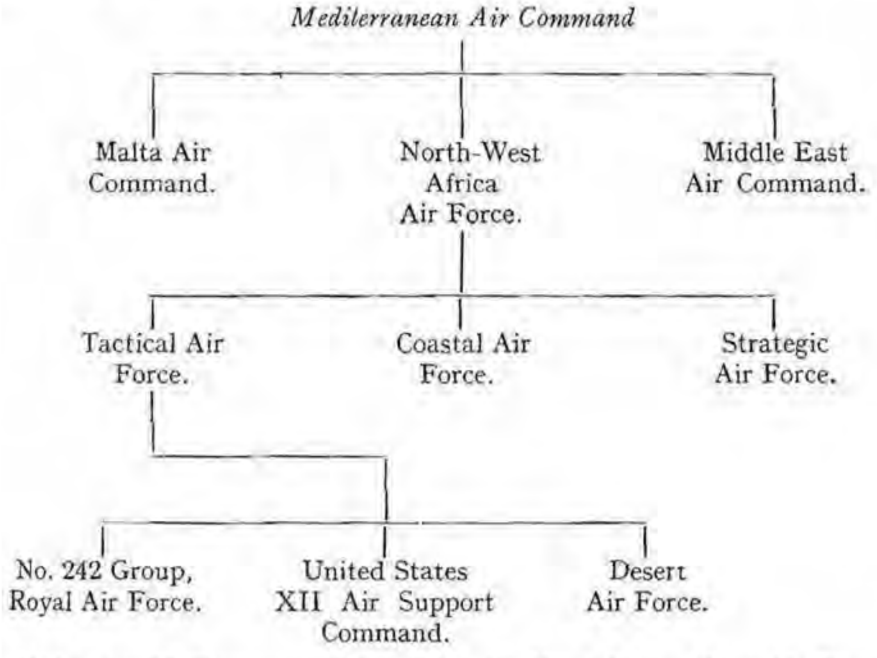
CHAPTER 18

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 :—



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

[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.
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> *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

[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.

[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.

[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

[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

[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 farm-house 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.

[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.

[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.

[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.

[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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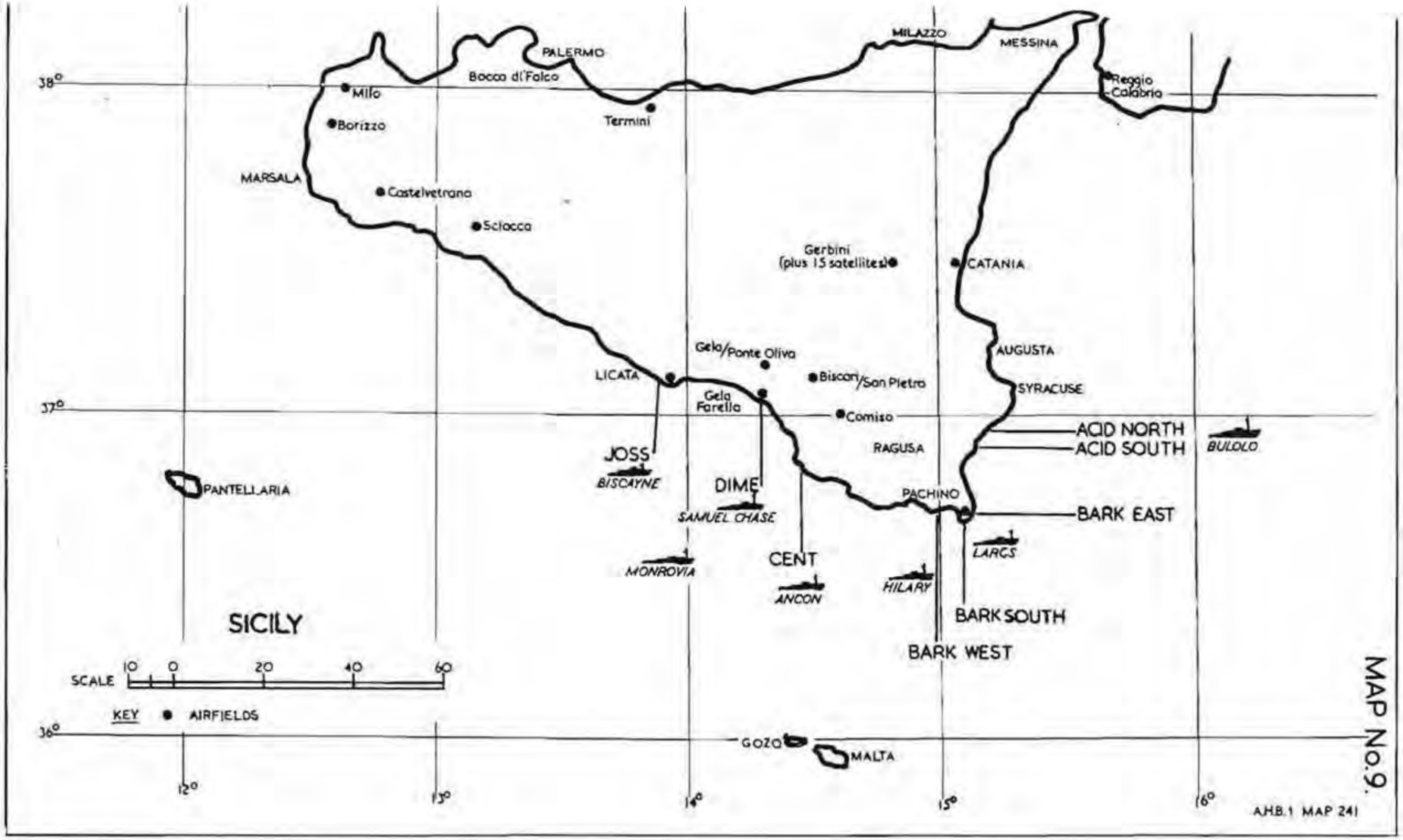
[1] Air Ministry File C.32154/46.

[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.



PALERMO
Bocca di Falco
MILAZZO
MESSINA
Reggio
Calabria
Milo
Borizzo
Termini
MARSALA
Castelvetrano
Sciacca
Gerbini
(plus 15 satellites)
CATANIA
AUGUSTA
Gela/Ponte Olivo
LICATA
Biscari/San Pietro
SYRACUSE
Gela
Farello
Comiso
ACID NORTH
ACID SOUTH
JOSS
BULOLO
RAGUSA
BISCAYNE
PANTELLARIA
DIME
PACHINO
SAMUEL CHASE
BARK EAST
LARGS
CENT
MONROVIA
ANCON
HILARY
BARK SOUTH
SICILY
BARK WEST
SCALE 10 0 20 40 60
KEY ● AIRFIELDS
GOZO
MALTA
38°
37°
36°
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

[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.

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

[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.

[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.

[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.

[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

[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.

[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.

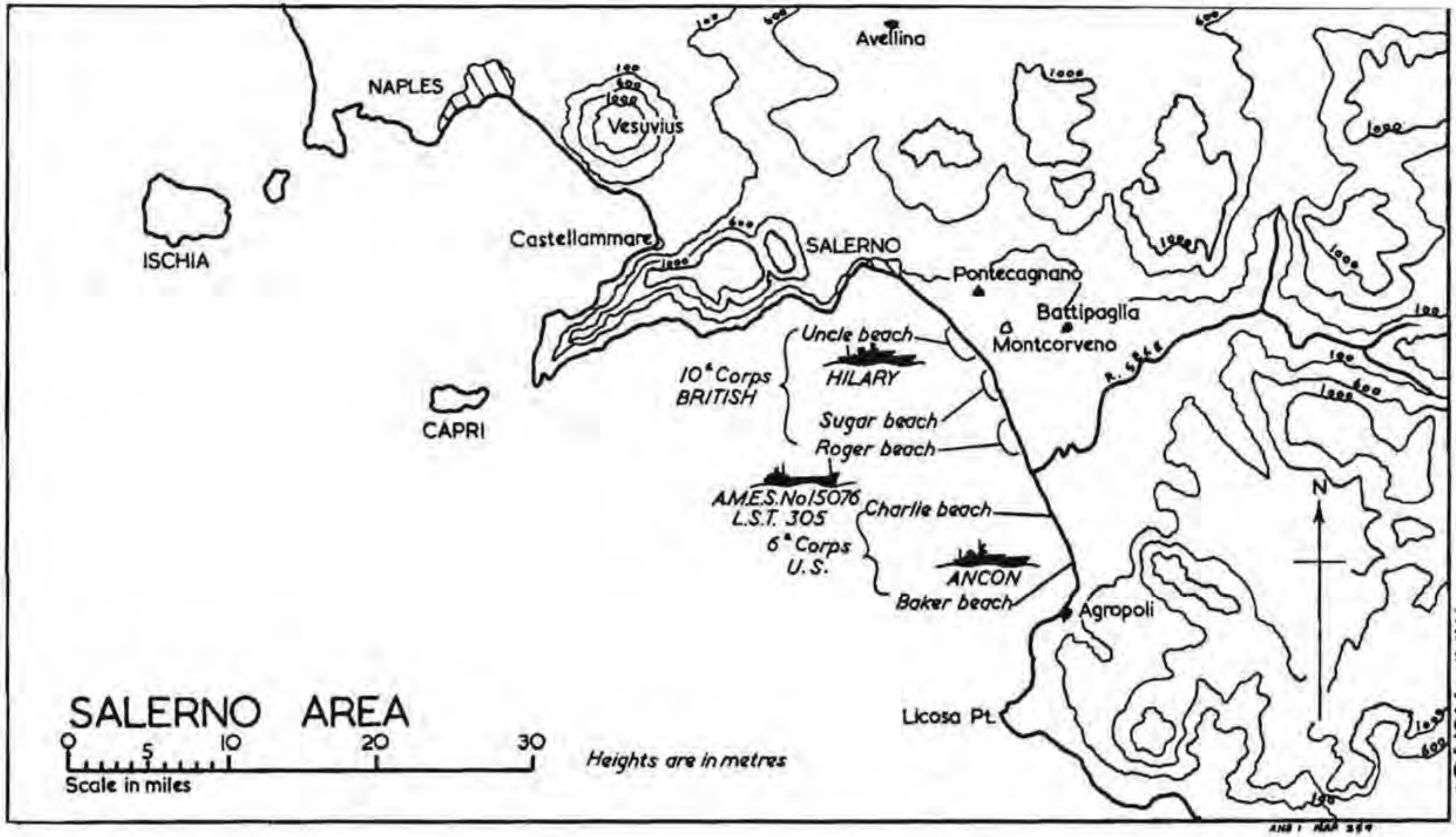
On board the ship there were two Operations Rooms, a Fighter Operations Room which housed the Operations and Filter Board in one room, and a Main Operations Room for the Directing Staff. The former was small and consequently suffered continual overcrowding by individuals seeking information on the air 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.

[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."



Avellina
NAPLES
Vesuvius
ISCHIA
Castellammare
SALERNO
Pontecagnano
Battipaglia
Montcorveno
CAPRI
Uncle beach
HILARY
10th Corps
BRITISH
Sugar beach
Roger beach
A.M.E.S. No 15076
L.S.T. 305
Charlie beach
6th Corps
U.S.
ANCON
Baker beach
Agropoli
Licosa Pt.
N
SALERNO AREA
0 5 10 20 30
Scale in miles
Heights are in metres

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

[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.

[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.

[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.

[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.

[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

[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]

[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.

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[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 period 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

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[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]

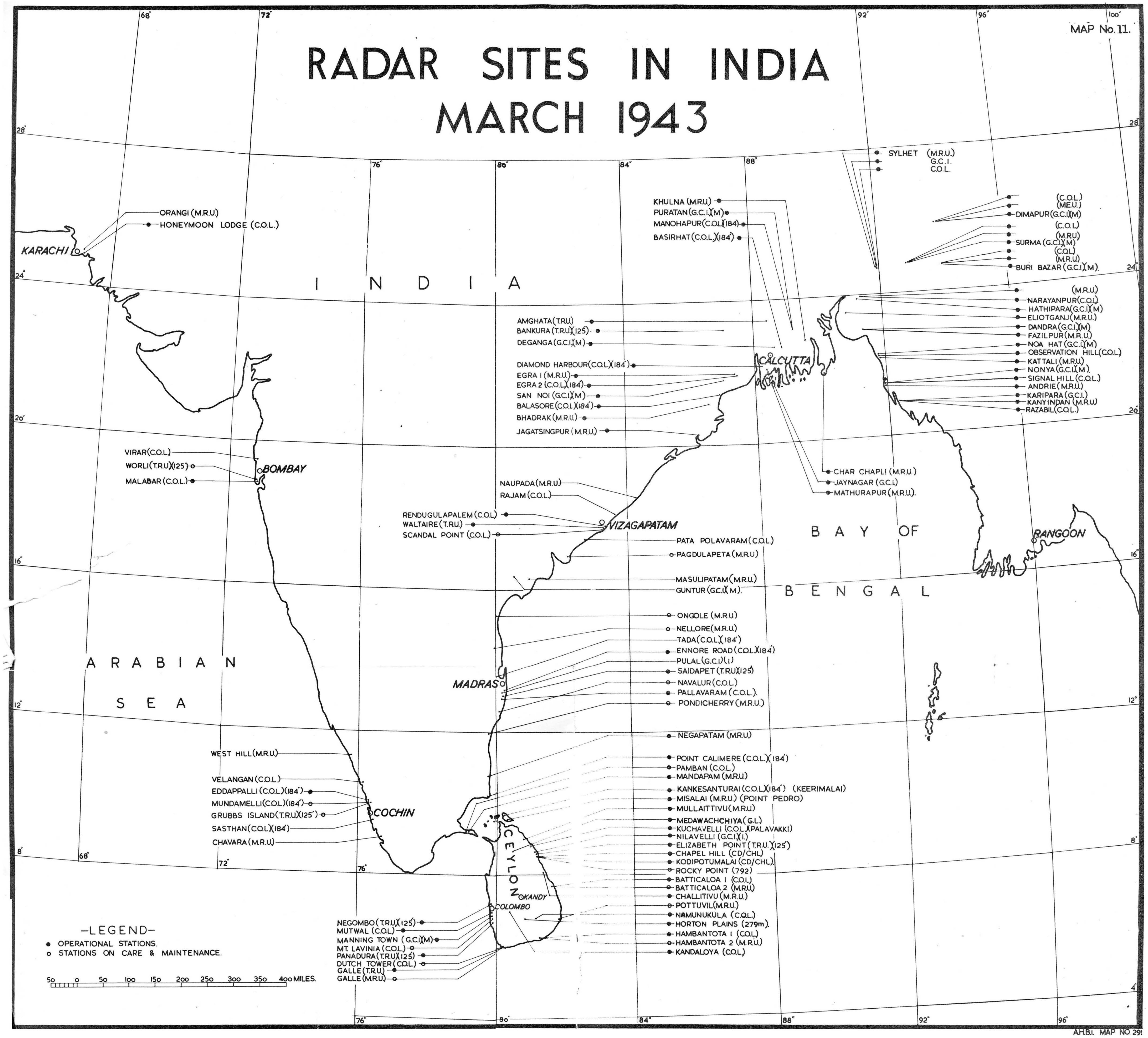
The year 1943 saw rapid progress being made with the siting and installation of ground radar equipment. In April, twelve months after radar cover was first established in India, there were fifty-two units in India and sixteen in Ceylon. Thirty-five of these provided cover for high-flying aircraft, and 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 Ceylon 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 threat

[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."

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 2½-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."

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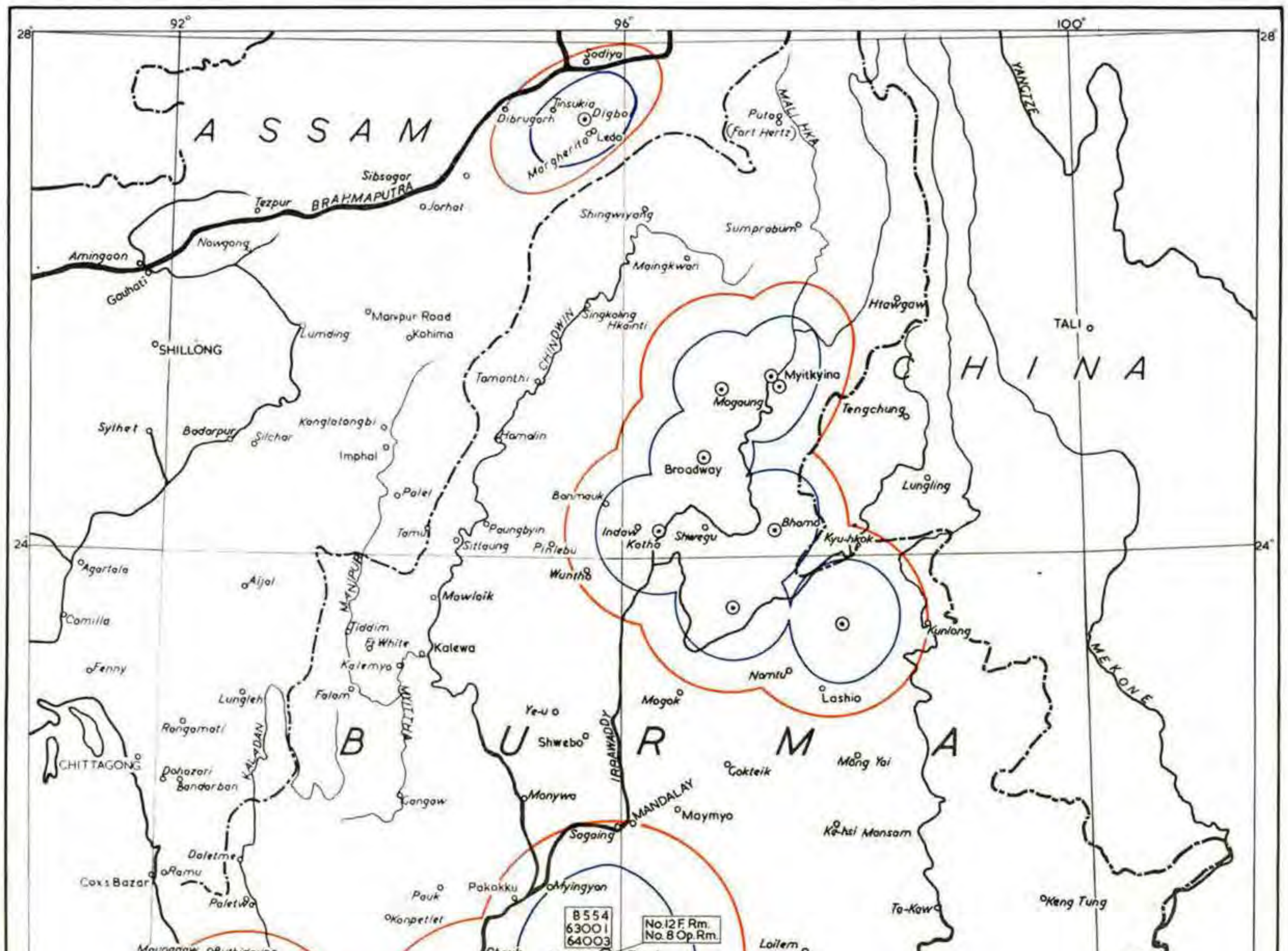


BURMA
SHOWING RADAR COVER
AS AT JUNE 1945.
LEGEND
COVER AT 10000 FEET
COVER AT 20000 FEET
OPERATIONS ROOM Op. Rm.
FILTER ROOM F. Rm.
RADAR UNITS indicated thus 8502
TOWNS of the 1st importance MANDALAY
2nd Maymyo
3rd Tiddim
ASSAM
BURMA
CHINA
SIAM
MAP No.13.
A.H.B.1 MAP NO 286

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 2½ 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.

[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 :—

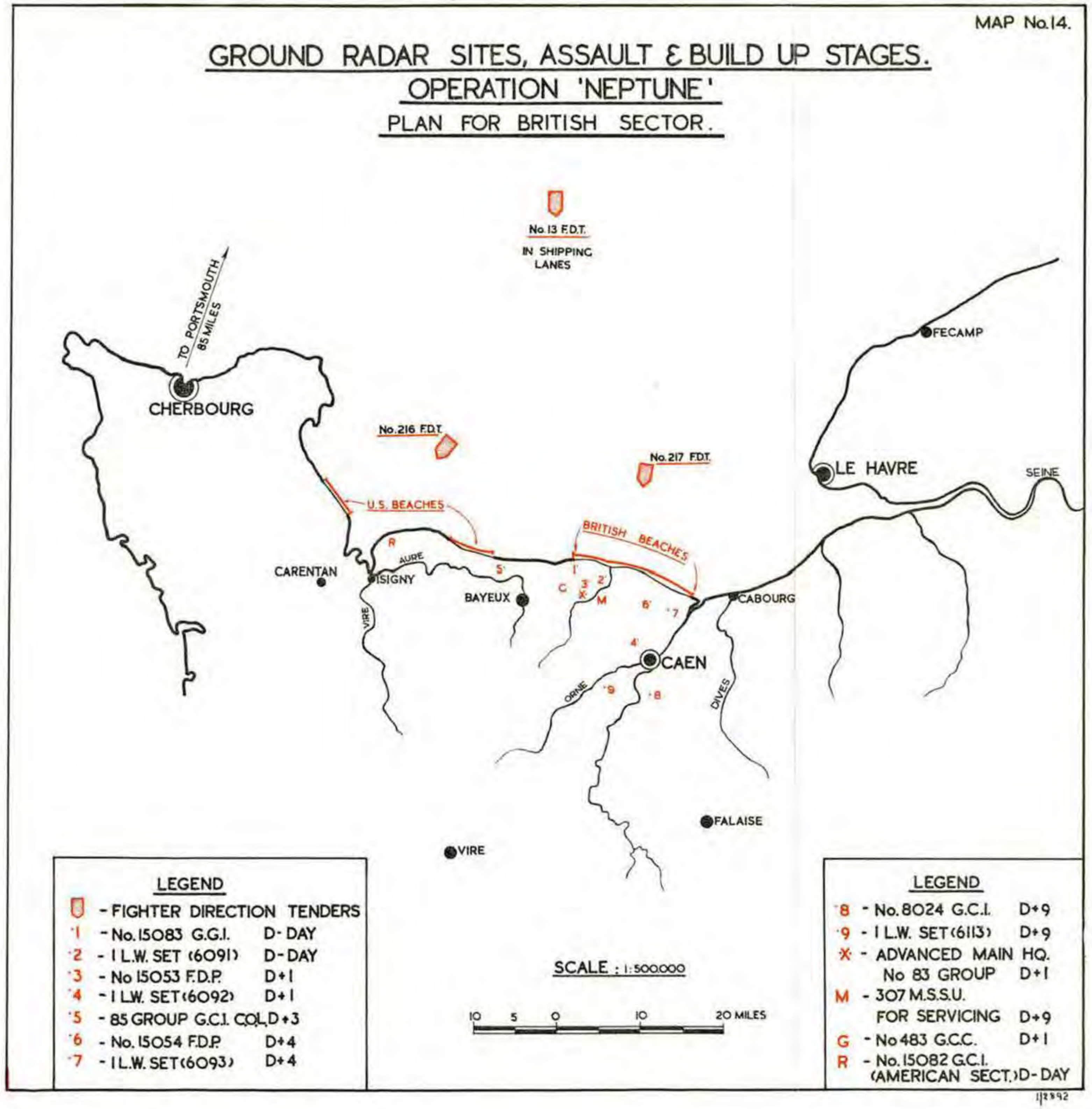
H.Q., A.E.A.F.

- 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.
No.13 F.D.T.
IN SHIPPING LANES
TO PORTSMOUTH 85 MILES
CHERBOURG
FECAMP
No.216 F.D.T.
No.217 F.D.T.
LE HAVRE
SEINE
U.S. BEACHES
BRITISH BEACHES
R
AURE
5
1
C
3
2
CARENTAN
ISIGNY
BAYEUX
M
6
7
CABOURG
VIRE
4
CAEN
ORNE
9
8
DIVES
FALAISE
VIRE
LEGEND
- FIGHTER DIRECTION TENDERS
1 - No.15083 G.C.I. D-DAY
2 - 1 L.W. SET (6091) D-DAY
3 - No 15053 F.D.P. D+1
4 - 1 L.W. SET (6092) D+1
5 - 85 GROUP G.C.I. COL. D+3
6 - No. 15054 F.D.P. D+4
7 - 1 L.W. SET (6093) D+4
SCALE : 1:500,000
10 5 0 10 20 MILES
LEGEND
8 - No. 8024 G.C.I. D+9
9 - 1 L.W. SET (6113) D+9
X - ADVANCED MAIN HQ. No 83 GROUP D+1
M - 307 M.S.S.U. FOR SERVICING D+9
G - No 483 G.C.C. D+1
R - No. 15082 G.C.I. (AMERICAN SECT.) D-DAY
1/2892

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.

[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.

[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.R.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 I.
[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 searchlight 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 I.
[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 waterproofing 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 telecommunications Mobile Signals Units, selected to be the nucleus of the Royal Air Force radar early warning and control organisation on the Continent.

[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

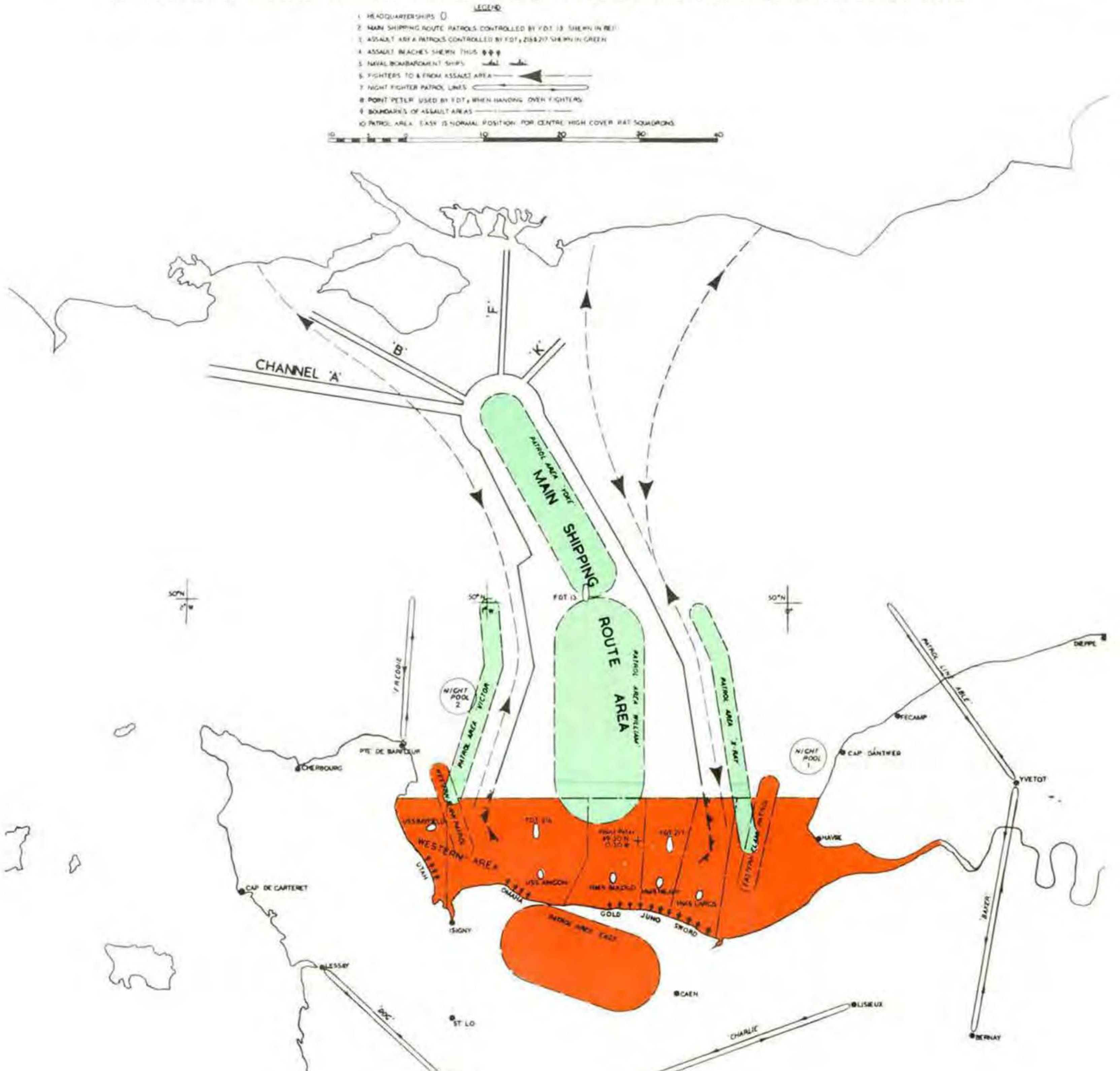
Meanwhile the advance element of No. 24 Base Defence Sector, which included No. 15083 G.C.I. and the associated telecommunications units drawn from No. 83 Group, landed without loss or casualty about 1200 hours in the British area, and the G.C.I. unit proceeded to its planned location near Meuvaines 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.

[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.

fp 424

MAP No.15

FIGHTER DIRECTION TENDER CONTROL AIRCRAFT AREAS IN ASSAULT AREA AND OVER MAIN SHIPPING ROUTE



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

[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.

[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.

[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.

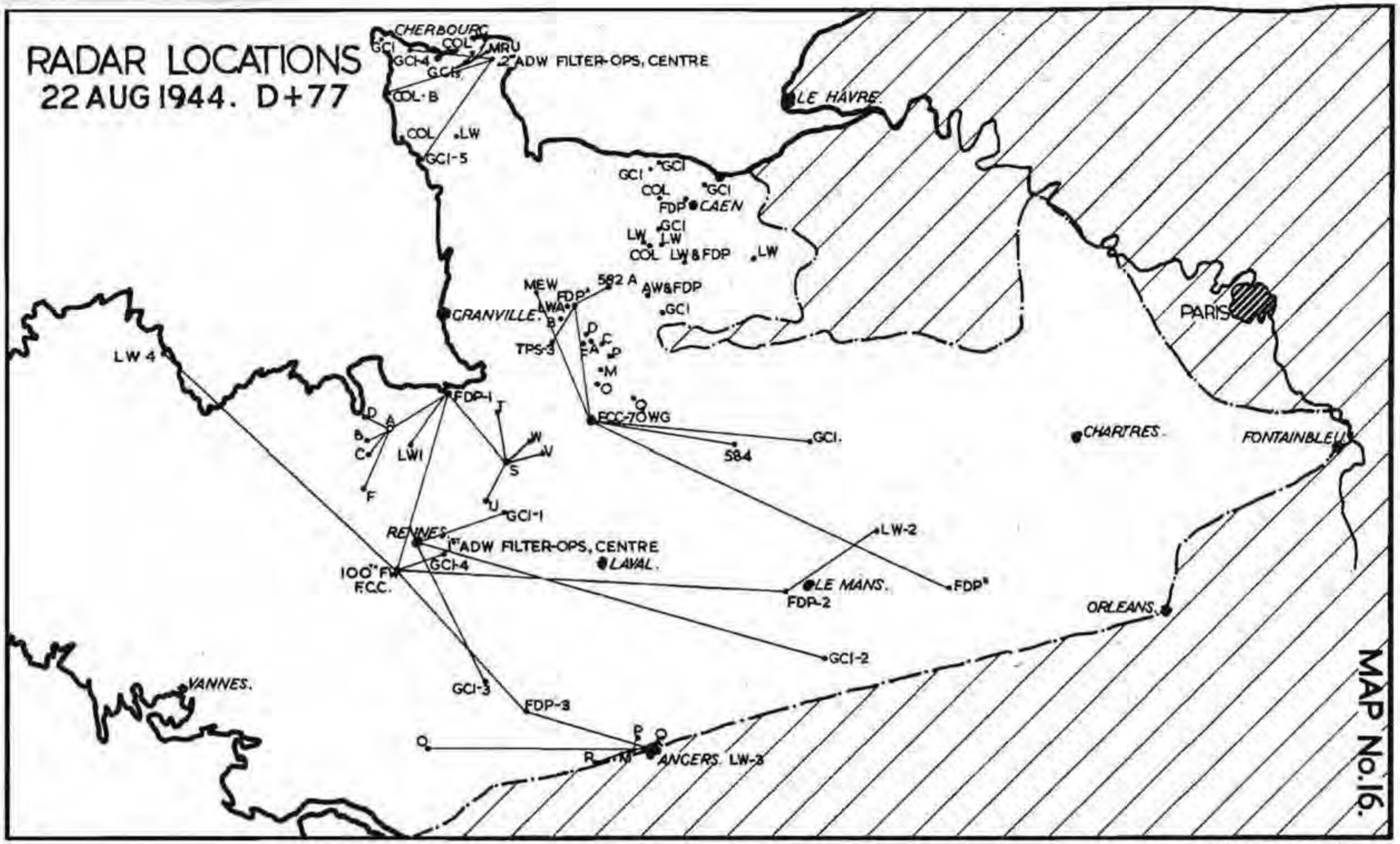
Nevertheless, the radar units maintained a standard of mobility not surpassed by any other Royal Air Force field units. The tactical Composite Groups, Nos. 83 and 84, pushed their F.D.P.s forward in an attempt to keep up with the rapid movement of the ground forces. The Group Control Centres divided 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]

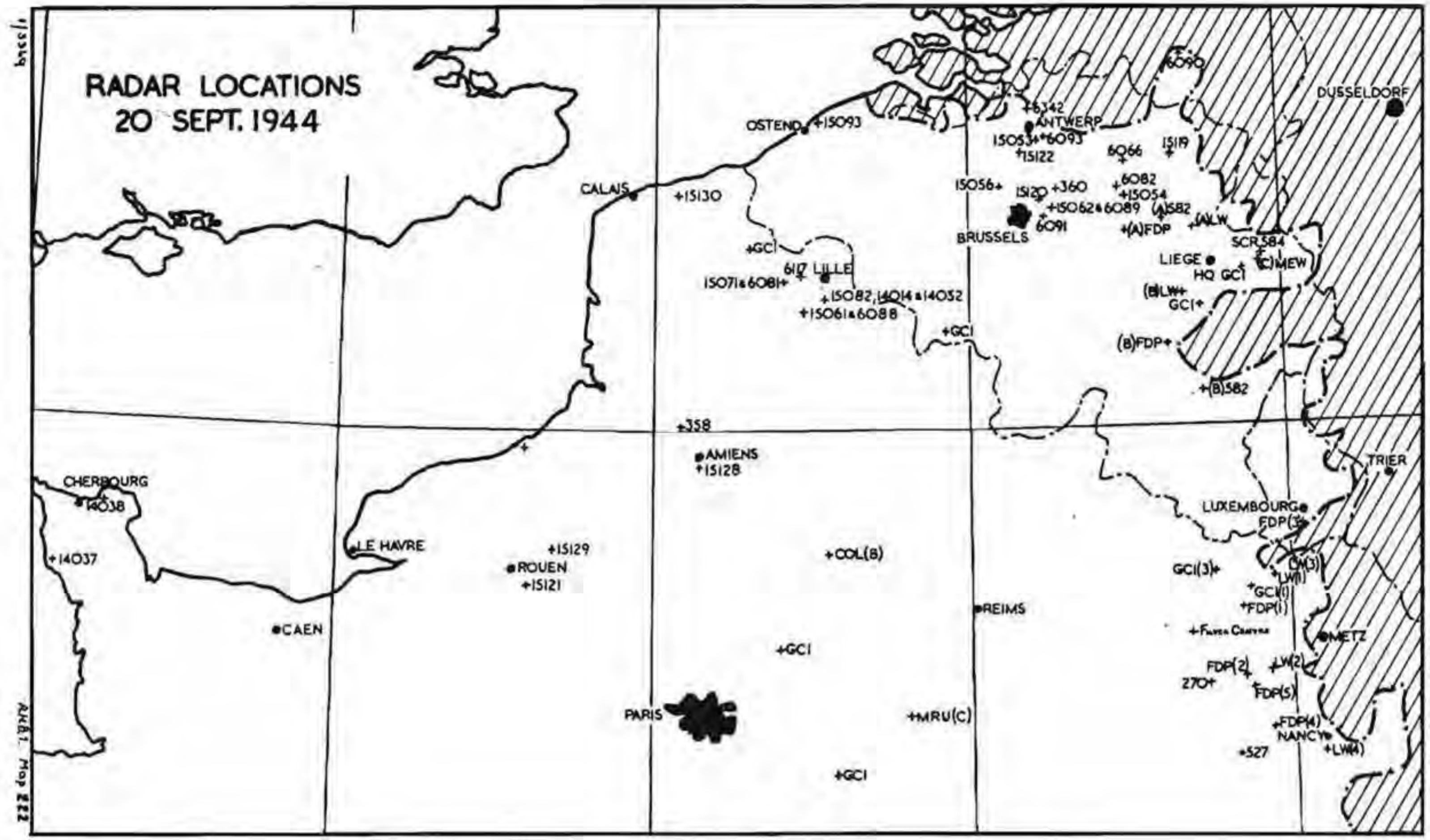
With such rapid movement and increasingly wide dispersal of the ground search radar units from the Group Control Centres, the provision of landlines for reporting purposes was impossible. Even the W/T contact between G.C.C. and the F.D.P.s was at times weak and difficult, due to interference. The inherent 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.



RADAR LOCATIONS
20 SEPT. 1944
OSTEND
+15093
CALAIS
+15130
ANTWERP
+6342
15053
+6093
+15122
6066
15119
15056+
15120
+360
+6082
+15054
+15062 & 6089
(A)582
6091
BRUSSELS
+(A)FDP
+(A)LW
6090
DUSSELDORF
SCR 584
LIEGE
HQ GCI
(C)MEW
(B)LW+
GCI+
(B)FDP+
+(B)582
+GCI
617 LILLE
15071 & 6081+
+15082, 14014 & 14032
+15061 & 6088
+GCI
+358
AMIENS
+15128
CHERBOURG
14038
+14037
LE HAVRE
+15129
ROUEN
+15121
CAEN
+COL(8)
REIMS
+GCI
PARIS
+MRU(C)
+GCI
TRIER
LUXEMBOURG
FDP(3)
LW(3)
GCI(3)+
LW(1)
GCI(1)
FDP(1)
+Filter Centre
METZ
FDP(2)
LW(2)
270+
FDP(5)
FDP(4)
NANCY
+LW(4)
+527
AHB.1 Map 222

MAP No. 17.

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.

[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.

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]

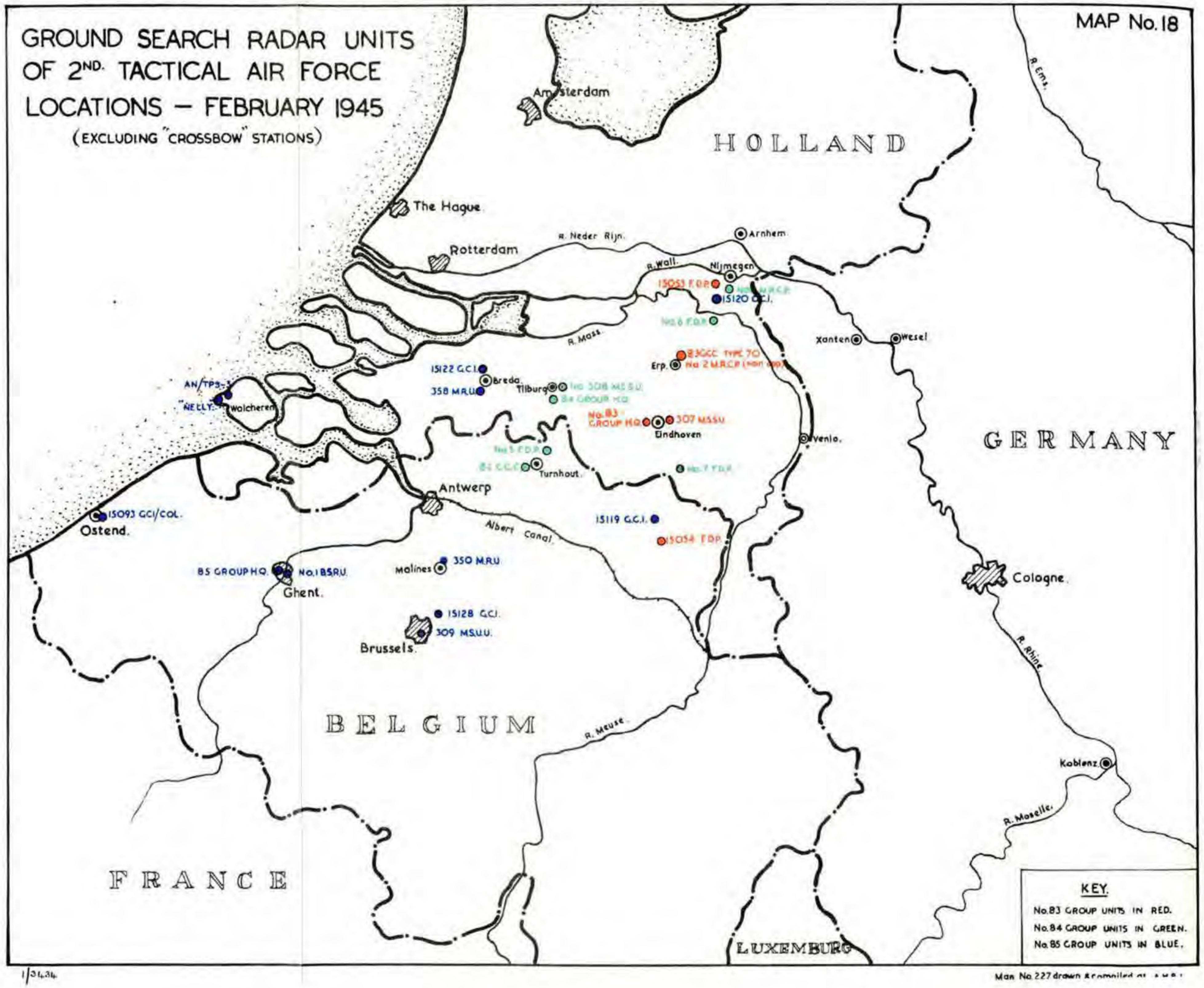
At first sight it appeared that this duplication of radar cover in the environs of Breda, Nijmegen and Helchteren signified an incorrect deployment of the radar resources of Second Tactical Air Force. However, an appreciation of the function of the three Groups concerned indicates that this deployment 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.


GROUND SEARCH RADAR UNITS
OF 2ND. TACTICAL AIR FORCE
LOCATIONS – FEBRUARY 1945
(EXCLUDING "CROSSBOW" STATIONS)
MAP No. 18
Amsterdam
HOLLAND
The Hague
Rotterdam
R. Neder Rijn.
Arnhem
R. Wall.
Nijmegen
15053 F.D.P.
15120 G.C.I.
R. Maas.
Xanten
Wesel
Erp.
No. 2 M.R.C.P.
15122 G.C.I.
Breda.
358 M.R.U.
Tilburg
AN/TPS-3
"NELLY"
Walcheren
No. 83 GROUP H.Q.
307 M.S.S.U.
Eindhoven
Venlo.
GERMANY
Turnhout.
Antwerp
15093 GCI/COL.
Ostend.
Albert Canal.
15119 G.C.I.
15054 F.D.P.
85 GROUP H.Q.
No. 1 85 R.U.
Ghent.
Malines
350 M.R.U.
Cologne.
15128 G.C.I.
309 M.S.U.U.
Brussels.
R. Rhine.
BELGIUM
R. Meuse.
Koblenz
R. Moselle.
FRANCE
KEY.
No. 83 GROUP UNITS IN RED.
No. 84 GROUP UNITS IN GREEN.
No. 85 GROUP UNITS IN BLUE.
LUXEMBURG
R. Ems.

fp 449

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

[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]

[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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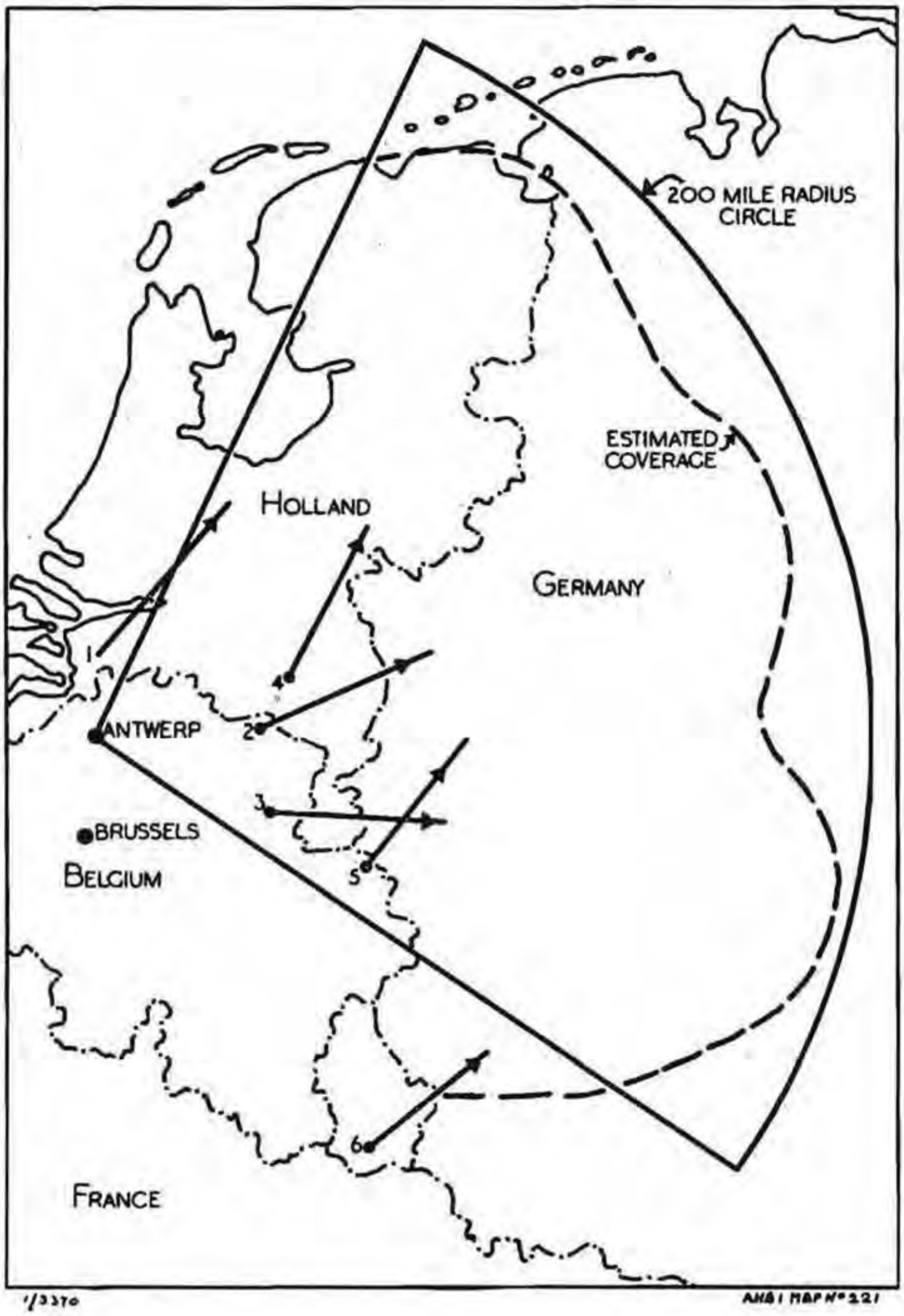
[1] No. 6 F.D.P., O.R.B.
[2] Details of the organisation in the United Kingdom are given in Chapter 27 of this volume.
[3] "Crossbow" was the codeword for all V-weapon operations—against rockets and flying bombs.
[4] Air Ministry File C.M.S. 636, Encl. 27A.
[5] *Ibid.*, Encl. 106A.
[6] *Ibid.*, Encl. 89A.

MAP No. 19.

A.M.E.S. TYPE 9. LOCATIONS & COVERAGE FOR CONTI-
-NENTAL 'CROSSBOW' INTELLIGENCE ORGANISATION



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AHB1 MAP No 221

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

[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 February 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

[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

[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]

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[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 Tréport (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

[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

[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.

[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 3½ : 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 (N.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 111. 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-outs 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 (17½ tons), Gravesend (12½ tons) and Southend (11½ 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.

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[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.

[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 rôle 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

[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

[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 (Milton, 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 ($1\frac{1}{2}$ 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. 7477, 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

[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.

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]

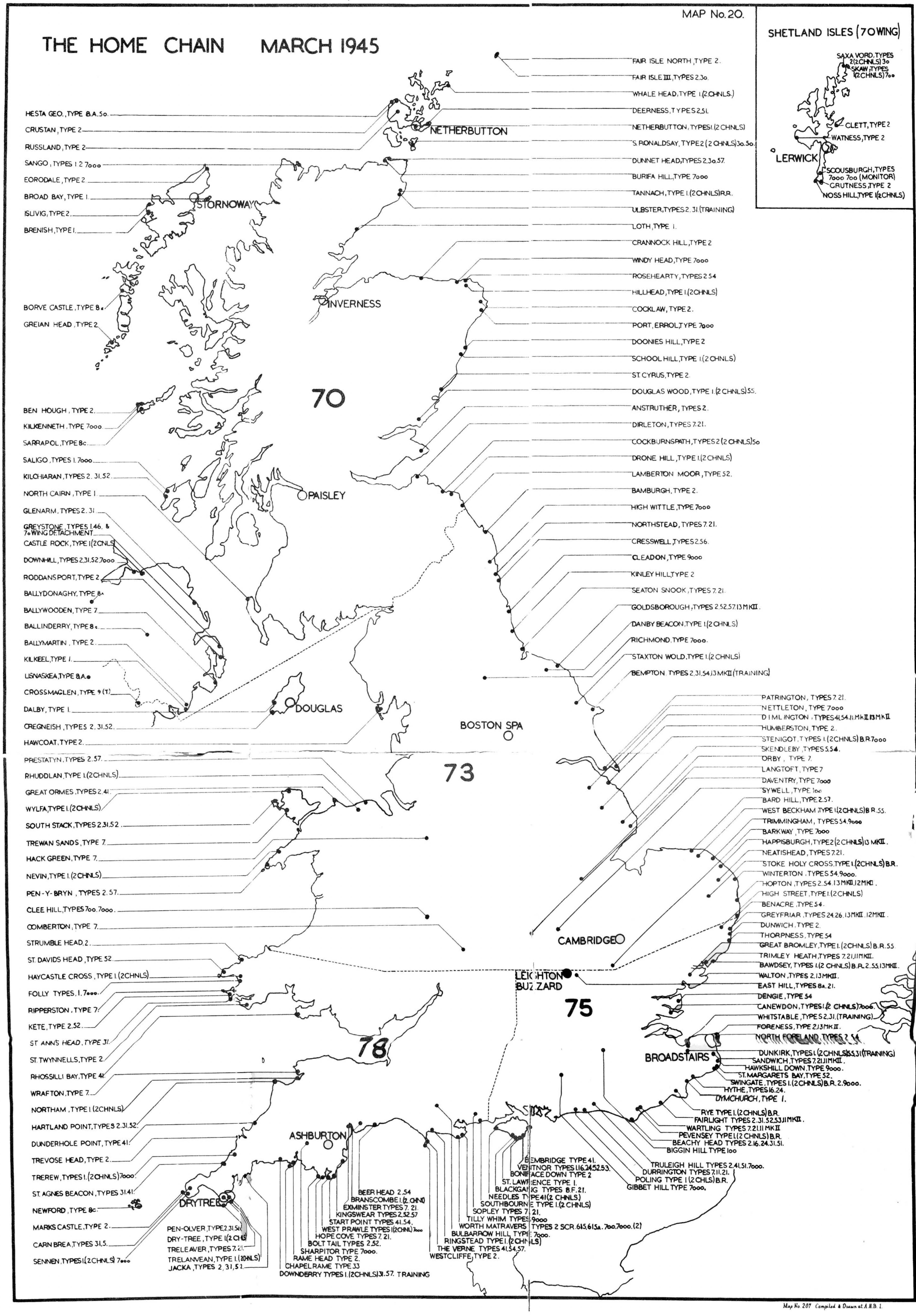
Closing Down of Surface-watching Stations

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.



Map No. 207 Compiled & Drawn at A.H.B. 1.

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.

* * *

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

[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
12 ~~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.

APPENDIX No. 2

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 co-ordination 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	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.

Barrapoli .. .. 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.

APPENDIX No. 12

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.

APPENDIX No. 15

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.	
			259	Bir El Abd ..	Converted to T.R.U.
205	Aboukir ..	Converted to T.R.U.	260	Sidi Bishr.	
219	Port Said.		261	Tel El Kebir.	
221	Gebel Qatrani	Will be replaced by 403.	262	Wadi Gindali.	
251	Wadi Natrun	Will be replaced by 404.			
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.	†522	Wadi Hagg.	
			523	Suez	C.D./C.H.L. equipment.
508	Aboukir ..	Will be replaced by *534 equipment.	†526	El Imayid.	
			533	Kantara.	
509	Geneifa ..	Will be replaced by *541 equipment.	535	Damietta.	
†510	Edge of Western Desert.		581	Qait Bai ..	C.D./C.H.L. equipment.
†515	Alam Shaltut.				
†516	Luxor.				
*519	Port Said ..	Will be replaced by *531 complete.			

Levant

503	Haifa ..	Will be replaced by *540 equipment.		Beirut.	
				Tripoli.	

Cyprus

577	Larnaca ..	C.D./C.H.L. equipment.	579	Kyrenia ..	C.D./C.H.L. equipment.
578	Paphos ..	C.D./C.H.L. equipment.			

Malta

501	Ta Dilch.	504	Dingli.
502	Maddalena.	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.		843	Dekheila.
831	Aboukir.		845	El Rus.
832	Fayid.		846	Faiyum Road.
833	Acre.. ..	From Sidi Bu Amed.		
842	Damietta.			

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.

[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.

APPENDIX No. 19

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, Kingswear — later moved to 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).	The Needles.
Dunnet Head (Navy).	Westcliff.
Rosehearty.	Beer Head.
Anstruther.	Rame Head.
Cleadon.	The Jacka.
Bempton.	Pen Olver.
Skendleby.	Hartland Point.
Bard Hill.	S. Stack.
Happisburgh 11.	Prestatyn.
Hopton.	Cregneish.
Bawdsey.	Cresswell.
Dunwich.	Easington (part-time G.C.I.).
N. Foreland.	Kingswear (part-time G.C.I.).
Truleigh Hill.	

51 dual-role stations (air reporting and surface watching) :—

Saxa Vord (Navy).	Cromarty.	Walton.
Clett.	Crannoch Hill.	Whitstable.
Watsness.	Westburn.	Bembridge.
Grutness (Navy).	Doonies Hill.	Worth Matravers.
Fair Isle 1 (Navy).	St. Cyrus.	Bolt Tail.
Fair Isle 11 (Navy).	Cockburnspath.	Marks Castle.
Crustan.	Bamburgh.	Trevose Head.
Deerness.	Kinley Hill.	Oxwich Head.
Ulbster.	Gt. Orme's Head.	Ballymartin.
Navidale.	Formby.	Roddan's Port.
St. Twynells.	Hawcoat.	Blackhead.
Strumble Head.	St. Bees.	Glenarm.
Pen-y-Bryn.	Kilchiarin.	Ben Hough.
Downhill.	Kendrom.	Rodel Park.
Greian Head.	Stoer.	Eorodale.
Islivig.	The Law.	Cocklaw (part-time G.C.I.).
Sango (Smoo).	Humberston.	Goldsborough (part-time G.C.I.).

13 engaged on surface watching only :—

Craster.	Ravenscar.
Shipsea.	Donna Nook.
Seaford.	Polruan.
Oldcastle Head.	Tor Point.
Dunderhole Point.	L. Sharpness Point.
Minehead.	Swansea.
Rhossilli Bay.	

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	Phillipèville.
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.).

APPENDIX No. 27

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; GI2345—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.

13 August 1943.

APPENDIX No. 31

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. 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.	Plotting to No. 1 M.O.R.U. and No. 1 F.F.C.U. (Desert Air Force).

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.

APPENDIX No. 34

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.
	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 Sup-	256	M.R.U.	St. Felice Circeo.
port Command, U.S.A.A.F.).	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 Sup-	392	M.R.U.	Ajaccio.
port Command, U.S.A.A.F.).	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 Sup-	294	M.R.U.	C. Mannu.
port Command, U.S.A.A.F.).	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.

APPENDIX No. 35—*continued*

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			

APPENDIX No. 35—*continued*

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 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.

APPENDIX No. 36

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.

APPENDIX No. 40

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.	*No. 24 Base.*	*No. 25 Base.*
Defence Sector.	*Defence Sector.*	*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.

APPENDIX No. 43

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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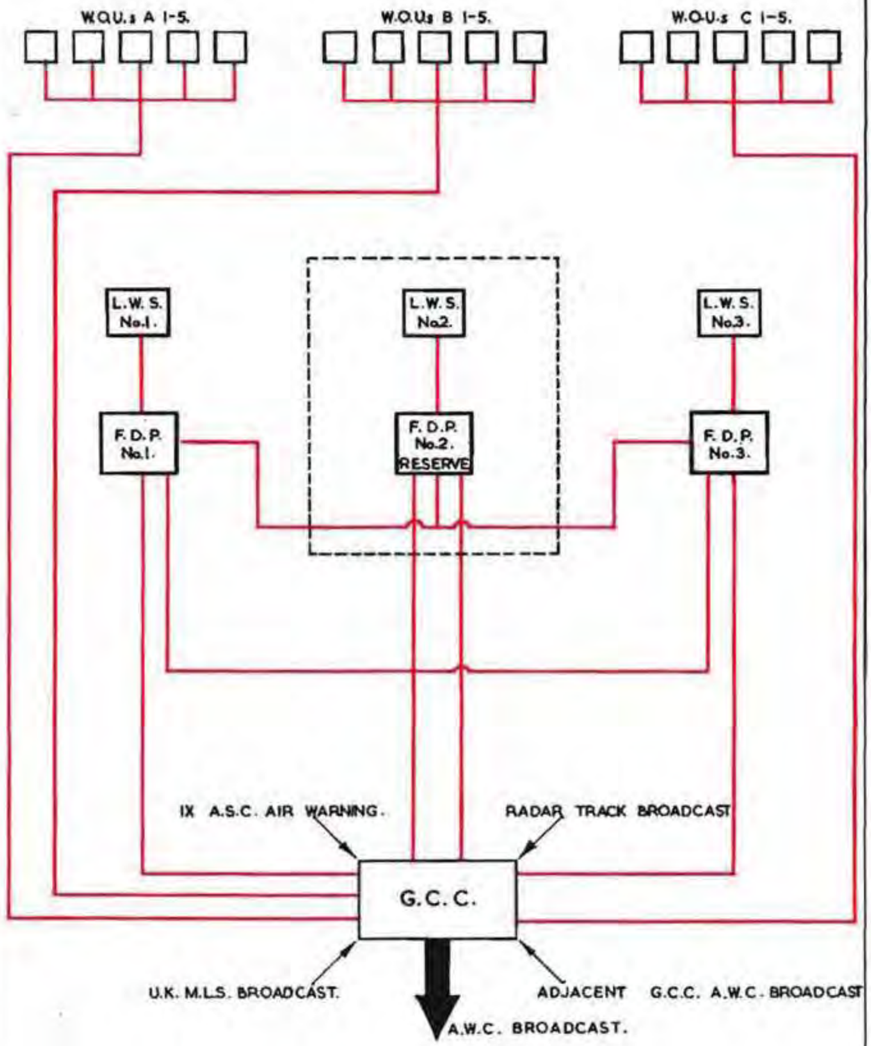
[1] A.H.B./IIM/683/1A, No. 83 Group R.A.F. "Neptune" Operations Plan ; 85 ADV/TS. 2382/Air Plans. 13 May 1944. Para. 92.

[2] *Ibid.*, Appendix "F."

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.

APPENDIX No. 45

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 :—

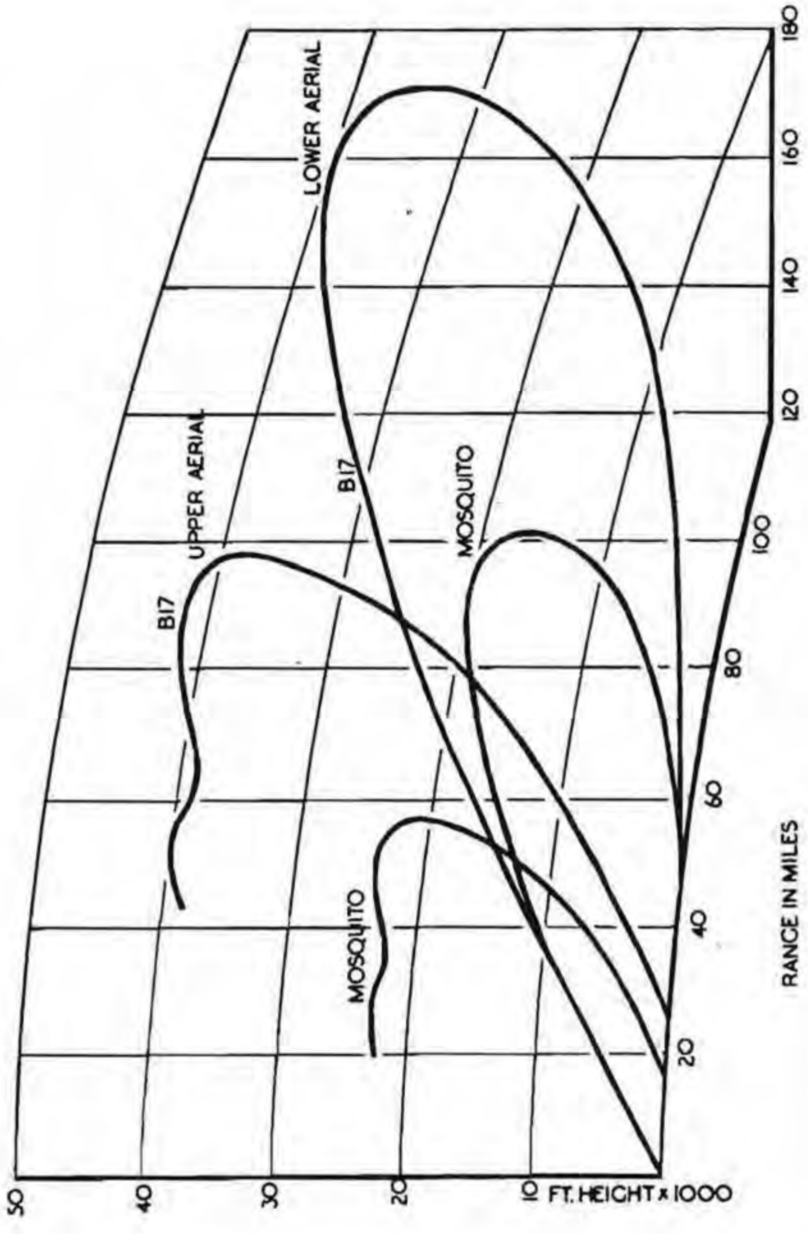
	Night Fighters Controlled.	*Number of Contacts.*	*Visuals on Friendly Aircraft.*	*Enemy Aircraft Destroyed.*
(*a*) *F.D.T.* 13.				
(i) 6 June to 12 June (in shipping lane) ..	18	13	10	(one fighter's guns jammed)
(ii) 15 June to 17 June (off Cherbourg. Fighters handed over from G.C.I. ashore on British 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	24 (and two probables)
			(70 per cent. of contacts)	(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.



A.H.B.I. DIAG. No. 41.

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.

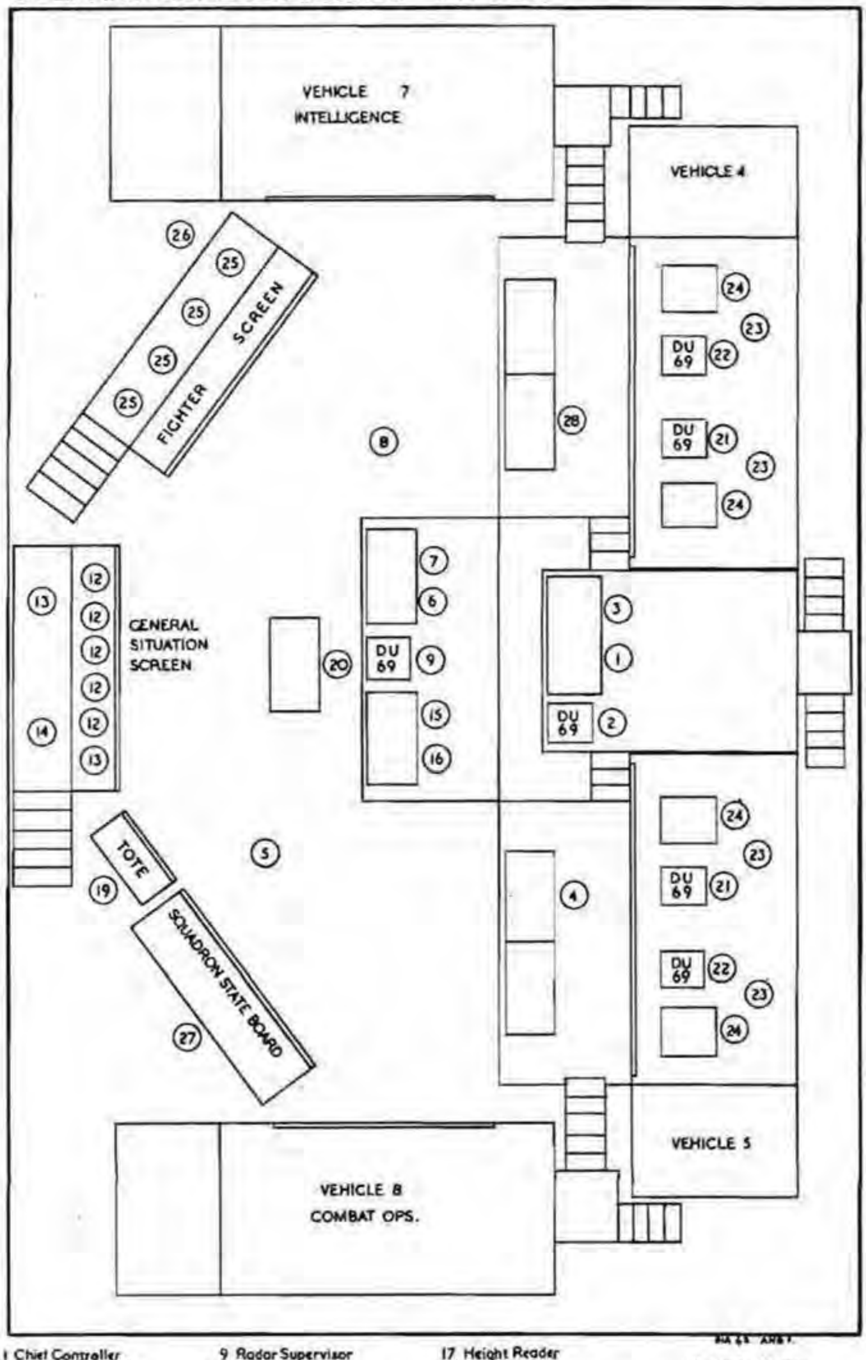
Vehicle 17.—Stores and Technical Office vehicle.

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. Frequency 176 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.I 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 2775 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.

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
Greiarf 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 8c	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 8c
Ballydonaghy ..	Type 8a
Crossmaglen ..	Type 9 (T)
Lisnaskea	Type 8a

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).	Fairlight T.52.	Prestatyn 57.
Beer Head 54.*	Goldsborough 52.	Rosehearty 54.
Bempton 54.	Hartland Point 52.	Skendleby 54.
Benacre 54.*	Hopton 54.	St. Margaret's Bay 52.
Carn Brea 52.	Jacka 52.	Trimingham 54.
Cresswell 56.	Kete 52.	Truleigh Hill 51.
Deerness 51.	Kingswear 52.	Ventnor 52.
Dimlington Highland 54.	Lamberton Moor 52.	The Verne 54.
Douglas Wood 55.	North Foreland 54.	Winterton 54.*
Downderry 57.*	Pen Olver 56.	Whitstable 57.
Dunnet Head 57. (Tech. Training)	Pen Ronaldsay 50.	West Beckham 55.
Fair Isle III 50.	Pen-y-Bryn 57 (Tech. Training) South.	

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 dipoles 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 without 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.

APPENDIX No. 57

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.