FIGHTER-DIRECTION MATERIEL AND TECHNIQUE, 1939-45

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INTRODUCTION

The concept of the control and direction of Naval fighter aircraft from their parent carrier had not been conceived prior to 1935. Rear Admiral Torlesse, then a member of the Naval Air Division, has attributed the lack of a suitable ship-to-air R/T link as a primary reason for the deficiency in the immediate pre-war years. Experience with ship borne WA radar early in the war was soon to lead to the provision of rudimentary FD facilities in carriers.

Pre-war responsibility for both maritime communications and radar was that of the Signal Division I the Admiralty. The fact that no adequate provision had been made for ship-to-air R/T communications reflected a general lack of interest in Naval fighter operations, which extended to a lack of liaison with Fighter Command of the RAF. In fairness to the Admiralty departments concerned it should, however, be pointed out that the Fleet possessed greater concentration of AA guns than could be found at most shore targets, as a result of recent modernisations. The alternative techniques available to Naval fighter aircraft in the immediate pre-war period were as follows:

- To fly a ‘square search’ centred on the carrier, accepting that there was a 50% probability of the fighters being on the wrong side of the Fleet when the Bombers appeared;

- To intercept from overhead, operating as a combat air patrol (CAP) – but probably resulting in being too late to effect an interception, quite apart from interfering with the AA gunfire;

- To fly off from the parent carrier in the hope of intercepting a few straggler enemy aircraft on their return to base.

From such inauspicious beginnings the growth of the Fighter Direction Branch from zero in 1940 to 800-odd fully qualified specialist officers using highly sophisticated equipment in 1945 is most remarkable.

THE BIRTH OF FIGHTER DIRECTION IN THE ROYAL NAVY

The origins and subsequent development of what became known as the Naval Fighter Direction Branch commenced during the Norwegian campaign in 1940. Credit for the invention of maritime fighter direction belongs chiefly to the then Lieutenant Commander Charles Coke, Air Signals Officer in the carrier HMS ARK ROYAL. This ship was never fitted with radar, and reliance had to be placed on reports of enemy air activity from the accompanying cruisers HMS SHEFFIELD or HMS CURLEW, equipped with Type 79 air warning radar. Coke possessed virtually no suitable facilities in ARK ROYAL. He took possession of a corner of the carrier’s Bridge Wireless Office, with a telegraphist beside him to take down incoming reports. Plots were made on a ‘Bigsworth Board’ – a portable device used by air observers. This was fitted with a pantograph-plotting arm, at the end of which was

a small mechanical device to solve the wind triangle. Converting course and air speed to track and ground speed or vice versa. Coke himself, as an expert in Morse Code, passed all directions to the carrier's aircraft by W/T. In the early days he passed the enemy's position, course and speed to own aircraft and left the observer to determine the intercept course to attack the enemy (the 'informative method'). However Coke soon established that he could track friendly fighters as well as enemy aircraft, primarily by dead-reckoning, with a periodic radar check, and he then took the decision to order the course, speed and occasionally height at which the fighters would fly. This became known as the 'directive method. However the overall process took some four minutes and, as a result, the success rate was varied.

Sometimes, after HMS ARK ROYAL and HMS SHEFFIELD had joined Force H at Gibraltar, HMS SHEFFIELD controlled fighters direct from her Type 79 office by the 'informative method', to cut down the time-lag. This worked quite well, as long as the fighters knew the cruiser's position. In the Western Mediterranean, even if the shadowing enemy aircraft were shot down, the force was still not immune to attack, since ARK ROYAL was sometimes covering Malta convoys, whose course was very predictable. At first Coke had only Skua fighter/dive bombers to direct, which were quite effective in the latter role, but 20 kts slower than a Gladiator. However, after a short UK refit late in 1940 half of these were replaced by Fulmars.

Whilst some of the remarkable success of HMS ILLUSTRIOUS in the Eastern Mediterranean was due to being equipped only with Fulmar fighters, it was primarily due to having her own radar. It must be remembered, however, that it was achieved against the Regia Aeronautica. Enemy shadowers that broke cover from time to time above the horizon or below the clouds were usually shot down. When they were in the Eastern Mediterranean attacks seldom materialised since the bombers relied on homing signals in attack. The attacks themselves could normally be broken up by fighters because the bombers tended to fly straight and level, at a predictable height.

Fighter direction was achieved by the most primitive means. There were no formally trained officers or men. There was no fighter direction radar and indeed, due to the state of the art, this was to be the case until after the war was over. Except for a single American Type SM-1 radar in the Pacific in 1945, the war was fought with radars originally developed for air and surface warning only. During the early stages of World War 2 the only radar available was Type 79, which was infinitely better than nothing, and surprisingly reliable. However its 70º beam width and lack of low cover were severe handicaps. In the Fighter Direction Office (FDO)– usually any small space in the carrier's 'island' within which a toehold could be secured – there were no radar displays. Reports were passed from the FDO to the small manual plot by telephone or voice pipe. Inter-ship radar reporting was in its infancy and filtering of radar detections was unknown. This was especially significant in the early days when a carrier was equipped with only a single radar. Inevitably, all round warning was lost when this radar was used to 'hold' a target in order to effect an interception.

Ship-to-air R/T communication was extremely unreliable and limited in range. Nevertheless its use was unavoidable when controlling single seat fighters (gladiators). Fighters in the carriers were greatly outnumbered by other aircraft. As regards performance, the Fulmar was 40 kts faster than a Skua, had eight 0.303 calibre machine gums and was an excellent deck landing aircraft – but it still could not catch a Ju 88. In the light of all of these limitations, interception technique was ambitious; the aim was to turn the fighters on to a converging course with the

bombers, up-sun, slightly above and ahead of them, thus giving the fighter leader maximum choice in planning his attack. Very low-level attacks usually only allowed time for head on interception.

Before the introduction of radar, the radio policy to be adopted was normally to maintain radio silence to avoid giving away the presence of a force at sea. Early experience of radar seemed to reinforce the need for silence. In the Summer Exercises of 1939, HMS RODNEY's Type 79 receiver had been able to detect HMS SHEFFIELD's Type 79 transmissions at a range of 100 miles, with a bearing accuracy of 2º. The risk of providing intelligence to the enemy by switching on the radar had made a deep impression, at the time when there was a reasonable chance of escaping detection from the air. When HMS ILLUSTRIOUS first operated in the Mediterranean, she was allowed one radar sweep per hour until a target was picked up, and could not break silence to her fighters until the raid was within 20 miles. Apart from the odds against switching on at the right time, the radar never warmed up sufficiently, and so did not reach its full performance. This in turn degraded height estimation. These restrictions were gradually relaxed and refined to take account of the tactical situation, and the varying risk of detection at different frequencies. The resulting compromise was the 'radio policy' in force. Initially there was no knowledge of the occurrence of anomalous radar propagation that could occur under certain meteorological conditions. This would have exacerbated the situation!

These weaknesses were not primarily responsible for the defeat of the Mediterranean Fleet by the Luftwaffe in 1941. This was due to the sheer weight of numbers of highly trained and skilful attackers. The weaknesses would have been far more significant if the Fleet had possessed more and faster fighters, because problems of saturation, of tracking raids that split, dog-legged and changed height, and of homing the fighters would have been more accurate. With three of our four radar fitter armoured carriers damaged at that time and the fourth needed by the Home Fleet, there were no more major head-on confrontations with the Luftwaffe until August 1942. Thus, the development of doctrine and materiel with which to confront a powerful shore-based air force remained untested.

FORMATION OF THE FIGHTER DIRECTION TRAINING SCHOOL

Coke had meanwhile been relieved in HMS ARK ROYAL, in the normal course of events, and at the beginning of May 1941 he called on the Naval Air Division of the Admiralty to discuss his next appointment. While talking, other people in the room started discussing fighter direction, and he joined in to plead for proper training. There was the usual opposition. However, before long a meeting was called to consider the issue, and he was given carte blanche to start a school in the control tower at Yeovilton. At the meeting David Pollock was asked by Rear Admiral Boyd to write the names of five RNVR officers to be the FDOs of the carriers. Keeping HMS ILLUSTRIOUS for himself, he chose Jason Borthwick (HMS VICTORIOUS), Ralph Swann (HMS FORMIDABLE), Stewart Morris (HMS INDOMITABLE) and George Tozer (HMS EAGLE); Peter Scott escaped because his Captain (D) required him for ship camouflage work. (Though up at Cambridge at roughly the same time, they were chosen for their prowess as international dinghy helmsmen, which proved their skill at the instantaneous solution of vector triangles!)

The vicissitudes experienced by Coke are recorded in detail in Schofield, Navigation and Direction. Very briefly, he borrowed a GCI radar from the RAF and arranged for its transport

and subsequent installation at Yeovilton. Unfortunately, too few aircraft were available to cram sufficient interception exercises into a three-week course, half of which was taken up with lectures. He therefore adapted an RAF system whereby mobile ice-cream tricycles acted as fighter and bomber. These were fitted with a compass and R/T, and screened to reduce visibility to a couple of yards. The 'aircraft' were pedalled in time with a metronome, triangulated, and reported to a dummy Fighter Direction Office. The system continued in use until replaced by one using controllable synthetic radar echoes, years after the war had ended. The first course began in July 1941 and the second in late August. Each consisted of six RNVR officers together with two from the United States Navy. The latter laid the foundations of the close and happy cooperation that has lasted ever since, and that stood the US Navy in good stead in the great sea-air battles in the Pacific in 1942. The initial courses were a great success, but the third brought problems. Selection had been largely delegated to HMS KING ALFRED, the shore establishment at Hove that turned Ordinary Seamen (Hostilities Only) into Sub Lieutenants Sp) RNVR. Clearly the importance of fighter direction had not been realised. A meeting was therefore called, attended by the Fifth Sea Lord (responsible for Naval Aviation), the Naval Assistant (responsible for officer personnel) and certain Directors of Divisions. Coke was awarded first pick from HMS King Alfred leavers, and there were no further problems. CAFO 1770/41 was issued in September 1941 describing the 'informative method' of direction in detail. This included the W./T and (above all) R/T codes agreed with the RAF, and a brief mention of the 'direction method', only to be used by qualified officers in suitable fitted ships. This had been drafted by Coke. The code was first used by VHF between east-coast destroyers and Fighter Command, but the Middle East Air Force soon followed suit.

At the end of the year Coke was relieved by Lieutenant Commander Archie Fleming RN, and left to found an Air Signal School at Arbroath. In July 1943 the Fighter Direction School moved across the airfield to far more spacious premises in Speckington Manor. It was now commanded by Commander Philip Yorke, with Jason Borthwick as Chief Instructor.

It finally moved late in 1945 to a specially built complex at Kete in Pembrokeshire, which became HMS Harrier, having sponsored many smaller schools at which ships' teams could be exercised. By this time the course lasted four months, followed by six months as understudy before any officer counted as fully qualified.

FIGHTER DIRECTION DEVELOPMENTS AT SEA

In the second half of 1942, working in the Home Fleet in the Navy's only operational radar fitted Fleet carrier, Jason Borthwick in HMS VICTORIOUS was mastering the art of intercepting long-range Focke-Wulf (FW 200) aircraft. These attacked convoys far out in the Atlantic, in conditions of cloud and visibility very different from those prevailing in the Mediterranean. He operated in a corner of the plotting office with a home made plotting board, portable R/T set and an array of voice pipes. He was assisted by one untrained plotter. At first he had an uphill task establishing his position in a big ship's hierarchy. (Only a little later, the senior Direction Officer in a Fleet carrier was automatically promoted Acting Lieutenant Commander). Continuing success brought status. A year later he had his own Fighter Direction Office, an FDO as Filter Officer with two plotters, two Intercept Officers with and intercept plot each, and a third intercept for Borthwick to use in emergency. He sat at a dais with room for the Fleet Direction Officer beside him.

When the Royal Navy's three damaged Fleet carriers completed their repairs in Norfolk, USA, they were not sent to the Mediterranean because Japan's entry into the war had moved the focus of naval warfare to the East. A somewhat motley Eastern Fleet was formed to face Admiral Nagumo's advance into the Indian Ocean. The main fleets never met, but the Japanese sank the old carrier HMS Hermes, the cruisers HMS CORNWALL and HMS DORSETSHIRE, and 80 000 tons of shipping before their recall for urgent business nearer home. The British carriers, which remained in the Indian Ocean until it was certain that the Japanese threat had receded, had no opportunity to test their efficiency against enemy air opposition in the first half of 1942. However they were able to exercise together for the first time, evolving new techniques for a multi-carrier force operating a substantial number of fighters.

Experience in the Fleet carriers confirmed Jason Borthwick's ideas on the need to separate the Main Air Display Plot (MADP), on which the air picture was built up, from the Intercept Plot(s), at which the fighters were controlled. It was also necessary to have an inter-FDO communications channel independent of a W/T radar reporting net. This used portable R/T sets to enable the deployment of fighters against raids to be coordinated. Both plots were still Perspex-topped paper sheets marked with a 'spider's web' graticule and fixed to a plywood board. The MADP was normally sloped at 45º and was 4 ft in diameter. The radar and W/T plotters stood on either side, and the Filter Officer sat between them. A telegraphist has a small desk beside the W/T plotter. The intercept plot was smaller and horizontal; the intercept plotter received 'bogey' reports, either direct from the radar or from the MADP when, for example, the raid was in a radar minimum in the radar's vertical polar diagram, but was being reported by another ship. The Intercept Officer kept a DR track of his fighters with his Craig computer (a plotting device similar to the one on a Bigsworth board). A carrier committed to an interception would normally 'hold' the target with her WA radar. This might give an occasional check on the fighters' position, but would terminate an all round search. For this, reliance had to be placed on the off-duty carrier (if any) or on the battleships and cruisers, which at this time had only the crudest of homemade air plots and no trained officers or ratings.

HMS VICTORIOUS was then chosen as Flagship for Operation Pedestal in August 1942, being a 'no-holds-barred' attempt to relieve the island of Malta. Apart from her experience against FW 200 long-range reconnaissance aircraft in the Atlantic, she had previously covered Malta convoys as part of Force H, based at Gibraltar. At that time, HMS VICTORIOUS had the best FD Office in the Fleet. The operation led to the most intense sea-air battle against the Luftwaffe yet seen, and the first full-scale test of the recent improvements in the Royal Navy's fighter direction. There was nothing else like it until the British Pacific fleet helped to cover the Okinawa assault in 1945. As regards fighter direction, in the carriers it was on the whole successful, despite the hit on HMS VICTORIOUS and serious damage to HMS INDOMITABLE, but the system was dangerously near saturation point. On the other hand the quite unacceptable loss of merchant ships after the carriers had been detached, proved how essential it was for all cruisers and above to be capable of fighter direction. This would enable them to control shore-based fighters, but when carriers were present it would help them to share some of the load. They would rarely be ordered to direct fighters from a carrier in company, because of the personal relationship between pilot and FDO was so important. However they would act as all round radar guard ships when the carrier radar was 'holding' a raid, and could help with height estimation.

The situation further improved when Admiral Fraser succeeded Admiral Tovey as C-in-C Home Fleet. He regarded HMS VICTORIOUS' Fighter Direction Office as a showpiece for VIP visitors. On one occasion the Prime Minister climbed into Borthwick's high chair at the dais, which had been unscrewed from the desk for maintenance. The chair tilted forward, and only a quick grab of each arm by C-in-C and the FDO saved Churchill from a dive into the MADP. These VIP visits helped Borthwick to obtain hardware and, above all, good officers.

Despite the priority rightly given to the Battle of the Atlantic, serious attempts were made to incorporate improvements derived from Operation PEDESTAL in the ships earmarked for Operation TORCH, the invasion of French North Africa in November 1942. HMS FORMIDABLE was refitting at Rosyth and acquired a Fighter Direction Office very similar to that in HMS VICTORIOUS. Her FDO, Ralph Swann, called in Jason Borthwick to advise. In the battleships and cruisers, newly appointed FDOs improvised Fighter Direction Offices for themselves, using as authority the splendidly worded letter from the Admiralty: 'Full facilities for Fighter Direction are to be fitted'. There were still no Staff requirements except those for radar Types 960, 294 and 295.

In late 1942 research effort at the Air Signals Establishment was allocated to the development of a 10 cm high-definition fighter direction radar that combined a continuously rotating antenna, associated with a PPI display, and height finding antennae on a single mast (Types 294 and 295). Difficulties in development led to the transfer of effort to Types 980 and 981, although the war ended before these sets could be installed in ships.

Apart from Types 294 and 295, prior to 1943 there was no Staff requirements, schedules of equipment or Admiralty layout drawings for FD offices in ships. The weaknesses shown up in Operation PEDESTAL were not curable. Both the main radar display and the intercept plots relied on reports telephoned from an A-scan at a rate of perhaps two a minute. Height estimation from the vertical polar diagram of a single radar was crude and slow. There was no cover with Type 79. The sloping MADP was only intermittently visible through the scrum. HF R/T was much improved - some aircraft had push button crystal controlled sets - but HF was vulnerable to jamming when close inshore. IFF was unreliable, and the homing beacon was difficult to use at best. Some of the fighters were still slower than a Ju 88. Fortunately, in Operation TORCH the Luftwaffe showed no inclination to repeat their experience of Operation PEDESTAL, with the result that there was not much conventional fighter direction. However, invaluable lessons were learned on the provision of close support to troops before shore-based support could be established. It took the personal intervention of Colonel Norstad (later SACEUR) to persuade the United States Air Force pilots that they must be on speaking terms with ground and shipboard controllers.

FURTHER DEVELOPMENTS AND IMPROVEMENTS

If fighter direction in Operation TORCH was not greatly in advance of that in PEDESTAL, the next year was to see dramatic improvements. Already on mid-1942 David Pollock in HMS ILLUSTRIOUS had 'borrowed' a PPI from Air Commodore McDonald's GCI in Ceylon, although this was an isolated fitting. In April 1943, sea trials began in HMS SALTBURN of the Naval PPI Type JE, together with a prototype radar Type 277X. Production models of the JE were soon being fitted throughout the Fleet. They at least doubled the efficiency of what had become the Air Direction Room (ADR). Although the full benefit had to await the advent of continuously rotating radar, at least 90% of the gain was immediate. The Intercept Officer now

had an almost continuous track of both the fighter and bomber, and so could control two simultaneous interceptions with good hope of success. If he still wanted to keep a dead reckoning, which had become of far less importance, he could use a Skiatron, which projected an enlarged PPI picture on to the underside of a horizontal plotting surface. Opinion always divided as to whether the Skiatron or a bank of PPIs provided a better intercept position. As regards radar reporting to the MADP, a good PPI reporter could telephone 12 plots a minute, which was rather more than the plotter could accept. The problem was solved almost as soon as it arose when HMS INDOMITABLE was refitting in Belfast. A dockyard electrician suggested that the plot should be vertical, transparent and edge lit, like the state board in the Home Guard headquarters. If was found that if two Perspex sheets were sandwiched together and the edge of the back one masked with metal strip, the plotters' markings were clearly seen by the Filter Officer and dimly by everyone else also, whereas the Filter Officer's red and yellow tracks stood out in brilliant contrast. The removal of the plotters to the back permitted an increase in their numbers to plot reports from the second WA set and the Type 277. they got in each other's way less than one might expect, because the Type 79 only dealt with tracks above or between the Type 281 lobes and the Type 277 with low fliers near the ship. A good crew could now handle twelve tracks per minute, enough for most purposes before the Kamikaze suicide bombers were encountered. The new equipment was soon standard in all carriers, although progress was slower in the battleships and cruisers, some of which never received a vertical plot. Indeed four cruisers were severely mauled in the Aegean in late 1943 because their fighter direction was inadequate, an incident that gave a welcome boost to the priority awarded to fighter direction in the Admiralty.

There were other improvements. In an Admiralty reorganisation the Director of Air Warfare and Training had become responsible for Staff Requirements, and the Director of Airfields and Carrier Requirements dealt with materiel and layouts. This was a welcome change by this time when doctrine and procedures needed formal promulgation and standardisation, and improvements in materiel required authority for major dockyard work. The layouts were standardised in Fleet and light Fleet carriers (and for that matter the US Navy), with the FDO on a dais, flanked by two Intercept Officers at deck level, all facing the Main Air Display Plot. There was room on the dais for the Fleet Fighter Direction Officer and Gunnery Liaison Officer. An ARL Table in a corner linked to the surface plots in the Operations Room, and was used for homing and air-sea rescues. In the escorts it was primarily used for the direction of air-sea searches and strikes. (A year later a Cathode Ray VHF DF display would be suspended above it.) This plus the YE beacon – a US built homing beacon that gave a coded course to steer to the pilot - finally solved the homing problem and enabled the Walrus amphibian aircraft to provide a good air-sea rescue service. The number of VHF channels available steadily increased, although there were never enough to match demand, chiefly due to problems of mutual interference. For internal communications the FDO was given a controlled talk back loudspeaker system with about twelve outstations from which to select. This was probably the first time in Naval history that an officer could cut off his Captain in mid-sentence (a facility not known to have been used). This was backed by a private PBX exchange. The plotters and various other users were given six-way rotary switches enabling them to select a radar reporting telephone line, or a 'told' plot. The FDOs never won their battle to dispose of the noisy sound powered telephones.

The ADR was first sound proofed, and then air- conditioned; conditions had been barely tolerable in Operation PEDESTAL and the PPIs gave off a great deal of additional heat. The dust problem was overcome when edge lit state boards replaced chalkboards. One more

British development missed the war, the concentration of radar control and reporting in a Radar Display Room (RDR) adjoining the ADR. It was first fitted in the light Fleet carriers, the first of which reached the Pacific, but not the operational area. It contained reporting PPIs for Types 281 and 277, and HPI for Type 277 and an A-scan with a slow fade for height estimation from a continually rotating Type 281. It should be noted that PPI reporting never entirely replaced A-scan reporting, which was more effective when jamming or land echoes blotted out the PPI.

Operationally these improvements were not tested against really heavy air attack until the British Pacific Fleet went into action in 1945. In the meantime, the development of air cover and support for the landings in Italy, and later in France, has been described in Howse, *Radar at Sea*. The Home Fleet in 1944 was able to attack the Tirpitz and shipping in the Norwegian Leads without damage from air attack. A report from HMS INDEFATIGABLE gives a glimpse of operations off Norway in September 1944. She was fitted with Type 277 and had a CAP airborne. She was far enough west to expect that any reconnaissance aircraft would probably approach from the east, and so vectored her CAP on a north-south patrol six miles long and six miles to the east. Thus they were well placed, and HMS INDEFATIGABLE always knew their position and course, which would normally be obscured by the radar transmission's ground wave. The tactic worked; two reconnaissance aircraft were shot down before they could make a report.

EXPERIENCES IN OTHER THEATRES

Reverting to 1943 in the Atlantic, the battle against the U-boats was nearing its climax. Here only the direction aspects are considered, and it must be said at the outset that by the time the escort carriers were operating in large numbers, it was becoming clear that the tide had turned in favour of the Allies. Some of the escort carriers carried Swordfish, and other Avenger aircraft. All carried fighters of some kind, partly because they were in range of the Focke-Wulf Condor (and later, on Arctic convoys, of the Ju 88), and partly for suppression of flak from U-boats just before they were attacked with depth charges. More or less independently, the carriers began to direct their air-sea patrols and searches. Patrols were easy because the aircraft were visible on radar most of the time. However searches out to a range of 120 miles flying at 1500 ft, often at night in bad weather, were another matter. Dead reckoning, now rather neglected by Intercept Officers, came back with a vengeance, and had to be far more accurate than before. Methods varied slightly, but most ships directed on the ARL Table, on which HF DF fixes might be plotted directly or transferred from another plot. A PPI, if fitted, would be nearby. At first, when ASV used metric wavelengths and the aircraft had a crew of three, direction was really a bonus to take some of the strain off the Observer. However in mid-1944 many of the aircraft were fitted with a 3cm ASV. Its size and weight meant that the Telegraphist/Air Gunner had to be left behind. The tiny fleeting echoes demanded a full-time lookout by the Observer, who now had to trust the ship entirely for his navigation. Fortunately there was little chance of an aircraft not being able to find its way back to the carrier, which by now was fitted with a YE beacon. Communication was, of course, by HF. It was at this point that 'Fighter Direction' became 'Aircraft Direction' to be practised in the Aircraft Direction Room.

In the Indian Ocean during 1944 and 1945 air supremacy was again established. The Japanese attack from Java on the eastbound British Pacific Fleet did no damage, and until July 1945 Japanese attacks on the Allied assault forces on the Burma coast never even saw

their targets, let alone reached the gun zone. But these attacks were of moderate size using crude tactics. The desperate battle to defend the Pacific Fleet against Kamikaze suicide aircraft is fully recorded in Howse, *Radar at Sea*.

Although the fleet's fighter direction was considerably more efficient than it had ever been, it was stretched to the limit. It was clear that the days of hand-plotting, metric interception radar and slow height finding were numbered. When, soon after the war, the problem of intercepting a stream of subsonic jet fighters with separately controlled subsonic jet fighters came to be studied, a radically new approach was seen to be unavoidable. But the Navy had come a long way since 1939. It has been suggested that the progress between 1940 and 1945 can be fairly compared to the progress in gunnery between Trafalgar and Jutland. It was pioneered by less than a dozen officers, all junior, and most of them reservists.