 Signals Wing

(*a*) *Operational Stations.*

(Filter Room, Imphal.)

382	M.R.U. ..	Algapur (Silchar).	
383	M.R.U. ..	Wix (Imphal).	
569	C.O.L. (M)	Wabagai (Imphal) ..	Operating pending completion of A.M.E.S. 5071.
6168	L.W. (M) ..	Tamu	Operating only by day.
857	G.C.I. ..	Nungoi (Imphal) ..	Operating G.C.I./C.O.B.
859	G.C.I. ..	Digboi	Under operational control of U.S.A.A.F.
870	G.C.I. ..	Jalinga (Silchar) ..	Operating G.C.I./C.O.B.
885	G.C.I. ..	Dimapur (Manipur Road)	Operating C.O.B.

(*b*) *Stations under Construction.*

5070	C.O.L. ..	Gungur (Silchar).	
5071	C.O.L. ..	Wabagai (Imphal).	
—	L.W. (M) ..	Manmaw	A.M.E.S. 6168 to go to this site.

1582 Calibration Flight (Kumbhirgram).

No. 182 Signals Wing

(*a*) *Operational Stations.*

(Filter Room, Chittagong.)

247	M.R.U. ..	Elliotgang (Comilla).	
376	M.R.U. ..	Fazilpur.	
378	M.R.U. ..	Kattali (Chittagong).	
5029	C.O.L. ..	Observation Hill (Chittagong).	
5054	C.O.L. ..	Narayanpur (Agaitala) ..	67-foot tower.
5055	C.O.L. ..	Noakhali	184-foot tower still under construction.
864	G.C.I. ..	Noa Hat (Chittagong) ..	Operating C.O.L. (M).
869	G.C.I. ..	Hathipara (Agartala) ..	Operating G.C.I.
877	G.C.I. ..	Dandra (Feni)	Operating C.O.B. Will operate G.C.I./C.O.B.
879	G.C.I. ..	Findli (Chittagong) ..	Operating C.O.L. (M).
670	Port (U.K.)	Dohazari.	
669	Wigwam (M.E.)	Chandranath.	

(Filter Room, Cox's Bazar.)

210	M.R.U. ..	Samadar Cox's Bazar).	
5042	C.O.L. ..	Signal Hill (C.B.).	
884	G.C.I. ..	Nonya, Ramu	Operating G.C.I./C.O.B.

1583 Calibration Flight (Chittagong).

A.M.E.S. No.	Type.	Site.	Remarks.
Ceylon			
No. 183 Signals Wing			
(*a*) *Operational Stations.*			
(Filter Room, Colombo.)			
290	T.R.U. ..	Negombo.	
2016	T.R.U. ..	Panadure.	
538	C.O.L. ..	Mutwal (Colombo).	
552	C.O.L. ..	Kandalaya.	
553	C.O.L. ..	Hambantota I.	
8513	G.C.I. ..	Manning Town, Colombo	Operating G.C.I.
(Filter Room, Trincomalee.)			
292	T.R.U. ..	Elizabeth Point, Trincomalee.	
296	M.R.U. ..	Periyan.	
377	M.R.U. ..	Challitivu.	
2015	T.R.U. ..	Galle.	
394	M.R.U. ..	Mullaitivu.	
546	C.O.L. ..	Namanukula	Reports Colombo F/R as well as Trincomalee.
589	C.O.L. ..	Palavakki	Operational on 20-foot gantry. 184-foot tower under construction.
5009	C.O.L. ..	Chapel Hill	Operating with Mark V equipment belonging to A.M.E.S. 5094.
5043	C.O.L. ..	Batticaloa I	184-foot tower.
858	G.C.I. ..	Nilaveli	Operating G.C.I.
(*b*) *Stations on Care and Maintenance.*			
272	M.R.U. ..	Batticaloa II.	
524	C.O.L. ..	Mount Lavinia.	
539	C.O.L. ..	Dutch Tower, Galle.	
5010	C.O.L. ..	Kodipotumalai.	
(*c*) *Stations under Construction.*			
8046	G.C.I. ..	Vasavilan.	
—	M.R.U. ..	Hambantota II	To go on C. and M.
—	M.R.U. ..	Pottuvil	To go on C. and M.
5060	C.O.L. ..	Keerimalai	184-foot tower.
1579 Calibration Flight, Raturalana.			
Indian Ocean Bases			
(*a*) *Operational Station.*			
2001	T.R.U. ..	Heratera (Addu Atoll).	
(*b*) *Station under Construction.*			
5018	C.O.L. ..	Can (Addu Atoll) ..	184-foot tower.
No. 223 Group			
(*a*) *Operational Station.*			
5059	C.O.L. ..	Honeymoon Lodge (Karachi)	For detection of shipping only. Operational in hours of darkness only.
(*b*) *Completed Sites.*			
—	T.R.U. ..	Orangi.	

A.M.E.S. No.	Type.	Site.	Remarks.

No. 225 Group

(a) *Operational Station.*

(Filter Room, Madras.)

293(H)	T.R.U. ..	Saidapet, Madras.	
225	M.R.U. ..	Nellore.	
370	M.R.U. ..	Negapatam.	
542	C.O.L. ..	Pallavaram.	
5028	C.O.L. ..	Ennore Road, Madras ..	184-foot tower.
8040	G.C.I. ..	Pulal.	

(Filter Room, Vizagapatam.)

2000(H)	T.R.U. ..	Waltair.	
570	C.O.L. ..	Rendugullapalem.	
8045	G.C.I. ..	Dryden (Vizagapatam).	

(Filter Room.)

Cochin ..	..	.. ..	Under construction.
5019(H)	C.O.L. ..	Edapalli	184-foot tower.

(b) *Stations on Care and Maintenance.*

228	M.R.U. ..	Ongole.	
268	M.R.U. ..	Pondicherry.	
284	M.R.U. ..	Pagdalapeta (Cocanada).	
291	T.R.U. ..	Grubbe's Island, Cochin.	
566	C.O.L. ..	Scandal Point.	
573	C.O.L. ..	Mundamelli	184-foot tower.
574	C.O.L. ..	Navalur.	

(c) *Stations under Construction.*

5061	C.O.L. ..	Tada	184-foot tower to go on C. and M.
5061	C.O.L. ..	Point Calimere	184-foot tower.

(d) *Completed Sites.*

	M.R.U.s ..	Nanpada; Masulipatam; West Hill (Calicut); Chavara (Quillon); Ganjam.	
	C.O.L.s ..	Rajam; Velangan (Trichur); Sasthan (Alleppey); Pata; Polavaram.	
	G.C.I.s ..	Guntur; Kolar; Tanjore.	

1580 Calibration Flight, Bangalore.

No. 227 Group

(a) *Operational Stations.*

(Filter Room, Bombay.)

554	C.O.L. ..	Malabar.	

(b) *Station on Care and Maintenance.*

289	T.R.U. ..	Worli	Maintained by personnel of A.M.E.S. 554.

(c) *Completed Sites.*

—	C.O.L. ..	Virar.	

Other Equipment Allotted

No. 51 *Radio School, Bangalore.*

M.R.U.	334, 335, 395.
C.O.L.	5041, 5072.
T.R.U.	2036, 318, 320.
L.W.	6136, 6187, 6172.

Unallotted Equipment

(*a*) *Bengal Area.*

No. 181 *Wing.*

L.W.	6170.
L.W. on Jeeps	6169, 6171.
G.C.I.	8502.

No. 182 *Wing.*

M.R.U.	379.
G.C.I.	853.
L.W.	6031, 6058.
L.W. (on Jeep)	6182.
Wigwam (M.E.) ..	642, 643, 676, 680, 641, 681, 682.
Portables, U.K. ..	671, 679.
Barges	8514, 5048 (both at Chittagong).

(*b*) *No.* 222 *Group.*

M.R.U.	209, 254, 333, 347, 346.
Port (N.Z.)	686.
L.W.	6183, 6184, 6185.

(*c*) *No.* 225 *Group.*

M.R.U.	353 (293(H) A.M.E.S.), 354 (2000(H) A.M.E.S.)
C.O.L.	5062.
G.C.I.	8047.
L.W.	5261 (293(H) A.M.E.S.), 6262 (2000(H) A.M.E.S.).

(*d*) *No.* 2 *Base Signals Unit.*

M.R.U.	365, 366.
T.R.U.	2004, 2044, 2045, 2046.
C.O.L.	5073, 5078, 5092, 5095, 5096, 5097, 5098, 5099, 5100, 5101, 5102.
Wigwam	648, 649, 650.
L.W.	6178, 6052, 6264, 6265, 6266, 6267, 6269, 6270, 6303, 6304, 6305, 6306, 6307, 6308, 6309, 6310, 6311, 6312, 6313, 6314, 6315, 6316, 6367, 6368, 6369, 6370, 6371, 6372.
L.W. (on amphibious Jeep)	6268.
Int. G.C.I.	8536.
C.O.L./G.C.I./C.H.B.(M)	15059.

Equipment ex-Assault Wing.

G.C.I.	863, 8026, 8039, 8519.
L.W. (on Fords C.29Q)	6097, 6098, 6099, 6100, 6101, 6102.
L.W. (on Jeep) ..	6032, 6053, 6054, 6055, 6056, 6057.

N.B.—863 G.C.I. was being used for air transportation investigations.

(*e*) *No.* 3 *Base Signals Unit.*

M.R.U.	227, 884, 355, 364.
C.O.L.	5004, 5047, 5003, 5103.
L.W.	6179, 6180, 6181, 6263.
Barges	5058, 5450.

A.M.E.S. 6263 being used for pack mule transportation investigations.

APPENDIX No. 39

DETAILED RADAR RESPONSIBILITIES DELEGATED BY A.E.A.F. TO SUBORDINATE COMMANDS

The Air Commander-in-Chief, Headquarters, Allied Expeditionary Air Forces, delegated the radar responsibilities to his subordinate Commands and Groups as follows :—

1. *Headquarters, Air Defence of Great Britain,* was responsible for—

(*a*) Operating and maintaining a fighter control organisation in the United Kingdom to direct fighter aircraft of the U.S. Ninth Air Force, the Royal Air Force Second Tactical Air Force, Air Defence of Great Britain, and fighter aircraft of the U.S. Eighth Air Force when so required.

(*b*) Operating and maintaining an air warning system in the United Kingdom, and making available air information to all forces requiring it during the operation.

(*c*) Operating and maintaining, in agreement with the Allied Naval combined Expeditionary Force (A.N.C.X.F.), the shipborne radar equipment installed in the fighter direction tenders allotted to the assault forces.

(*d*) Operating and maintaining such Air Force radar ground stations and beacons in the United Kingdom as were required to provide navigational assistance to aircraft and Naval units of the Allied Expeditionary Force.

(*e*) Operating and maintaining airborne radar in aircraft of the Air Defence of Great Britain which were to be used to provide night fighter protection during the assault.

(*f*) Controlling operationally the night fighter aircraft of No. 85 Group while based in the United Kingdom.

(*g*) Operating and maintaining, through Headquarters, No. 60 Group, the necessary stations in the United Kingdom.

2. *Headquarters, No.* 85 *Group, and the U.S. Ninth Air Force* were to be responsible for—

(*a*) Operating and maintaining an aircraft warning and fighter control system in the Base Defence areas on the Continent.

(*b*) Providing aircraft warning information to Naval and ground forces of the Allied Expeditionary Forces in the Base area.

(*c*) Co-ordinating with Naval forces, the use of air warning information obtained by Naval radar equipment ashore.

(*d*) Providing surface-watching radar to fulfil the requirements for surface watching of the Naval and ground forces in the Base area.

3. *Headquarters, Second Tactical Air Force, and Headquarters, U.S. Ninth Air Force,* were to be responsible for—

(*a*) The operation and maintenance of the radar early warning system and fighter control in the forward areas.

(*b*) Making available to the ground forces (and Naval also when applicable) air warning information.

(*c*) Maintaining and operating ground and airborne radar equipment which was to be used to provide navigational aid to reconnaissance and bomber aircraft, other than Gee, G-H and Oboe ground stations. These latter equipments to be used on the Continent were to be arranged by A.E.A.F. through Air Ministry.

TELECOMMUNICATIONS FOR FIGHTER DIRECTION TENDERS

R/T Communication—V.H.F.

It was considered that each F.D.T. required seven V.H.F. channels for communications as follows :—[1]

(a) Four medium power V.H.F. channels for communications to aircraft.

(b) One medium power V.H.F. transmitter and receiver required to provide liaison and plotting facilities between the Fighter Direction Tender and the Headquarters Ship. This channel was to be used for plotting radar information to the Headquarters Ship and the telling of Plots was to be interrupted for liaison purposes.

(c) Two high power V.H.F. transmitters and associated receivers were required: one for communications between all the Fighter Direction Tenders and the Home Shore Fighter Control at Tangmere, and the other V.H.F. channel was for the three Fighter Direction Tenders and the Far Shore Group Control Centre.

(d) Two low power V.H.F. sets modified for continuous listening watch were also installed for stand-by facilities.

R/T Communications—H.F.

Two medium power H.F. transmitters and receivers were provided as stand-by facilities on the inter-Fighter Direction Tender–Home Shore and inter-Fighter Direction Tender–Far Shore Channels indicated in (c) above. W/T keying facilities were also available on these channels and the inter-Fighter Direction Tender–Far Shore Waves could be used either for radar track broadcasts or for liaison purposes.

W/T Communications—H.F.

It was decided that three H.F. W/T Channels were required for :—

(a) Two transmitters and receivers for R.A.F. Ship–Shore work as base and information waves.

(b) One transmitter and receiver for a Naval Inter-Ship Channel.

Receivers

Five W/T receivers were necessary for listening watches on—

(a) Two M.F. W/T for receiving the radar broadcast from the United Kingdom.

(b) One M.F. W/T Channel for receiving aircraft movement information.

(c) One H.F. W/T receiver to maintain watch on the Force broadcast.

(d) One H.F. W/T Channel for the radar broadcast from H.M. ships.

Additional Signals Equipment

A Naval type (F.V.3) V.H.F. D/F equipment was installed to obtain bearings on enemy aircraft, and two V.H.F. D/F sets for bearings on friendly fighter aircraft. In addition, one H.F. receiver was provided to receive a T broadcast from the United Kingdom.

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[1] A.E.A.F. File S.14111, Encl. 1A, para. 7.

APPENDIX No. 41

ESTABLISHMENT FOR R.A.F. PERSONNEL FOR FIGHTER DIRECTION TENDERS

Officers

Fighter Controllers (Sector (G))	2 Squadron Leaders. 3 Flight Lieutenants.
Fighter Controllers (G.C.I./C.H.L.)	3 Flight Lieutenants.
Filter Officer	1 Squadron Leader. 3 Flight Lieutenants.
Movements Liaison Officer	2 Flight Lieutenants.
Signals (G)	1 Flight Lieutenant.
Signals (Radar)	1 Flight Lieutenant.
Admin. (" Y " Intelligence)	1 Flight Lieutenant.
Code and Cypher	1 Flying Officer.
Intelligence	1 Flying Officer.

Other Ranks

Wireless Mechanics	1 Sergeant. 3 A.C.s.
Wireless Operators	1 Sergeant. 3 Corporals. 20 A.C.s.
Radar Mechanics	1 Flight Sergeant. 2 Corporals. 4 A.C.s.
Radar Mechanics (Air). (*See* Note 1)	1 A.C.
R.T.O.s (Group IV)	20 A.C.s.
R.T.O. (D/F)	3 A.C.s.
R.T.O. (D/F) (for " Y " Duties)	3 A.C.s.
R.T.O. (for " Y " Duties)	5 Sergeants.
Ground Observers	4 A.C.s.
M.T. Mechanics. (*See* Note 2)	2 A.C.s.
Clerks, G.L.	1 A.C.
Clerks, G.D. (Code and Cypher)	2 Sergeants.
Clerks, S.D. (O). (*See* Note 3)	7 Sergeants. 3 Corporals. 33 A.C.s.
Radar Operators (I). (*See* Note 4)	1 Sergeant. 5 Corporals. 30 A.C.s. 2 A.C.s.

Note 1.—For A.I. beacon maintenance.

Note 2.—For M.T. and diesel power units maintenance.

Note 3.—(*a*) Non-Watch basis :—

Deputy Controllers	4 Sergeants.
Controller's Assistant	3 Sergeants.
N.C.O. i/c Ops. Room	1 Sergeant.

(*b*) Per Watch (total of 2½ Watches) :—

Supervisor	1 Corporal.
Plotters	4 A.C.s.
M.L.O.s Clerks	2 A.C.s.
Tellers (to H.Q. Ship for Shore and Bridge Plots).	3 A.C.s.
Bridge Plotters	2 A.C.s.
Vertical Plot Plotters	1 A.C.

Other Ranks—*contd.*

Note 4.—(*a*) Non-Watch basis :—

N.C.O. i/c Radar Room .. 1 Sergeant.

(*b*) Per Watch (total of 2½ Watches) :—

	G.C.I.	*Type II.*
Supervisor	1 Cpl.	1 Cpl.
Navigator	1 A.C.	1 A.C.
P.P.I. Reader	1 A.C.	1 A.C.
Liaison Teller	1 A.C.	1 A.C.
G.S.M. Plotter	1 A.C.	1 A.C.
Height Reader	1 A.C.	1 A.C.
C.T.T. Teller	1 A.C.	1 A.C.

Summary

Officers : 3 S/Ldrs. ; 14 F/Lts. ; 2 F/O.s = 19

Other Ranks : 1 F/Sgt. ; 17 Sgts. ; 13 Cpls. 126 A.C.s = 157

AEAF/S. 13221/Ops. 5.

9 *April* 1944.

APPENDIX No. 42

ROYAL AIR FORCE RADAR UNITS UNDER THE ALLIED EXPEDITIONARY AIR FORCE, JUNE 1944

2nd Tactical Air Force

No. 83 *Group.*	*No.* 84 *Group.*
15053 G.C.I./F.D.P.	15056 G.C.I./F.D.P.
15054 G.C.I./F.D.P.	15061 G.C.I./F.D.P.
8024 G.C.I./F.D.P.	15062 G.C.I./F.D.P.
8007 G.C.I./F.D.P.	15071 G.C.I./F.D.P.
6066 L.W S.	6081 L W.S.
6092 L.W.S.	6081 L.W.S.
6093 L.W.S.	6089 L.W.S.
6113 L.W.S.	6117 L.W.S.

No. 85 Group

(Basc Defence)

No. 21 *Base. Defence Sector.*	*No.* 24 *Base. Defence Sector.*	*No.* 25 *Base. Defence Sector.*
(Originally planned to be the " Master " Sector.) (American Area.)	(British Sector in Normandy.)	(Reserve Sector remaining in U.K. until required.)
15082 G.C.I.	15083 G.C.I.	15119 G C.I.
15081 G.C.I.	15121 G.C.I.	15120 G.C.I.
15072 G.C.I.	15128 G.C.I.	15122 G.C.I.
15073 C.O.L.	15129 C.O.L.	15092 C.O.L.
15074 C.O.L.	15130 C.O.L.	15093 C.O.L.
349 M.R.U.	358 M.R.U.	350 M.R.U.
Four L.W.S.	Four L.W.S.	Four L.W.S.

INTERCOMMUNICATION FOR G.C.I. UNITS LANDING ON D-DAY (OPERATION "NEPTUNE")

It is of the highest importance that land line communication should be established between units in the bridgehead at the earliest possible moment but, owing to the congestion and movement in the bridgehead area during the initial stages, the maintenance of these communications will be very difficult.

Operational requirements by the last light of D-day at No. 15083 G.C.I. are :—[1]

(*a*) 1 H.F. W/T Channel (Air Command Wave) to Combined Control Centre, Uxbridge. Essentially for use of the Air Commander in United Kingdom, but may be used in emergency by ships and far shore stations.

(*b*) 1 H.F. W/T Channel to Combined Control Centre, Uxbridge, and Combined Headquarters, Portsmouth.

(*c*) 1 H.F. W/T Channel to Combined Control Centre, Uxbridge.

(*d*) 2 V.H.F. R/T Channels to No. 11 Group (Uxbridge) Operations Room, Headquarters Ship, and F.D.T. 217.

(*e*) 2 H.F. R/T or W/T Channels as stand-by for (*d*).

(*f*) 1 H.F. W/T Channel and 1 V.H.F. Channel to No. 15082 G.C.I. in the U.S. Sector.

(*g*) 1 V.H.F. R/T Channel for F.D.T./G.C.I. liaison.

(*h*) 1 H.F. W/T F.D.T./G.C.I. Plotting Wave.

(*i*) 1 land line to A.A.O.R.

(*j*) 4 V.H.F. R/T ground to air Channels.

(*k*) 1 V.H.F. D/F station for fighter aircraft navigational aid.

The R.A.F. policy for communications in the British Sector for raid reporting was to provide essential operational point-to-point communications by telephone, to supplement telephones with teleprinters and to provide a comprehensive wireless stand-by system.[2]

By D + 1 receiving stations would supplement local radar inf. by the reception of warning broadcasts from the United Kingdom and from the warning screen which will be built upon the bridgehead.

Night D + 1/D + 2 anticipated a line will be available from 15083 in the British Sector to 15072 in U.S. Sector. Land lines between 85 Group G.C.I. and 483 G.C.C. will be specially reinforced and run on separate routes to guard against damage and temporary disruption. All op. land lines will be reinforced by V.H.F. R/T Channel and stand-by W/T system.

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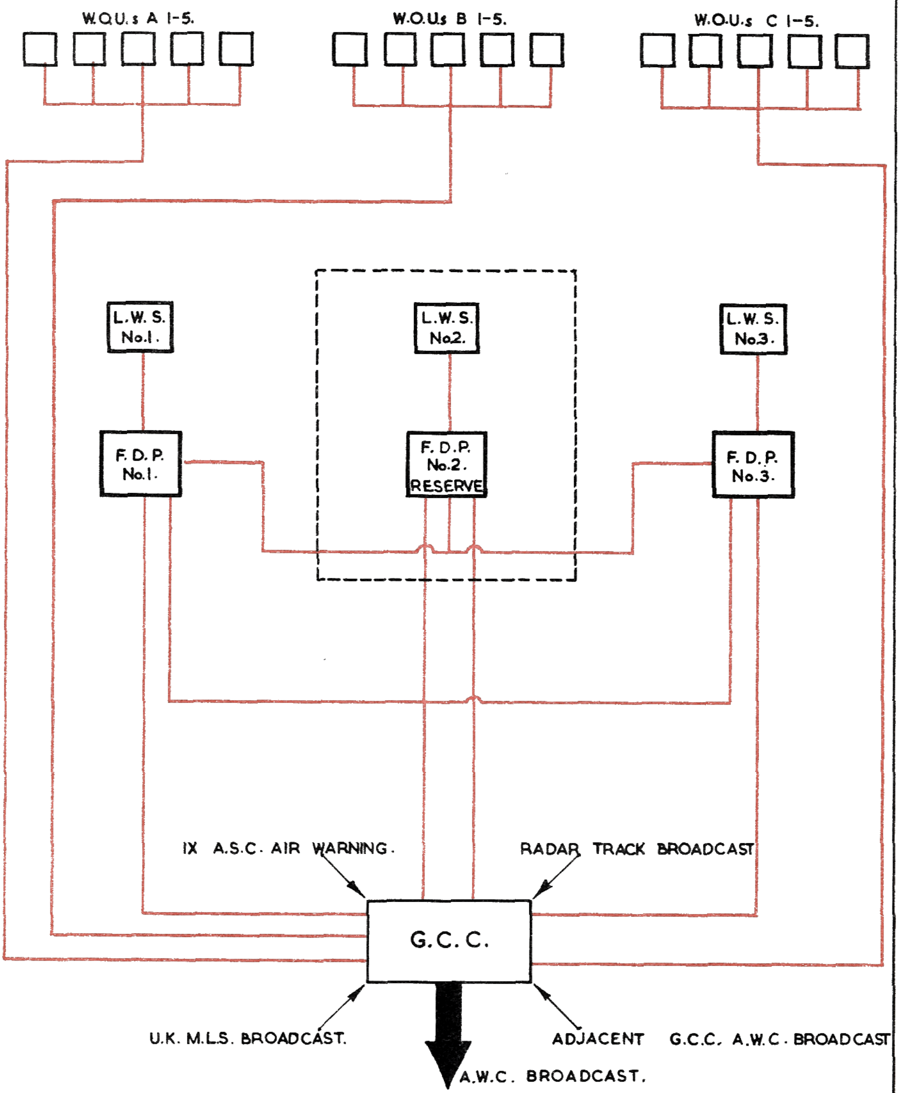
[1] A.H.B./IIM/683/1A, No. 83 Group R.A.F. " Neptune " Operations Plan ; 85 ADV/TS. 2382/Air Plans. 13 May 1944. Para. 92.
[2] *Ibid.*, Appendix " F."

APPENDIX No. 44.

RADAR REPORTING & AIR WARNING W/T COMMUNICATIONS FOR A TACTICAL GROUP



Each line indicates a W/T channel: If lines join this indicates common frequency working.

C.B.H. 17227 - Wt. 16623 - Dd. N.538 - 1250 - 4/50

OUTLINE OF INITIAL BUILD UP OF THE EARLY WARNING SYSTEM IN THE BRITISH SECTOR

Appendix " E " to 83Adv/TS.2382/Air Plans dated 13 May 1944

Day.	Unit.	Map Reference Location.	Function.
1. D	No. 15083 G.C.I. Type 21 Station Type 11 Station	T.881848	Night interception, forward direction by Day and local warning for A.A. Type 21 will allow control in the face of " Window " ; Type 11 is an insurance against deliberate jamming of G.C.I.
2.	1 L.W. set ..	T.933823	Inward-looking low cover for 85 Group G.C.I.
3. D + 1	No. 15053 F.D.P. (consisting of Type 11 Station or Type 13 Station).	T.9283	To act as stand-by for 15083 G.C.I.
4.	1 L.W.S.	U.0080	To provide low cover looking inland, particularly south and east.
5. D + 2	5 W.O.U. Posts ..	—	To be deployed by M.A.R.U. H.Q. for visual warning in accordance with tactical situation.
6. D + 3	5 W.O.U. Posts ..	—	*See* Serial No. 5.
7.	85 Group G.C.I./ C.O.L.	T.750879	To provide seaward looking low cover for 15083 G.C.I.
8. D + 4	5 W.O.U. Posts ..	—	*See* Serial No. 3.
9.	No. 15054 F.D.P.	U.037783	F.D.P. role for forward direction of day fighters.
10.	1 L.W. set ..	U.0777	Low cover for No. 15054 F.D.P.

APPENDIX No. 46

RESULTS ACHIEVED BY FIGHTER DIRECTION TENDERS IN OPERATION "NEPTUNE"

I. By Day

Enemy aircraft destroyed by fighters under F.D.T. control in period 6 June to 26 June 1944 :—

H.M. F.D.T. 13	Nil.
H.M. F.D.T. 216	13
H.M. F.D.T. 217	39
Total ..	52

II. By Night

Period 6 June to 26 June 1944 :—

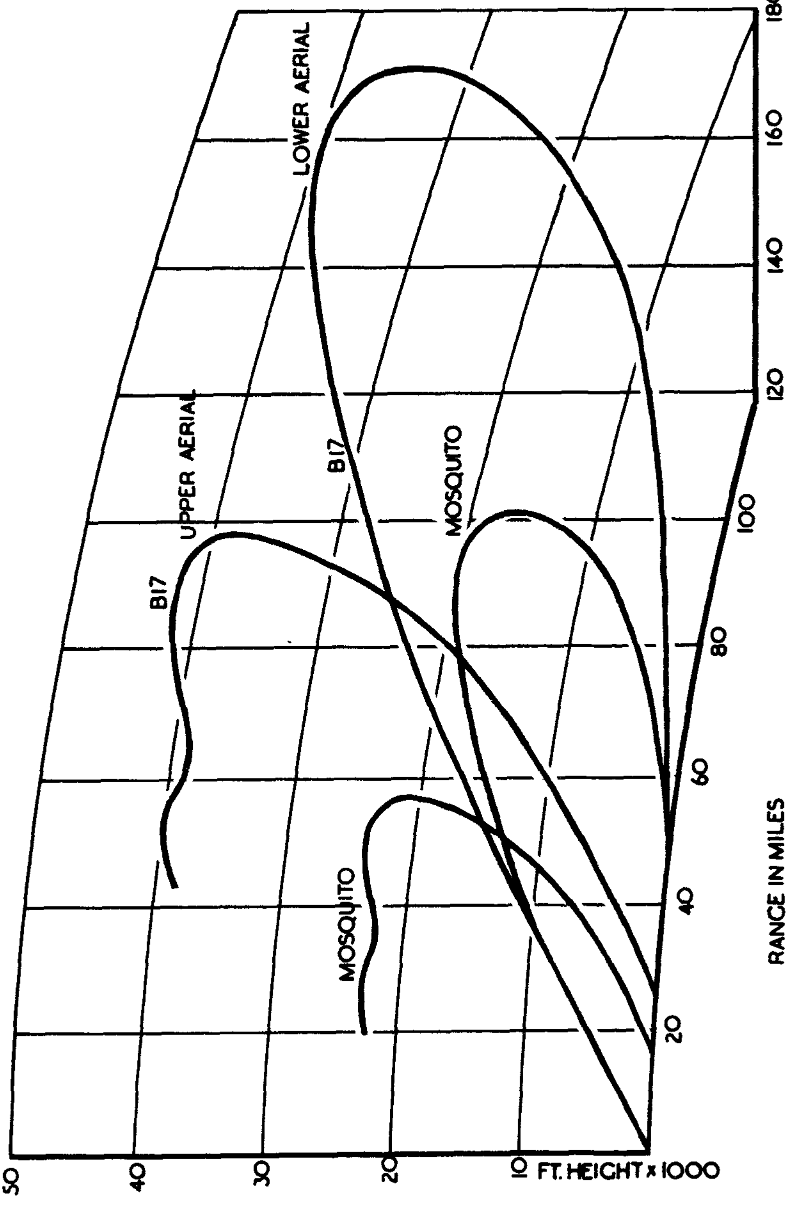
	Night Fighters Controlled.	*Number of Contacts.*	*Visuals on Friendly Aircraft.*	*Enemy Aircraft Destroyed.*
(*a*) *F.D.T.* 13.				
(i) 6 June to 12 June (in shipping lane) ..	18	13	10	(one fighter's guns jammed)
(ii) 15 June to 17 June (off Cherbourg. Fighters handed over from G.C.I. ashore on British beach) ..	9	13	13	—
(iii) 19 June to 26 June (off Cherbourg. Fighters handed over from Sopley)	55	182	144	12 (and one probable)
(*b*) *F.D.T.* 216.				
(i) 6 June to 14 June (in assault area off U.S. beaches)	62	49	33	3
(*c*) *F.D.T.* 217.				
(i) 6 June to 14 June (in assault area off British beaches)	205 (*See* Note 2)	78	46	6
(ii) 15 June to 23 June (in assault area off U.S. beaches)	70	45	21	3 (and one probable)
	419	380	267 (70 per cent. of contacts)	24 (and two probables) (6·4 per cent. of contacts)

Note 1.—All dates are inclusive.

Note 2.—Until 12 June F.D.T. 217 was co-ordinating control for the whole Assault Area and Shipping Lane, and therefore took over all night fighters and re-allotted them to other F.D.T.s and G.C.I.s ashore as necessary. It is not possible to determine how many night fighters were actually controlled by F.D.T. 217 for her own interceptions.

APPENDIX NO. 47.

A.M.E.S. TYPES 70 VERTICAL COVERAGE DIAGRAM



APPENDIX No. 48

BRIEF DESCRIPTION OF A.M.E.S. TYPE 70

Because of the mobility requirement, vehicles were used as far as possible in the design of the station. A brief survey of these is given below :—

Vehicle 1.—Plan position reporting vehicle. Contained four B-scan indicators on first equipment, four Display Units 69 on the second, six Display Units 69 or Display Units 70 on later stations.

Vehicle 2.—Plan position reporting and information generator vehicle. Contained two Display Units 69 on the first and second equipments, but these (or Display Units 70 in place of them) have been moved to Vehicle 1 on later equipments, leaving Vehicle 2 as a purely technical vehicle. All information from the plan position aerials is fed to the information generator, which in turn feeds all plan position indicator displays.

Vehicle 3.—Height reporting vehicle, containing one 12-inch cathode ray tube height display and one 12-inch plan position indicator. The height display is fed direct with signals from the A.M.E.S. Type 13 aerial vehicle No. 12. The P.P.I. displays plan position signals fed from the information generator and acts as a reference display for laying-on the height-finding aerial in azimuth.

Vehicle 4.—Controllers' vehicle, containing two Display Units 69 or 70 and located inside the operations tent.

Vehicle 5.—Opposite hand version of Vehicle 4, located inside operations tent.

Vehicle 6.—Height-reporting vehicle exactly similar to Vehicle 3, but working in conjunction with the second A.M.E.S. Type 13 height-finder, Vehicle 13.

Vehicle 7.—Office vehicle for Intelligence liaison officers and located inside the operations tent.

Vehicle 8.—Opposite hand version of Vehicle 7 for Combat and Planning officers, and located inside the operations tent.

Vehicle 9.—Telephone exchange vehicle.

Vehicle 10.—Low-angle cover plan-position aerial vehicle.

Vehicle 11.—High-angle cover plan-position aerial vehicle.

Vehicles 12 *and* 13.—A.M.E.S. Type 13 height-finding aerial vehicles, working in conjunction with Vehicles 3 and 6 respectively.

Vehicle 14.—Workshops vehicle.

Vehicle 15.—Used only on the first two equipments as a carrier for the plan-position aerials when the station was in convoy. On later equipments, the reflectors are carried on the aerial vehicles themselves.

Vehicle 16.—Cable carrier. Mounted with cable drums to carry all cables over 100 yards in length when the station was in convoy.

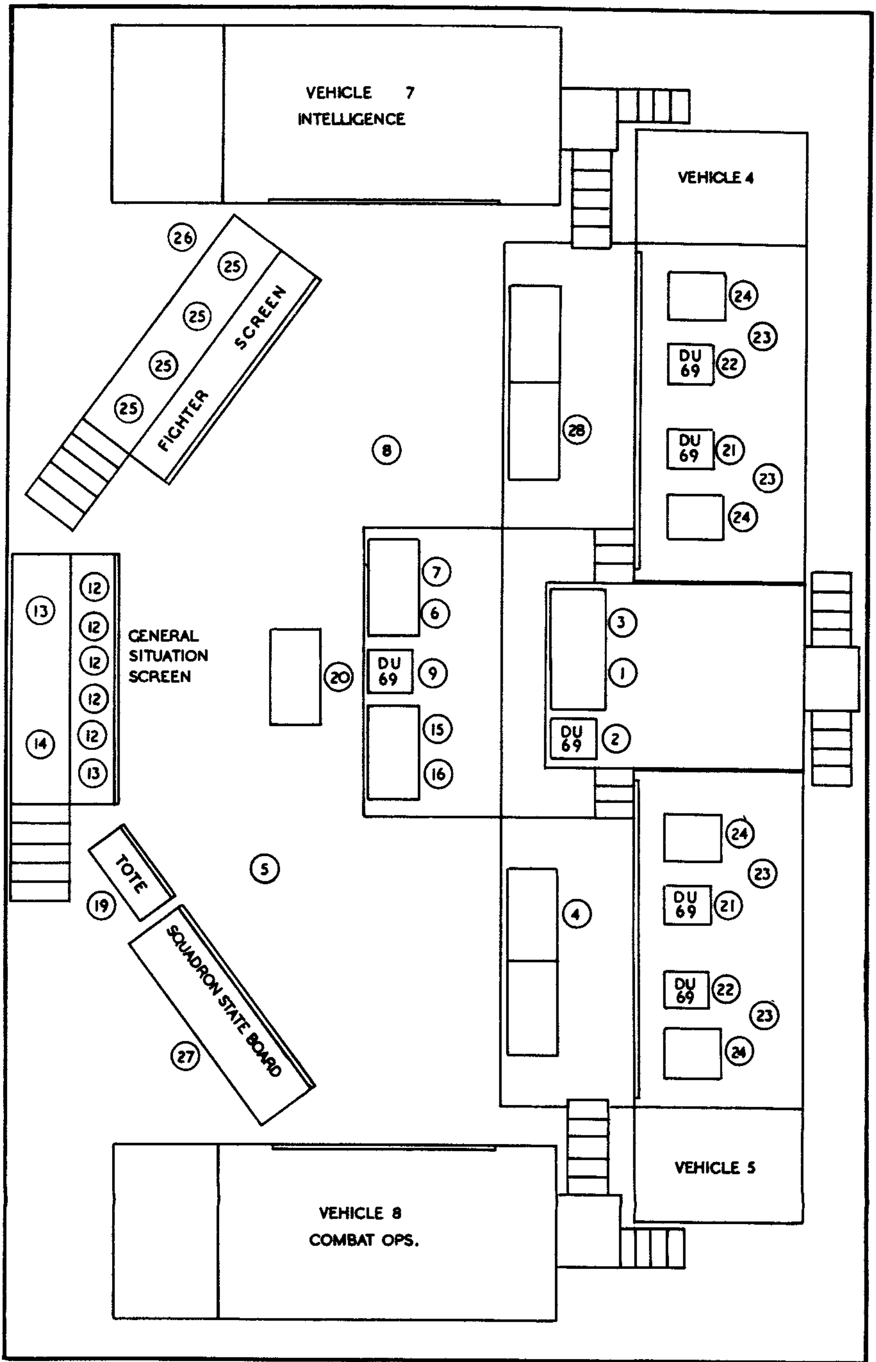
Vehicle 17.—Stores and Technical Office vehicle.

Vehicle 18.—180 v. 500 c.p.s. power supply vehicle. This power is supplied to all four transmitters in the aerial vehicles so that they operate synchronously. Mutual ground-ray interference is thereby eliminated.

In addition to these vehicles, nine 20 kVA. 230 v. 50 c.p.s. generator vehicles are included, three of which are used as stand-bys. The Operations Room is housed in a very large tent, and this, together with the Operations Room furnishings, is carried in three 3-ton general purpose vehicles.

OPERATIONS ROOM LAYOUT - TYPE 70

APPENDIX NO. 49.



1 Chief Controller
2 Assistant Controller
3 Ops.'B'
4 Group Liason Op.
5 Crew Chief
6 Movement Liason Officer
7 " " Clerk
8 Teleprinter Runner

9 Radar Supervisor
10 Radar NCO
11 Reporting PPI Reader
12 General Situation Plotter
13 " " NCO
14 Group Plotter
15 Height & Tote Liason Op.
16 Recorder

17 Height Reader
18 Azicator Op.
19 General Situation Tote Op.
20 Group Teller
21 Interception Controller Snr
22 " " Jnr
23 " PPI Reader
24 " Navigator

25 Fighter Plotter
26 Triangulator Plotter
27 Squadron State Board Op.
28 Y Liason Clerk

10,11,17 & 18, Not shown on diagram.

APPENDIX No. 50

NOMENCLATURE OF GROUND RADAR STATIONS AS SHOWN IN A.M.C.O. 31/1945

(Air Ministry File C.S. 12796/D.D.R.2 dated 21 April 1945.)

When referring to a particular A.M.E.S. the letter " T " after the type number denotes a mobile equipment using trailers.

The letter " M " similarly used indicated fully mobile equipment, all vehicles being prime movers.

The omission of a suffix indicates that the station is static or transportable—static indicating fixed buildings, and transportable semi-permanent buildings or tents.

Suffix " AT " denotes station is air transportable.

In connection with Centimetre Air and Surface Watching stations it is intended to use blocks of A.M.E.S. type numbers to indicate power as follows :—

30–39 .. .. .. Low power.
40–49 .. .. .. Medium power.
50–59 .. .. .. High power.

As far as possible the unit figure will indicate a common type of equipment using different power transmitters. This scheme cannot be universal as odd types have to be included. These are indicated by the unit 1.

Types in common categories are :—

0 .. .. Basic Admiralty static shore station.
2 .. .. Basic Air Ministry static station, employing Nissen hut straddled by C.D./C.H.L. gantry.
3 .. .. Equipment housed in existing C.D./C.H.L. or similar building.
4 .. .. War Office design steel tower 200 feet high with Nissen huts.
5 .. .. Air Ministry design on cantilever 200 feet high of C.H. steel tower with Nissen hut.
6 .. .. Air Ministry design wooden towers with Nissen hut.
7 .. .. Trailer set.
8 .. .. Prime mover set, Admiralty design.

Function.—In order to indicate the function it is proposed to use the following prefixes :—

A .. .. Air reporting.
S .. .. Surface watching.
C-S.. .. Continuing sweep, dual role air reporting and surface watching.
S-B .. Stand-by (commonly for surface watching).

A.M.E.S. Type Number.	*Variety.*	*Designation and Short Description.*
1	Static only	C.H. Floodlit Early Warning station with height-finding. Frequencies 22·69–46·25 Mc/s.
2	Static only	C.H.L. Beam Early Warning station. Includes ex-C.D./C.H.L. stations used for air reporting.
3	Static only	C.H./C.H.L. Types 1 and 2 in close proximity administered as one unit. Obsolescent.
4	Static only	C.O./I.C.O. Overseas C.H./I.C.H. Obsolescent.

A.M.E.S. Type Number.	*Variety.*	*Designation and Short Description.*
5 Mk. I ..	Static only	C.O.L. Overseas C.H.L. prior to A.M.E.S. No. 530. Hand-turned. Obsolete.
5 Mk. IIA ..	Static only	From A.M.E.S. No. 531, using gantries. Power-turned.
5 Mk. IIB ..	Static only	As Type 5 Mk. 2A, but using towers.
6 Mk. I ..	Transportable ..	Early Warning set. Converted A.S.V. pack set. Obsolete.
6 Mk. II ..	Transportable or mobile.	LightWarning set. Frequency176 Mc/s. Army nomenclature AA. No. 4 Mk. II.
6 Mk. III ..	Transportable or mobile.	LightWarning set. Frequency 212 Mc/s. Army nomenclature AA. No. 4 Mk. III.
6 Mk. IV ..	Transportable or mobile.	As Mk. II, but modified to operate on a lower frequency.
6 Mk. V ..	Mobile only	High Frequency Light Warning set using a multiple Yagi aerial system.
6 Mk. VI ..	Mobile only	As Mk. V, but using paraboloid reflectors. Abandoned.
6 Mk. VII ..	Air transportable ..	Light Warning set modified for air transportation and for use as G.C.I., using A.M.E.S. Type 8A aerial mechanism.
6 Mk. VIII..	Air transportable ..	As Mk. VII, but using S.C.R. 636 aerial and mounts in lieu of A.M.E.S. Type 8A.
6 Mk. IX ..	Mobile air transportable.	Air transportable installation of A.M.E.S. Type 6 Mk. III and associated communications equipment installed in a Morris 4 × 4 vehicle (RVT 430D) and Jeep (430E).
6 Mk. X ..	Mobile air transportable.	T.R.E. version of Mk. IX.
6 Mk. XI ..	Air transportable ..	As Mk. VII, but using steel gantry in lieu of aerial trailer.
7	—	G.C.I. Final. Ground controlled interception.
8	Mobile with trailer ..	G.C.I. Mobile Mk. 3, with hand-turned aerials. Obsolescent.
8A	Transportable or semi-static.	G.C.I. intermediate mobile with hand-turned aerials. Hutted operations and transmitter rooms.
8B	Transportable ..	G.C.I. transportable. Additional 35-foot aerial system mounted on gantry. Obsolete.
8C	Transportable ..	G.C.I. Intermediate transport G.C.I. As 8B, but operations and transmitter rooms hutted. Obsolete.
8E	Mobile or mobile with trailer.	Mobile G.C.I. Mk. IV.
8F	Transportable ..	G.C.I. Mk. IV. Intermediate mobile, as Type 8E, but with operations and transmitter rooms hutted. Obsolescent.

A.M.E.S. *Type Number.*	*Variety.*	*Designation and Short Description.*
9 Mk. I	Transportable or mobile with trailers.	All-round looking floodlight early warning with height-finding. M.R.U. or T.R.U. Obsolescent. Frequency 42·5–43·75 Mc/s.
9 Mk. II	—	Special arrays on A.M.E.S. Type 9 Mk. I (T) masts. T.3102 with hutted C.R.D.F. receiver. Obsolete.
9 Mk. III	—	Similar to Mk. II, but with C.R.H.F. receiver. Obsolete.
9 Mk. IV	—	Special arrays on A.C.H. towers (Tx), hutted transmitter and C.R.H.F. Rx. Abandoned.
9 Mk. V	Mobile with trailer	Mobile version of Mk. III.
9 Mk. VI	Mobile with trailer	Special Rx arrays on 105-foot masts with C.R.H.F. and R.1426.
10	Transportable	A.C.O. All-round looking overseas A.C.H. using 125-foot towers. Frequency as Type 9. Obsolete.
11C	Mobile with trailer or air transportable.	Canadian version of A.M.E.S. Type 11 Mk. II.
11 Mk. I	Mobile with trailer	565 Mc/s. C.H.L. mobile. Obsolete.
11 Mk. II	Mobile or mobile with trailer.	Improved version of Type 11 Mk. I, with variable frequency. D.U. 3 or 58.
11 Mk. III	Mobile	Includes a prime mover universal operations room incorporating consoles 15 and 16.
11 Mk. IV	Mobile	Includes universal operations room and T.3587 with R.3575 in R.V.435 with demountable aerial and cabin.
11 Mk. V	Mobile	As Mk. III, but modified for coherent pulse working.
11 Mk. VI	Mobile	As Mk. IV, but modified for coherent pulse working.
11 Mk. VII	Mobile	As Mk. IV but with T.3605 and R.3575.
12 Mk. I	Static	C.H.L. A-J stand-by on alternative frequency. Obsolete.
12 Mk. II	Mobile	Modified A.M.E.S. 15 Mk. II (M) for G.C.I. special purposes (late "Red Queen").
13 Mk. I	Mobile with trailer	C.M.H. Mk. I. 10-cm. equipment designed for height-finding, but with one exception now used for cover against very low-flying aircraft. Obsolete.
13 Mk. II	Mobile	C.M.H. Mk. II. Consists of a vehicle with power-turned vertical cheese aerial (demountable) and T.R.3561 radio equipment, with signal output at I.F. Feeding D.U. Type 58 (mobile operations room), or D.U. Type 57 (static).
13 Mk. III	Mobile	C.M.H. Mk. III. Aerial vehicle as Mk. II, with operations vehicle incorporating console 15 and 16.

A.M.E.S. Type Number.	Variety.	Designation and Short Description.
13 Mk. IV	Mobile	C.M.H. Mk. IV. Aerial vehicle as Mk. II (M) with universal operations vehicle incorporating consoles 15 and 16.
13 Mk. V	Mobile	C.M.H. Mk. V. As Mk. IV but with improved aerial vehicle.
14 Mk. I	—	Abandoned. *See* A.M.E.S. Type 51.
14 Mk. II	Mobile with trailer	N.T.277T, overseas version of A.M.E.S. Type 57.
14 Mk. III	Mobile	Power-turned aerial system using T.R.3561, separate operations vehicle with D.U.3 or D.U.58 or separate building with D.U.56.
14 Mk. IV	Mobile	As Mk. III but with operations vehicle incorporating a console 15 and 16.
14 Mk. V	Mobile	As Mk. IV but with universal operations vehicle.
14 Mk. VI	Mobile	As Mk. V but with improved aerial vehicle.
15 Mk. I	Transportable mobile, or mobile with trailer.	C.O.L./G.C.I./C.H.B. Superseding Type 8F, 8E (T) or 8E (M).
15 Mk. II	Transportable mobile, or mobile with trailer.	As Mk. I but capable of operating on three different frequencies.
15 Mk. III	Mobile	Projected. Using T.3255 or T.3263 in aerial vehicle and universal operations vehicle. Variable frequency.
15 Mk. IV	Mobile	As Mk. II but using T.3154 in aerial vehicle in addition to T.3079 in R.V.405.
16 Mk. I	Static	Fighter Director. Fixed installation.
17 Mk. I	Mobile with trailer	C.O.L./G.C.I./C.H.B. on alternative frequencies. Abandoned.
18 Mk. I	Mobile with trailer	Formerly A.M.E.S. Type 11 Mk. II(H). Abandoned.
19 Mk. I	Mobile with trailer	Final G.C.I. stand-by. Spot frequencies in 255–295 Mc/s band. Interception and reporting vehicles. Obsolete.
20 Mk. I	Static	D.M.H. Mk. I, 590 Mc/s height-finding equipment. Fixed installation, used on fixed G.C.I. stations. Obsolete.
20 Mk. II	Static	D.M.H. Mk. II. Transportable version of Mk. I. Abandoned.
21 Mk. I	Transportable	Fixed 10-cm. station for G.C.I. use. Consists of A.M.E.S. Type 14, Mk. III, modified, and A.M.E.S. Type 13, Mk. II, both mounted on plinths.
21 Mk. II	Mobile	Consists of A.M.E.S. Type 13, Mk. II, plus A.M.E.S. Type 14, Mk. III, aerial vehicle.
21 Mk. III	Mobile	Consists of A.M.E.S. Type 13, Mk. III (M), plus A.M.E.S. Type 14, Mk. III (M), aerial vehicle.

A.M.E.S. Type Number.	*Variety.*	*Designation and Short Description.*
21 Mk. IV ..	Mobile	Consists of A.M.E.S. Type 13, Mk. IV (M), plus A.M.E.S. Type 14, Mk. III (M), aerial vehicle.
21 Mk. V ..	Mobile	Consists of A.M.E.S. Type 13, Mk. V (M), plus A.M.E.S. Type 14, Mk. VI (M), aerial vehicle.
22 Mk. I ..	Mobile or mobile with trailer.	Consists of A.M.E.S. Type 13, Mk. II (M), plus A.M.E.S. Type 11, Mk. II (T) or (M), aerial vehicle.
22 Mk. II ..	Mobile or mobile with trailer.	Consists of A.M.E.S. Type 13, Mk. III (M), plus A.M.E.S. Type 11 (T) or (M), aerial vehicle.
22 Mk. III ..	Mobile	Consists of A.M.E.S. Type 13, Mk. IV (M), plus A.M.E.S. Type 11, Mk. II (M), aerial vehicle.
22 Mk. IV ..	Mobile	Consists of A.M.E.S. Type 13, Mk. V (M), plus A.M.E.S. Type 11, Mk. IV (M), aerial vehicle.
22 Mk. V ..	Mobile	Consists of A.M.E.S. Type 13, Mk. IV (M), plus A.M.E.S. Type 11, Mk. V, aerial vehicle.
22 Mk. VI ..	Mobile	Consists of A.M.E.S. Type 13, Mk.V(M), plus A.M.E.S. Type 11, Mk. VI, aerial vehicle.
22 Mk. VII ..	Mobile	Consists of A.M.E.S. Type 13, Mk.V (M) plus A.M.E.S. Type 11, Mk. VII, aerial vehicle.
23	Static or mobile with trailer.	Ground stations for use with A.R.I.5267 overseas.
24	Static	Long range C.M.H., using modified A.M.E.S. Type 20, Mk. I, turning gear and aerial frame with a large cheese aerial.
25	Mobile	An operational combination of *any* Marks of mobile A.M.E.S. Type 11, 13, 14 and 15 to effect economies in personnel.
26	Static	British version of American " M.E.W." modified.
27	Air transportable ..	Air transportable G.C.I. operating on 3,350 Mc/s.
28	Air transportable ..	Air transportable centimetre height-finder operating on 3,350 Mc/s.
29	—	Air transportable centimetre C.H.E.L. Abandoned.
30	Static	C.D. No. 1, Mk. III, or N.T. 273P (S). Obsolescent.
31	Static	C.D. No. 1, Mk. V. Surface watching station in most common use. Equipment housed in a small wooden transportable cabin (Gibson box). Obsolescent.
32	Static	C.D. No. 1, Mk. VI. Nissen hut straddled by C.D./C.H.L. gantry supporting power-turned aerial system. No stations planned. Obsolescent.

A.M.E.S. Type Number.	Variety.	Designation and Short Description.
33	Static	C.D. No. 1, Mk. VI. Equipment housed in Army C.D./C.H.L. or similar solid building. Obsolescent.
34	Static	C.D. No. 1, Mk. VI (Tower). War Office steel tower 200 feet high, with equipment housed in Gibson box. All stations now converted to Type 54. Obsolete.
37	Mobile with trailer	C.D. No. 1, Mk. IV. Mainly used as a stand-by for static types. Obsolete.
40	Static	As Type 30 with medium power transmitter. Obsolescent.
41	Static	As Type 31 with medium power transmitter.
42	Static	As Type 32 with medium power transmitter. No stations planned.
43	Static	As Type 33 with medium power transmitter. No installations or conversions yet made.
46	Static	C.D. No. 1, Mk. VI (Tower). Air Ministry wooden tower with Nissen hut.
47	Mobile with trailer	As Type 37 (T) with medium power transmitter. No equipments exist and doubtful whether any will be fabricated.
48	Mobile	N.T. 273Q (L), Admiralty set.
50	Static	N.T. 277S, Admiralty set.
51	Static	Previously Type 14, Mk. I.
52	Static	As Type 32, but with high power transmitter. Standard type of station used for both air and surface watching.
53	Static	As Type 33 but with high power trans mitter.
54	Static	As Type 34 with high power transmitter. Conversion of all Army tower stations to this type is complete.
55	Static	C.D. No. 1, Mk. VI** (Tower). Aerial system mounted on C.H. cantilever.
56	Static	As Type 46 but with high power transmitter.
57	Mobile with trailer	N.T. 277T, Admiralty set, for use in the United Kingdom only. Formerly known as A.M.E.S. No. 14, Mk.II(T), which designation now applies to the overseas version only.
58	Mobile	N.T. 277L, Admiralty set.
60	Transportable	A.N./T.P.S. 1 (American Light Warning set).
61 Mk. I	Transportable	A.N./T.P.S. 1A (American Light Warning set).
61 Mk. II	Transportable	A.N./T.P.S. 1B (American Light Warning set).

A.M.E.S. Type Number.		*Variety.*	*Designation and Short Description.*
62	..	.. Transportable ..	A.N./T.P.S. 2 (American Light Warning set).
63	..	.. Transportable ..	A.N./T.P.S. 3 (American Light Warning set).
64	Mk. I	.. Transportable ..	Australian L.W./A.W.
64	Mk. II	.. Transportable ..	Australian L.W./G.C.I.
65	..	.. Air transportable ..	Specialised combination of A.M.E.S. No. 6, Mk. III, and 63, formerly known as " Dinner Waggon."
66	Mk. I	.. Static	S.C.R. 615.
66	Mk. II	.. Static	S.C.R. 615A.
66	Mk. III	.. Static	S.C.R. 615B.
67	Mk. I	.. Mobile	S.C.R. 584 modified for M.R.C.P.
67	Mk. II	.. Mobile	S.C.R. 584 modified for M.R.C.P. with kit A.C. 106.
68	Mk. I	.. Portable	S.C.R. 720 employed in surface watching role.
69	..	.. Transportable ..	A.N./T.P.S. 9.
70	..	.. Mobile	Special long range " S " band station with multiple display facilities to be used for simultaneous G.C.I. and reporting functions.
100	Mk. IA ..	—	Ground station for use with A.R.I. 5525.
100	Mk. IB ..	—	Heavy mobile ground station for use with A.R.I. 5525.
100	Mk. IC ..	—	Light mobile or transportable. Ground version for use with A.R.I. 5525.
700	.. ..	—	Ground station for use with A.R.I. 5267 in the United Kingdom. Static.
7000	.. ..	—	Ground station for use with A.R.I. 5083. Static or heavy mobile. (GEE.)
9000	Mk. I ..	—	Ground station for use with A.R.I. 5513. Static. (OBOE.)
9000	Mk. II (F)	—	Ground station for use with A.R.I. 5582. Static.
9000	Mk. II (M)	—	Ground station also for use with A.R.I. 5582. Mobile with trailers.
9000	Mk. II (SM)	—	Ground station for use with A.R.I. 5582. Mobile with trailers.
9000	Mk. II (H)	—	Ground station for use with A.R.I. 5582. Mobile with trailers.
9000	Mk. III ..	—	Improved version of Mk. II. Static.

APPENDIX No. 51

A.M.E.S. TYPE 21, MARK I

The Type 21, Mark I, comprised two associated equipments—A.M.E.S. Type 14, Mark III, and A.M.E.S. Type 13, Mark II, both 10 centimetre sets. The former consisted of a Plan Position Indicator unit, rotating about six times per minute and the latter was a height finding unit, capable of giving a height reading in any desired direction.

" Window " had proved a great hindrance to C.H., C.H.L. and the ordinary G.C.I. wavelengths in the territories affected, and it was therefore hoped that by the installation of high frequency equipment at the G.C.I. stations, interception of enemy raiders would be simplified. The narrow beam width ensured that the returns from " Window " would clutter up a minimum of the display, and provided an opportunity for tracing the echoes from rapidly moving aircraft through the almost stationary " Window " signals.

The first installations to become operational, early in 1944, were at Sandwich (Kent) and Wartling (Sussex). By June 1944 most of the installations were complete.

Other G.C.1 stations equipped with A.M.E.S. Type 21 :—

Dirleton (East Lothian).	Durrington (Sussex).
Northstead (Northumberland).	Sopley (Hants).
Seaton Snook (Durham).	Black Gang (I. of W.).
Patrington (Yorks).	Exminster (Devon).
Neatishead (Norfolk).	Hope Cove (Devon).
Trimley Heath (Suffolk).	Treleaver (Cornwall).
East Hill (Beds.).	

APPENDIX No. 52

CENTIMETRE STATIONS OF THE HOME CHAIN AT 1 JANUARY 1944

Station Type Numbers revised by Air Ministry, 7 December 1943

(*See* Air Ministry File C.S. 19935 " Nomenclature of radar Equipment.")

Naval Stations denoted by (*).
For geographical position of these stations *see* Map, No. 20.

A.M.E.S., Type 30. Formerly C.D. No. 1, Mark II (Naval, Type 273 P.S.).,
These were Admiralty stations, two of which were taken over by Air Ministry by the end of 1943. (Grutness and Dunnet Head.)

A.M.E.S., Type 31. C.D. No. 1, Mark V (Naval, Type P (A).
The Surface Watching stations in most common use.
The equipment was housed in a small transportable wooden cabin known as the " Gibson Box."
The stations already in use were Breckness*, Ulbster, Navidale, Crannoch Hill, Doonies Hill, St. Cyrus, The Law, May Island*, Lamberton Moor, Craster, Cresswell, Cleadon, Saltburn, Warden Point, Leathercoates, Lyddenspout, Capel*, Fairlight, Beachy Head, Truleigh Hill, The Needles, Jacka, Pen Olver, Carn Brea, St. Agnes Beacon, Dunderhole Point, Hartland Point, Rhossilli Bay, St. Anne's Head, South Stack, Great Orme, Cregneish, Glenarm, Downhill, Kilchiarin, Kendrom and Eorodale.

A.M.E.S., Type 33. C.D. No. 1, Mark VI. The equipment was housed in a C.D./C.H.L. compound, and only one existed at the beginning of 1944. (Rame Chapel, in Cornwall.)

A.M.E.S., Type 34. C.D. No. 1, Mark VI (Tower).

This had a War Office 200-foot steel tower with the equipment housed in a "Gibson Box." All stations (Rosehearty, Bempton, Dimlington, Skendleby and Dengie) were being converted to Type 54, the high power version of the same set.

A.M.E.S., Type 37. C.D. No. 1, Mark IV.

A trailer equipment. (Highdown Hill, The Verne, Kingswear, Beer Head, Start Point, St. David's Head.)

A.M.E.S., 40–44. Medium power versions of Types 30–34.

A.M.E.S., Type 46. C.D. No. 1, Mark VI + (Tower).

One only—Greystone, in Northern Ireland.

A.M.E.S., Type 50. Admiralty static set 277S at Capei.

A.M.E.S., Type 51. Formerly Type 14, Mark I.

Only three of these equipments were used—at Beachy Head, Truleigh Hill and Deerness (Orkney).

A.M.E.S., Type 52. High power versions of Type 32.

(Carn-Brea, Hartland Point, St. Annes, St. David's, South Stack, Cregneish, Down Hill, Kilchiarin.)

A.M.E.S., Type 53. High power version of Type 33 (Fairlight and the H.P.T. set at Ventnor).

A.M.E.S., Type 54. High power version of Type 34. All Army stations were eventually converted to this type (Bard Hill, Trimingham, Winterton, Benacre, Thorpeness, North Foreland. Three were under construction at The Verne, Beer Head and Start Point).

A.M.E.S., Type 55. C.D. No. 1, Mark VI (Tower). The set mounted on a C.H. cantilever.

(Bawdsey, and under construction at Douglas Wood, Drone Hill, Great Bromley and Dunkirk.)

A.M.E.S., Type 56. C.D. No. 1, Mark VI, + + (Tower). This used a timber tower and equipments were later installed at Cresswell and Pen Olver.

A.M.E.S., Type 57. Naval, Type 277, and formerly R.A.F., Type 14, Mark II (Trailer).

(St. Margaret's Bay, Capel*, The Verne, Beer Head, Start Point, Bolt Tail and Pen Olver).

APPENDIX No. 53

THE HOME CHAIN

March 1945

To be read in conjunction with Map No. 20.

H.Q. 60 Group: Leighton Buzzard.

Wing Boundaries in 60 Group

	North.	East.	South.	West.	Other Territory.	Detachments.
70	Coast.	Coast	Border.	Coast.	Orkneys. Shetlands. Fair Isle. Lewis. Skye. North Uist. Barra. Tiree. Islay. Northern Ireland.	Lerwick. Nether Button. Stornoway. Paisley. Greystones. Loth (Equipment section.
73	Border.	Coast.	Line from* wM 9797 to wL 8550 to vO 6550 to vN 6270	Coast.	Isle of Man. Anglesey.	Douglas. Cambridge.
75	73 Wing.	Coast.	Coast.	Line from* vP 9050 to vP 9000 to vU 7030 to vU 7012.	Isle of Wight.	Ventnor. Tonbridge. (Equipment Section).
78	73 Wing.	75 Wing.	Coast.	Coast.	Scillies.	Dry Tree.

* CASSINI GRID.

Stations on Care and Maintenance.—Stage I.

(Station or Channel maintained in such a state of readiness that it could return to Operations at 14 days' notice.)

Beachy Head ..	Type 16	Hythe	Type 16, 24
Bolt Tail	Type 2	Loth	Type 1
Comberton	Type 7	Newford	Type 8c
Dunderhole Point	Type 41	Northam	Type 1
Exminster	Type 7, 21	North Cairn ..	Type 1
Folly	Type 1	Saligo	Type 1
Glenarm	Type 2	St. Lawrence ..	Type 1
Greian Head ..	Type 2	St. Twynells ..	Type 2
Hack Green ..	Type 7	Trewan Sands ..	Type 7
Hawcoat	Type 2	Ventnor	Type 1, 16

Stations on Care and Maintenance.—Stage II.

(Station or Channel maintained at such a level that it might return to Operations at six months' notice.)

Ballymartin ..	Type 2	Kilkeel	Type 1
Barrapol	Type 8*c*	Nevin	Type 1
Ben Hough ..	Type 2	Prestatyn	Type 2
Castle Rock ..	Type 1	Roddans Port ..	Type 2
Dalby	Type 1	Rhuddlan	Type 1
Great Orme ..	Type 2	South Stack ..	Type 2
Greystone	Type 1	Strumble Head ..	Type 2
Kilchiarin	Type 2	Wylfa	Type 1

Stations on Care and Maintenance.—Stage III.

(Station or Channel pending dismantling, not required to return to Operations.)

Ballinderry ..	Type 8*c*
Ballydonaghy ..	Type 8*a*
Crossmaglen ..	Type 9 (T)
Lisnaskea	Type 8*a*

APPENDIX No. 54

GROUND RADAR STATIONS OPERATIONAL IN OCTOBER 1945

Note.—Stations marked (*) were scheduled for reduction to a Care and Maintenance basis, Stage II.

Stations marked (†) were retained for Flying Control purposes only.

G.C.I.

Dirleton.
East Hill.*
Langtoft.
Hope Cove.
Neatishead.
Northstead.
Patrington.
Ripperston.
Russland.*
Sandwich.
Seaton Snook.
Sopley.
Treleaver.
Trimley Heath.
Wartling.
Wrafton.

C.H.

Bawdsey.
Broad Bay.†
Brenish.†
Downderry.*
Drone Hill.*
Dry Tree.*
Hill Head.
Nether Button.*
Pevensey.*
Ringstead.
Sango.*
School Hill.
Stenigot.*
Stoke Holy Cross.*
Tannach.*
Trelanvean.*
Trerew.*
West Beckham.
West Prawle.*
Whale Head.

C.H.B.

Borve Castle.†

C.H.L.

Bamburgh.
Bard Hill.
Bawdsey.
Beer Head.*
Bempton.
Boniface Down.
Cockburns Path.
Cocklaw.
Cresswell.
Crustan.
Deerness.
Doonies Hill.*
Dunnet Head.*
Dunwich.*
Eorodale.†
Fair Isle III.
Fairlight.
Goldsborough.
Happisburgh II
Hartland Point.
Hopton.
Humberston.
Islivig.†
Marks Castle.
North Foreland.
Pen Olver.
Rame Head.*
Rosehearty.*
St. Cyrus.
Sango.*
Swingate.
Truleigh Hill.
Ulbster.
Westcliffe.
Kingswear.
Fair Isle II.

C.H.E.L.

Bawdsey (T.55).
Beer Head 54.*
Bempton 54.
Benacre 54.*
Carn Brea 52.
Cresswell 56.
Deerness 51.
Dimlington Highland 54.
Douglas Wood 55.
Downderry 57.*
Dunnet Head 57.
(Tech. Training)
Fair Isle III 50.
Fairlight T.52.
Goldsborough 52.
Hartland Point 52.
Hopton 54.
Jacka 52.
Kete 52.
Kingswear 52.
Lamberton Moor 52.
North Foreland 54.
Pen Olver 56.
Pen Ronaldsay 50.
Pen-y-Bryn 57
(Tech. Training) South.
Prestatyn 57.
Rosehearty 54.
Skendleby 54.
St. Margaret's Bay 52.
Trimingham 54.
Truleigh Hill 51.
Ventnor 52.
The Verne 54.
Winterton 54.*
Whitstable 57.
West Beckham 55.

APPENDIX No. 55

FINAL CONTRACTION OF HOME CHAIN COVER

Surface-Watching Stations closed down in 1944

On 22 August 1944 Air Ministry, in accordance with the wishes of the Radar Board, issued instructions that the following stations should close :—

The C.H.L. stations at Swansea Bay and Ravenscar.
The Type 30 equipment at Grutness.
The Type 31 equipments at Kendrom, Doonies Hill, St. Cyrus, The Law, Cleadon and Saltburn.

The mobile high power, Type 57, apparatus at Flat Point, Ilfracombe, which had been transferred from Bolt Tail in May to guard the Bristol Channel, had already been closed at the end of July.

The Radar Board also recommended that the Type 31 equipment at Whitstable, originally used for training operators, should come into the reporting chain. The actual decision was deferred until the Commander-in-Chief, The Nore, was able to confirm that a definite requirement existed for this station and this was not done until March 1945.

Further orders were given by Air Ministry to the effect that the Type 31 equipments at Jacka and St. Anne's Head, and the Type 41 set at Kingsweir, should become stand-by only, and that the C.H.L. stations at Sango, Cocklaw, Walton and Hawcoat should revert to an air-detecting role. It was anticipated that the saving in manpower as a result of these economies would be thirty mechanics and one-hundred operators.

On 24 May 1945 the Admiralty decreed that all naval plots save Rosyth, Humber, The Nore, Dover, Portsmouth, Plymouth and Falmouth should close, and stated that the following radar stations would be sufficient to cater for all their needs—Fair Isle, Ronaldsay, Dimlington, Trimingham, North Foreland, Beachy Head, Capel, Ventnor, The Verne, Start Point, Pen Olver, Carn Brea and Hartland Point.

APPENDIX No. 56

CHAIN POSITION BY JUNE 1939

By the end of June 1939 a chain of nineteen R.D.F. stations (including the temporary station at Ravenscar) was carrying out continuous watch. Details of the equipment in use at the stations were :—[1]

Station.	Line of Shoot.	Tx.	Rx.	Tx. Array.	Rx. Array.[2]	Wave-length.
Douglas Wood	114°	MB1	RF5	Standard	Standard	10·82 m.
Drone Hill ..	58°	TF3	BRS	Standard ..	Standard ..	11·95 m.
Ottercops ..	50°	MB1	RF5	Standard plus gap-filler.	Standard plus gap-filler.	11·10 m.
Danby Beacon	65°	MB1	RF5	Standard ..	Standard ..	10·82 m.
Ravenscar ..	—	TM1	BRS	Single dipole with reflector switched for sensing, on a 90-foot tower.	Single pair of crossed dipoles with height dipole, on a 90-foot tower.	11·40 m.
Staxton Wold	66°	MB1	RF5	Standard ..	Standard ..	11·95 m.
Stenigot ..	79°	MB1	RF5	Standard ..	Standard ..	12·60 m.
W. Beckham	40°	TM1	BRS	Standard ..	Standard ..	11·95 m.
Stoke Holy Cross.[3]	33°	MB1	RF5	Standard ..	Standard ..	11·95 m.
High Street ..	102°	MB1	RF5	Standard ..	Standard ..	11·10 m.
Bawdsey ..	110°	CH Exp. Exp.	 RF3 RF4	One bay of four elements with gap-filler.	Array of three pairs of crossed di-poles and gap filler.	Non-op. 13·25 m. Tx.11 m.
Great Bromley	124°	IF3	RF4	One bay of six elements plus gap-filler.	As Bawdsey's	13·25 m.
Canewdon ..	110°	TF3	RF4	As Bromley's	As Bawdsey's	13·25 m.
Dunkirk ..	56°	TF3	RF3	As Bromley's	As Bawdsey's	13·25 m.
Dover ..	90°	T2	RF5	As Bromley's	As Bawdsey's	13·25 m.
Pevensey ..	151°	MB1	RF5	Standard ..	Standard ..	10·82 m.
Rye ..	144°	TM1	RF5	Standard plus gap-filler.	Standard plus gap-filler.	11·10 m.
Poling ..	172°	MB1	RF5	Standard ..	Standard ..	11·95 m.
Ventnor ..	148°	MB1	RF5	Standard ..	Standard with-out height dipole.	11·80 m.

[1] Air Ministry File S.47412 Encl. 110A.

[2] The standard transmitter array consisted of a single bay of three centre-fed half-wave elements with reflector, installed on a 240-foot wooden tower. It radiated effectively only over a certain horizontal arc centred on a bearing known as the " line of shoot." The standard receiving array consisted of a single pair of crossed dipoles, with a reflector for sense determination, at the top of a 240-foot wooden tower; and a single dipole, with a reflector, at 80 feet, for height measurement.

[3] Stoke Holy Cross line of shoot altered to 71° in August 1939.

EXTENT OF COMPROMISE OF R.D.F. SECRECY BY THE FALL OF FRANCE

No direct evidence exists as to the extent of the disclosure of R.D.F. information to the enemy consequent upon the defeat of France. In the original disclosure of our R.D.F. secrets to the French in 1939 prior to the outbreak of war, they were given a clear picture of the principles of R.D.F. but kept in ignorance of our manufacturing processes—as it had been agreed that the production of R.D.F. equipment was to be reserved to Great Britain.[1] In addition, six French Officers had been attached to Bawdsey Research Station on an eight weeks' course beginning in June 1939 and had therefore an excellent knowledge of the working of our C.H. stations and Filter Centre technique of raid reporting.[2] After the outbreak of war there were many French staff officers with varying degrees of knowledge of R.D.F. It must also be recalled that training on G.M. and G.L. sets, and I.F.F., Mark I, had taken place in France of Army and Air Force personnel at Montpellier and the French Navy personnel at Hyères and Toulon. In addition, French Air Force personnel had carried out complete watch-keeping duties on British mobile R.D.F. stations.[3] French technical personnel also visited England to study C.H.L. and A.S.V. sets. Admiral Darlan, Commander-in-Chief of French Naval Forces, was kept informed with regard to A.S.V. developments. What amount of information the Germans obtained during routine interrogation of these military prisoners is not known. Some of the equipment in the French training establishments may also have fallen into enemy hands.

With regard to documents on the subject of R.D.F., full specifications and plans of the 240 foot aerial towers and typical lay-out of a C.O. station were supplied to the French through General Jullien.[4] The French themselves had conducted research and constructional work on R.D.F. contrary to their agreement with us. Furthermore, they had not confined themselves solely to ground R.D.F.; it was known that a group of three technicians had been working on the development of 50 cm. A.I. aircraft equipment by the pulse method at the *Le Materiel Telephonique* laboratories. Assurances were given that all *L.M.T.* blue-prints of developments and all details of R.D.F. production were destroyed at the time of the French capitulation. The R.D.F. station at Toulon, constructed by *L.M.T.*, was acceptance-testing at the time of the French Armistice and was also destroyed. Nevertheless it was only safe to assume that practically all the information about our ground R.D.F. stations and some in regard to aircraft equipment was in enemy hands after the fall of France.

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[1] C.I.D. 1546B, para. 3, sub-para. (*d*).

[2] Air Ministry File S.1336, Encl. 2A, and Air Ministry File S.45967, Encl. 189A, paras. 11 and 17.

[3] A.H.B./IIH2/190, Encls. 22A, 24A, and Air Ministry File S.1796, Encl. 51A.

[4] Air Ministry File S.1796, Encl. 61B.

APPENDIX No. 58

DUTIES OF R.D.F. STATION PERSONNEL

The following is a brief explanation of the duties of individual operators and others composing one watch at a typical R.D.F. station in early 1941.[1]

C.H. Station.—(*a*) *Observer.*—This Radio Operator sat opposite the cathode ray tube wearing a Head and Breast Telephone Set and observed the echoes on the tube. He dealt with them in turn starting with the echo nearest the ground ray on the left-hand side of the tube. He first sensed the echo to determine whether the aircraft was in front or behind the C.H. station and then side-sensed it to decide which side it was of the line-of-shoot. He then placed the manually controlled range pointer on the left-hand edge of the echo and took a bearing by swinging the goniometer until the minimum signal strength was obtained. When the operator pressed two switches which actuated the electrical calculator this caused a grid reference (controlled by the settings of the positions of the range marker and the goniometer dial) to appear on an illuminated display panel situated in front of the teller.

The Observer then switched to the height aerials and repeated the performance, causing a height to appear below the grid reference. A further set of switches indicated the estimated number of aircraft in the raid. As soon as the complete set of information was displayed the Observer announced the name of the R.D.F. station by telephone to Stanmore Filter Room followed by the track number or identification and I.F.F., if showing.

(*b*) *Teller.*—The Teller continued with the plot, speaking on the same common telephone line, giving the number of aircraft, the height and the grid reference of the plot as shown by the plotter. The Teller also gave plots by reading off the C.H.L. record sheet, giving priority for this over C.H. plotting. The Filter Room plotter repeated back all the information as a check to the Teller.

(*c*) *C. H. Recorder.*—The C.H. Recorder recorded on loose sheets every plot registered on the electrical calculator, noting the time of the plot, its number, height (if any), friend or foe and other relevant information such as the number of the raid allocated by the Filter Room at Stanmore, the fade and pick-up ranges, signal-noise ratios, the equipment in use, interference, the time of the last range calibration and any Filter Room remarks. These records were sent to Stanmore daily for record and technical investigation purposes.

(*d*) *Plotter.*—The plotter sat before a large grid-reference map and plotted all information passed to Stanmore, so that if a query arose, the Supervisor had a picture of the recent activity. C.H.L. tracks were also plotted in a different coloured pencil to distinguish them from C.H. plots.

(*e*) *C.H.L. Recorder.*—The C.H.L. Recorder sat next to the Teller and recorded all C.H.L. information, having an open line to the associated C.H.L. station for receiving plots. The C.H.L. Recorder also took up any C.H.L. queries from Stanmore Filter Room.

(*f*) *N.C.O. in charge of the Watch.*—He was the N.C.O. link between the officer Supervisor and the Radio Operator A.C.s or A.C.W.s. It was part of his duty to see that each member of the watch did his or her job efficiently. He also kept the operational log for the station and generally assisted, sometimes as an Operator, in maintaining the smooth running of the watch.

(*g*) *The Supervisor.*—The Supervisor was a Flying Officer or Assistant Section Officer (W.A.A.F.) Radio Specialist. This officer was in charge of the watch and had much experience in interpretation of R.D.F. information on the cathode ray tube. He or she was the most experienced person on the watch and was therefore invaluable in sorting out the observed echoes and maintaining a smooth organisation —for which he or she was directly responsible.

C.H.L. Station.—(*a*) *Observers.*—There were two observers as two cathode ray tubes were used; one watched the Range tube and the other the Azimuth (or bearing) tube. The observer at the Azimuth tube operated the receiver aerial by

[1] Air Ministry File S.7739, Encl. 12A.

hand, rotating it, since C.H.L. vision was beamed like a perpendicular slice compared with the C.H. station radio " floodlight." It was therefore necessary to sweep continually to search their area. Otherwise the duties, including those of the Range tube observer, were similar to the C.H. observer.

(*b*) *Plotter-Teller.*—He plotted the information spoken by the observers and told it to the C.H. station. The plots were not a record as they were marked on a celluloid-covered map and rubbed off periodically, only being needed for identifying tracks and answering any queries raised by Filter Room through the C.H. station.

(*c*) *Recorder.*—This airman recorded all plots as told by the observers and plotted by the plotter-teller. The record was sent to Stanmore for analysis.

(*d*) *Corporal Supervisor.*—This junior N.C.O. supervised the watch. He was responsible for clearing up queries and for assistance in the identification of echoes. He was directly responsible for the smooth running of the watch.

Both C.H. and C.H.L. stations had a complement of Radio Mechanics responsible for the day-to-day serviceability of the stations. They were also capable of acting as observers and usually assisted during their tour of duty.

GLOSSARY OF ABBREVIATIONS AND TERMS USED IN GROUND RADAR

A.M.E.S. .. Air Ministry Experimental Station. Official name for R.A.F. ground radar stations.

A.C.H. .. .. Advance Chain Home. The early type of C.H. station, using 70 or 90-foot wooden towers for receiving and transmitting, and an M.B.I. transmitter.

A-J. .. .. Anti-Jamming.

A.J.B.O. .. Anti-Jamming Blackout Unit. (A device on Chain Home receiving equipment for countering enemy jamming.)

A.S.R. .. .. Air–Sea Rescue. Organisation for the rescue of aircrew making forced landings in the sea.

B.R. .. .. Buried Reserve. (A standby Chain Home Station, with all equipment in underground rooms, aerial arrays on 105-foot wooden towers.)

C.H. .. .. Chain Home. (" Floodlight " stations.)

C.H.L. .. .. Chain Home Low. (" Beam " stations.)

C.O. .. .. Chain Overseas. (Overseas equivalent of C.H.)

C.O.L. .. .. Chain Overseas Low. (Overseas equivalent of C.H.L.)

C.D. .. .. Coast Defence.

C.D./C.H.L. .. Coast Defence/Chain Home Low.

C.H.E.L. .. Chain Home Extra Low. (10-centimetre equipments for the detection of surface craft and very low-flying aircraft.)

C.M.H. .. .. Centimetre Height Finding. (A.M.E.S. Type 13.)

C.R.T. .. .. Cathode Ray Tube

C.R.D.F. .. Cathode Ray Direction Finding.

Cm. .. .. Centimetre.

C.W. .. .. Continuous Wave.

C.H.B. .. .. Chain Home Beamed. A station using C.H.L. equipment with height-finding facilities, placed where siting difficulties made it impossible to erect a full C.H. station. Reported to Filter Room in usual way.

C.D.P. .. .. Combined Directional Plotting.

Clutter .. .. Ground or sea returns, tending to obscure the C.R.T. and making radar observations more difficult. Also applied to excessive responses on the I.F.F. display.

D.M.H. .. Decimetre Height Finding. Radar equipment for height-finding operating on 50 cm.

D.P. .. .. Directional Plotting.

D.C.D. .. .. Directorate of Communications Development at the Ministry of Aircraft Production.

D./F. .. .. Direction Finding.

E.R.M. .. .. Electrical Range Marker.

F.D.P. .. .. Fighter Direction Post—a mobile radar unit employed for the control of day fighters.

F.D.T. .. .. Fighter Direction Tenders—Ships fitted with radar for the control of day and night fighters, and early warning in an invasion.

F.M.C.W. .. Frequency Modulated Continuous Wave. (A form of intentional jamming much used by the enemy.)

G.C.C. .. .. Group Control Centre—the operational centre or Ops. Room with a mobile force overseas.

G.C.I. .. .. Ground Controlled Interception.

G.L. .. .. Gun Laying. (Army radar sets.)

G.M. .. .. Mobile Gun-laying Radar sets.

I.F.F. .. .. Identification Friend or Foe.

I.C.H. .. .. Intermediate Chain Home.

I.C.W. .. .. Interrupted Continuous Wave.

I.F.R.U. .. Intermediate Frequency Rejector Unit. (An anti-jamming device on C.H. and C.H.L. receivers.)

I.U. ..	..	Installation Unit.
J. Watch	..	Organisation responsible for keeping 24-hour watch on all enemy jamming.
(M) ..	..	Mobile. (Fully mobile equipment, all vehicles being prime movers.)
M.A.R.U.	..	Mobile Air Reporting Unit. The centre of a radar network for early warning and reports to the M.O.R.U. with an overseas field force.
M.B. ..	..	Mobile Station. (Overseas.)
M.B.I.–3	..	Mobile Transmitters, used either at home or overseas.
M.E.W.	..	Microwave Early Warning.
M.G.R.I.	..	Mobile Ground Radio Installations.
M.O.R.U.	..	Mobile Operations Room Unit—for employment with an overseas field force.
M.R.C.P.	..	Mobile Radar Control Point.
M.R.U. ..	..	Mobile Radio Unit—a mobile radar station giving " floodlight " facilities similar to C.H. station.
M.S.S.U.	..	Mobile Signals Servicing Unit—for Signals and Radar Servicing in an overseas theatre of operations.
N.P.L. ..	..	National Physical Laboratory.
O.R.S. ..	..	Operational Research Section. Scientists from T.R.E. who were attached to R.A.F. Commands at home and overseas for advice and assistance in assessing technically the operational employment of technical equipment.
P.R.F. ..	..	Pulse Recurrence Frequency.
P.P.I. ..	..	Plan Position Indicator. (Cathode ray tube display with radial time base.)
R.C.M. ..	..	Radio Counter Measure.
R.D.F. ..	..	Radio Detection and Direction Finding. The original British name for Radar.
R.R. ..	..	Remote Reserve. (Standby C.H. equipment at some distance from main C.H. station.)
Radar ..	..	Radio Detection and Ranging.
R.A.E. ..	..	Royal Aircraft Establishment.
R.F. ..	..	Receiver (Fixed), also Radio Frequency.
Rx ..	..	Receiver.
R/T. ..	..	Radio Telephony.
R.M.U.	..	Radio Maintenance Unit.
(T) ..	..	Transportable.
T.G.R.I.	..	Transportable Ground Radio Installation.
T.R.E. ..	..	Telecommunications Research Establishment.
T.R.U. ..	..	Transportable Radio Unit.
Tx ..	..	Transmitter.
V.H.F. ..	..	Very High Frequency. Frequency band between 30 Mc/s and 225 Mc/s.
V.E.B. ..	..	Variable Elevation Beam. Radar equipment for height finding.
W.O.U.	..	Wireless Observer Unit.
W/T ..	..	Wireless Telegraphy.

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