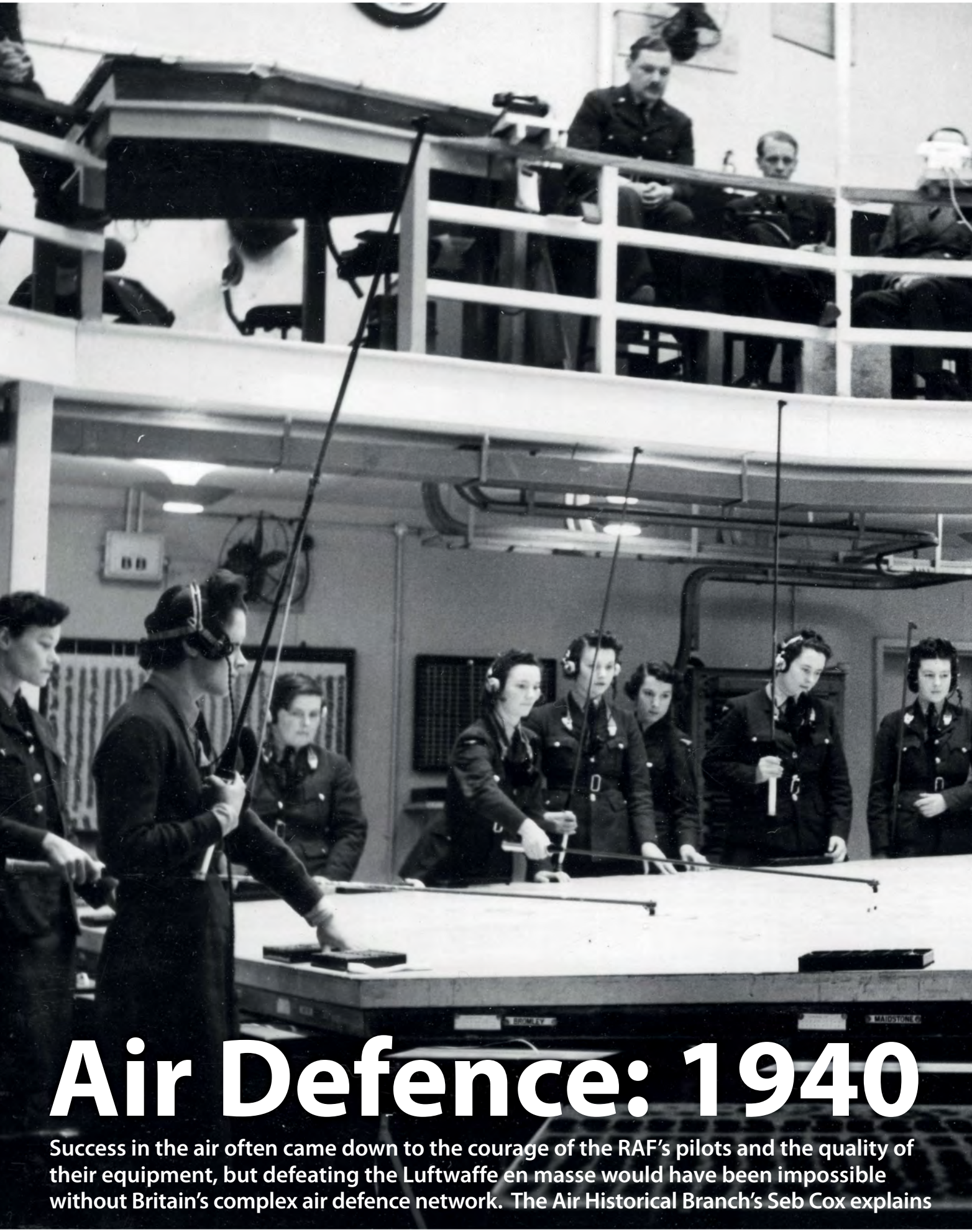


Air Defence: 1940

Success in the air often came down to the courage of the RAF's pilots and the quality of their equipment, but defeating the Luftwaffe en masse would have been impossible without Britain's complex air defence network. The Air Historical Branch's Seb Cox explains

In a scene that sums up much of the UK's air defence control system in 1940, WAAF plotters work in the underground operations room at HQ Fighter Command, Bentley Priory. A senior officer studies the unfolding events from the viewing deck above. RAF (AHB)/© UK MoD Crown Copyright 2015

The Battle of Britain surely ranks alongside the Battles of Trafalgar and Waterloo as one of the most significant in British history. As with the Battle of Trafalgar, it lifted the threat of invasion; like Waterloo it limited the ambitions of an expansive European power in thrall to a megalomaniac. It was the first significant strategic defeat suffered by Adolph Hitler's Third Reich during World War Two. In the longer term, the Battle ensured that Britain could serve as an 'unsinkable aircraft carrier', enabling the Western Allies, including the USA and Canada, to launch their invading armies into continental Europe on D-Day.

The iconic vision of Spitfires and Hurricanes battling to preserve our democratic freedoms as they swept into action against large formations of German aircraft is an accurate one. However, it gives us only a partial understanding of what was a far more complex picture with a myriad cast of characters and a host of participating organisations, extending well beyond the RAF fighter pilots, sweating in their cramped cockpits high above the hop fields of Kent.

The air battles of 1940 were a struggle for supremacy rooted in a fiercely technological domain, where science and its application were as important as the courage and skill of the pilots. Britain was no stranger to air attack. Indeed, the story begins more than two decades earlier, when German Zeppelin airships and giant heavier-than-air bombers attacked London during World War One. The sight of formations of bombers flying apparently unmolested over the capital in broad daylight in the summer of 1917 caused a political storm, and the subsequent enquiry led directly to the formation of the RAF.

The Prime Minister, David Lloyd George, appointed the razor-sharp South African General Jan Christian Smuts, to investigate. He recommended that the effective aerial defence of the nation required a single professionally qualified and expert air service. His recommendation was approved and the necessary legislation put in place. As a result, on April 1, 1918, the Royal Air Force was formed, although steps had already been taken to create an effective air defence organisation for the British Isles.

Air Defence Defined

It was quickly recognised a century ago that the basic requirement for effective air defence was a system comprising several constituent parts. The first, the observation element, identified and located the enemy aircraft, while the second, an efficient communications system, sent the information as rapidly as possible to an air defence operations centre.

At the operations centre the information could be displayed in an understandable form quickly enough to enable the air defence commander to react by alerting anti-aircraft (AA) gun batteries and despatching fighter aircraft to intercept and shoot the enemy down. All parts of the system, identification and location, dissemination and display, command and control, fighter interception or AA fire control, had to function efficiently and in concert to achieve the desired end result – the destruction of the enemy.

The system developed in World War One involved observation by military personnel (some using concrete 'acoustic mirrors' for sound detection of aircraft), police and railway officials. Curious as this latter arrangement might appear, it was in fact a sensible and imaginative innovation. The railway network at the time was an important strategic asset to the country, boasting stationmasters and a dense patchwork of stations extending across large parts of the country. Just as importantly, these were linked together by telephone and telegraph, which provided that most vital component – rapid communication.

Operations rooms with map tables and other communications equipment were established in London, one being located at Liverpool Street Station. Eventually, a central control room was set up in Horse Guards and 25 sub-controls around the country passed details of 'plots' on raiders. There were ten 'plotters' seated at the map table, each with a headset connecting him to several sub-controls.

Colour-coded counters with arrows were placed on the map tables to depict the tracks of hostile aircraft and airships, and there were indicators to show where bombs had been dropped. The colours on the counter corresponded to five-minute coloured segments on the operations room clock, which thus indicated how old the plot was. 'Stale' plots more than ten minutes old were removed from the table. The air defence commander, General EB Ashmore, sat in a raised gallery, giving him an unobstructed view of the map table, and could talk directly to any sub-control.

By the time of the Armistice, Ashmore and his team had thus more or less solved the organisational problems associated with air defence. The foundations of the later air defence system, which came to be known as the Dowding System, had their origins in Ashmore's organisation, known as the London Air Defence Area (LADA).

The technological issues that LADA faced were less easily addressed. The acoustic mirrors were not particularly successful, and the limited results of enemy air attacks owed as much to the technical shortcomings of German aircraft as to the rapid improvement of UK air defences. However, the acoustic mirrors were the focus for some of the earliest attempts at co-operation between scientists and the military in the air defence field. This relationship, although not without its difficulties, would bear far more significant fruit in a later conflict.

Air Defence Under Pressure

In the 1920s, as now, defence spending came under intense pressure. However, this did not mean that UK air defences were entirely neglected. Under the Treaty of Versailles, Germany was forbidden military aircraft, leaving France as the only major power theoretically capable of threatening the UK from the air. The 1920s air defence system was therefore designed to address that »

potential, if unlikely, eventuality. A number of committees investigated various aspects of the air defence problem and produced recommendations for a new approach, drawing on the experience of the LADA and creating separate zones for AA guns and fighters (to avoid friendly fire incidents).

The Aircraft Fighting Zone originally extended from Duxford, near Cambridge, to Devizes in Wiltshire. The outer edge of this Zone was about 35 miles (56km) inland from the coast, a distance dictated by the amount of warning expected of an incoming raid combined with the time it took the contemporary biplane fighters to climb up to 14,000ft – the height at which it was anticipated the bombers would fly.

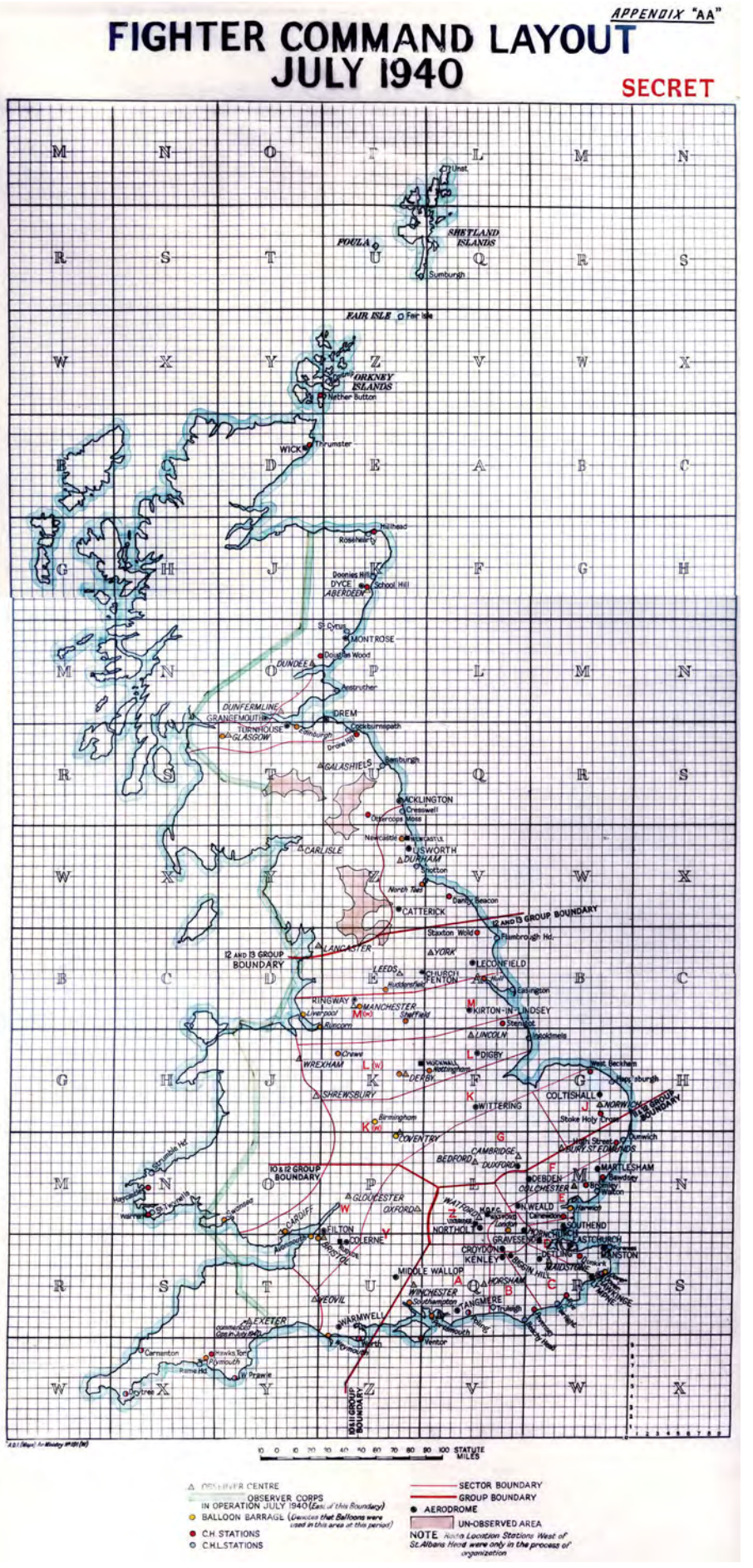
There was an Outer Artillery Zone in front of the Aircraft Fighting Zone, and an Inner Artillery Zone behind it, mainly covering London. The Aircraft Fighting Zone was sub-divided into ten Sectors, each with a front of about 15 miles (24km). The four Sectors to the south and east of London were to be defended by two fighter squadrons, and the others would have one squadron. A further three squadrons would be stationed near the coast to intercept and harass the incoming raids as early as possible. Observer posts were to be established across Southern England, linked to observer centres; those on the coast were to be equipped with acoustic mirrors. In October 1925 an Observer Corps (later Royal Observer Corps) was established, using volunteer civilians to man the observer posts.

Defensive Reorientation

In the 1930s, following Hitler's rise to power and the establishment of the Luftwaffe, the air defence system was progressively reorientated from south to east and extended to cover the whole country. Of course, it was anticipated that France would be allied with Britain in the event of war and that the threat from Germany would come from across the North Sea. However, the rapid development of aviation during the 1920s and 1930s served to complicate the issue.

The German Gotha biplane bombers of 1917 had flown at a stately 70mph (110km/h), but by the 1930s, their sleek monoplane Dornier and Heinkel descendants could reach almost 200mph (320km/h). With enemy bombers flying at such speeds, there would be less time to mobilise the air defence system against them.

The advent of an aggressive potential enemy capable of threatening the UK so worried the government that it set up a Committee for the Scientific Survey of Air Defence, with a membership that included several distinguished scientists. The very first meeting of this committee in January 1935 heard a proposal from Mr (later Sir) Robert Watson-Watt of the National Physical Laboratory on the possibility of detecting aircraft using reflected radio waves – the principal of what is now known as radar. This required Treasury approval for the expenditure of some £10,000, and Air Marshal Sir Hugh



Dated July 1940, this map depicts the division of UK airspace into Groups and Sectors for the purposes of fighter control. Chain Home (CH) and Chain Home Low (CHL) radar stations are shown, as are airfields, balloon barrages and Observer Corps coverage. RAF Museum

Fighter Command's squadrons relied on the RAF's comprehensive early warning and control network to scramble them in time to reach and engage incoming enemy formations. These 85 Sqn Hurricanes were airborne on October 5, 1940, with Sqn Ldr Peter Townsend leading. RAF (AHB)/© UK MoD Crown Copyright 2015

"From the map references relayed to the Ops Room the squadrons could be scrambled to deal with the approaching enemy aircraft."

Patricia Clark (nee Robins), WAAF plotter

Dowding, the senior officer responsible for research and development for the RAF, wisely considered that this would more probably be forthcoming if some basic evidence was available.

Dowding therefore arranged for an RAF aircraft to be made available to Watson-Watt. The latter, with help from AF Wilkins, set up a crude experiment in the middle of a field near Weedon, Northamptonshire. At this location, on February 26, 1935, Watson-Watt and Wilkins parked a van with a radio receiver connected to an antenna slung from wooden poles and linked to a cathode ray oscilloscope. Meanwhile, Flt Lt RS Blucke approached the nearby town of Daventry in a Handley-Page Heyford biplane bomber. Blucke proceeded to fly a predetermined route backwards and forwards between Weedon and Daventry, where there was a BBC Radio short-wave transmitter. In the field below, the receiver was tuned to the signal from the BBC, which showed as a straight line on the oscilloscope; however, as Blucke's aircraft passed, it reflected the radio waves, producing a distinct spike on the oscilloscope trace.

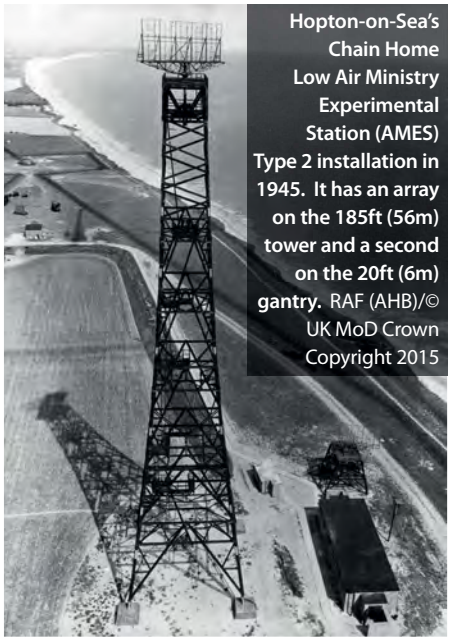
Radar Reality

Watson-Watt immediately wrote a memo entitled *Detection and Location of Aircraft by Radio Methods* and presented it to the Air Ministry next day. Radar was born. Much work and further experimentation was necessary to turn this first, very crude, almost comical experiment into a functional early warning system integrated into the UK's air defences. Nevertheless, this humble beginning was to have the most profound effect on the outcome of the Battle of Britain. Dowding duly got his money from the Treasury, and that notoriously parsimonious organisation actually sanctioned expenditure of £12,300 in the first year; much more was to follow.

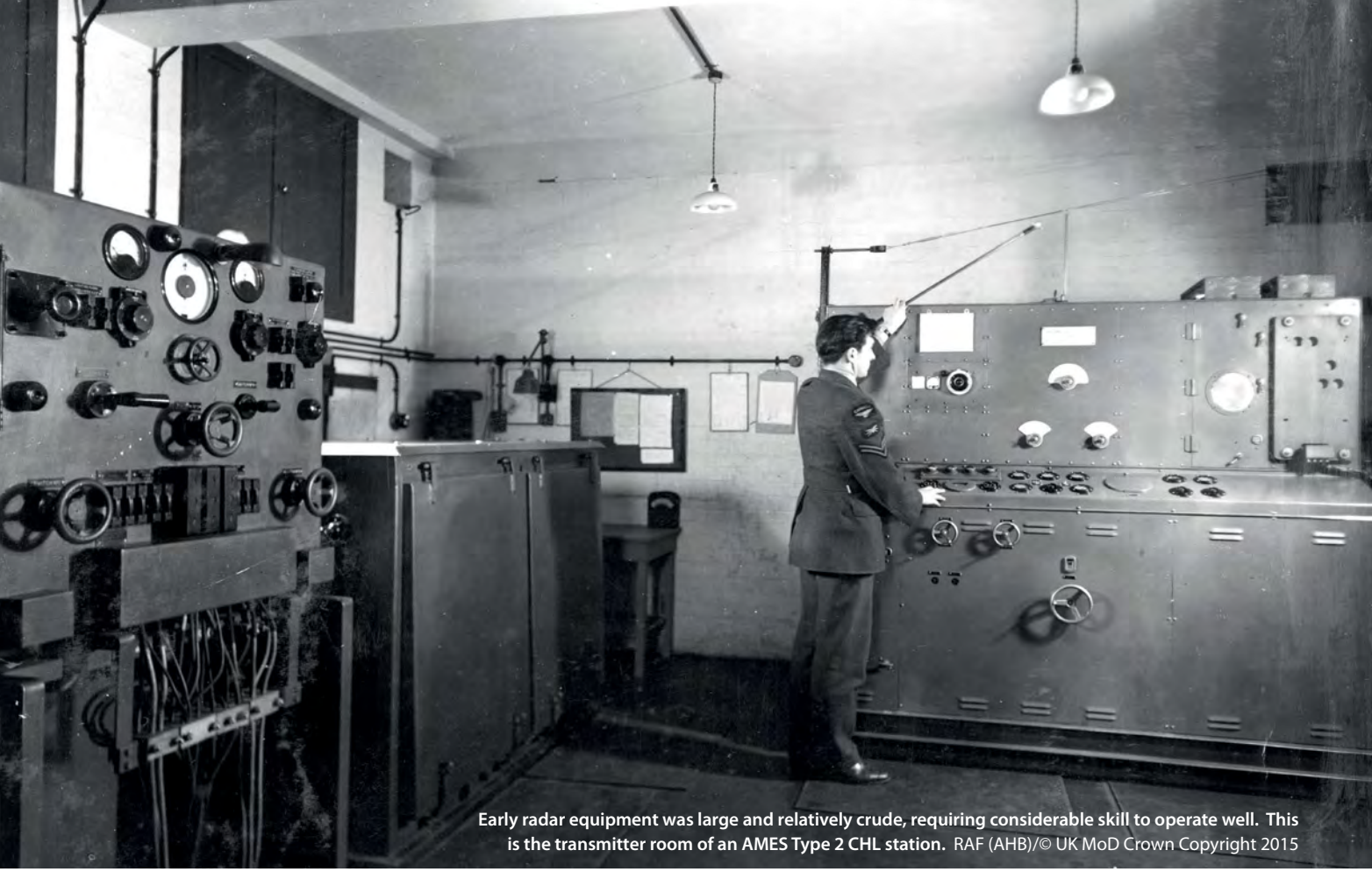
A research station was established for Watson-Watt and a team of scientists at Bawdsey Manor in Suffolk, and the Treasury approved the construction of an experimental chain of five radar stations to cover the Thames Estuary, while the Air Ministry suspended all expenditure on the acoustic mirrors it had been building.

Despite many hiccups and setbacks, RAF senior officers were convinced by 1937 that a full chain of radar stations should be built to protect the east coast. By the outbreak of war in September 1939, 20 radar stations were in operation, and further expansion followed »

Observer Corps' posts were strategically sited around the country, personnel detecting and plotting all aircraft over their area. Information, including the height and track of friendly and hostile machines, was passed to the local control centre. Dated April 1941, this photograph shows a typical post. RAF (AHB)/© UK MoD Crown Copyright 2015



Hopton-on-Sea's Chain Home Low Air Ministry Experimental Station (AMES) Type 2 installation in 1945. It has an array on the 185ft (56m) tower and a second on the 20ft (6m) gantry. RAF (AHB)/© UK MoD Crown Copyright 2015



Early radar equipment was large and relatively crude, requiring considerable skill to operate well. This is the transmitter room of an AMES Type 2 CHL station. RAF (AHB)/© UK MoD Crown Copyright 2015

under the impetus of live hostilities; 27 more radars were operational before the Battle of Britain.

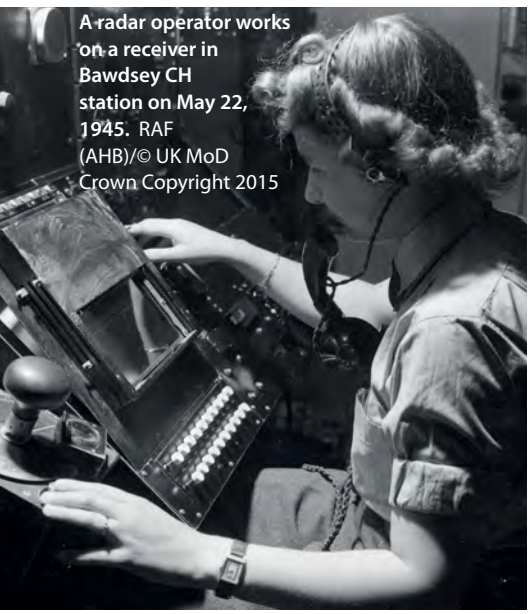
Experiments had also been conducted at the other end of the 'system', whereby the plots originating at the radar stations were displayed on the operations room map tables at the newly established Fighter Command, and at Group and Sector headquarters lower down the chain, interception orders then being passed by radio telephone to squadron commanders in the air.

In addition to building the radar stations, all the necessary communications facilities had to be installed, linking radars, observer posts and Observer Corps centres with Fighter Command Headquarters at Bentley Priory, near Stanmore, and connecting the Fighter Command operations room with Group and Sector operations rooms.

Vital Communications

This communications network, linking the component parts of the system, would prove to be of vital importance to UK air defence in 1940. By the time the Battle of Britain began, the Luftwaffe's bases were far closer to the UK than they had been at the start of the war. A German fighter squadron based in the Pas de Calais could cross the Straits of Dover in just six minutes. However, the German bombers were based further inland and, heavily laden with bombs and fuel, they had to climb slowly to their operational altitude. The Luftwaffe's Bf 109 fighters were handicapped by their relatively short endurance, which is why they were based further forward on aerodromes near the coast. There they would wait for the bombers to approach, before taking off and joining up into much larger formations.

This process took a little time and, as the formations assembled, they began to appear on British radar screens. This generally provided about 20 minutes' warning of their approach. The radar station would report the raid through constantly open telephone lines to Bentley Priory, where the plots were received in a filter room and placed in the appropriate map square on the filter room map table. The function of this room was literally to filter the plots, combining



A radar operator works on a receiver in Bawdsey CH station on May 22, 1945. RAF (AHB)/© UK MoD Crown Copyright 2015

Defiant crews in August 1940, awaiting the Sector controller's call to scramble. RAF (AHB)/© UK MoD Crown Copyright 2015

Above left: **Taken at HQ 11 Group, RAF Uxbridge in October 1942, this image illustrates how plotters received information on aircraft positions through earphones, then carefully plotted their courses on table maps for the controllers.** Above right: **This May 1945 photograph shows an East Coast receiver room with one of the two RF7 receivers (left) and the Mk 3 console (right) in use.** both RAF (AHB)/© UK MoD Crown Copyright 2015

those from different radars and weeding out extraneous returns, which might be flocks of geese or meteorological phenomena.

When the filterer officer was sure that a plot was genuine, it was allocated a hostile raid number and a 'teller' would speak into her microphone (most tellers were Women's Auxiliary Air Force (WAAF) personnel) and pass the details of the hostile raid plot. Her words would simultaneously echo in the headphones of WAAF 'plotters' in every operations room in the affected region, from Fighter Command at Bentley Priory right down to the Group and Sector levels. Instantly and simultaneously, the plotters would place the appropriate plot counter in the correct map square on all the operations room map tables throughout the system. From the first radar contact to the operations room plot appearing, the process took about four minutes.

There were now around 16 minutes left, but it took a Spitfire squadron in a battle climb 14 minutes to reach 20,000ft and a Hurricane squadron a few minutes longer. So the controllers at the Group HQ, who determined which fighter squadrons were to be scrambled to intercept incoming raids, had very little time to make the right decision if they were to intercept.

As the radars tracked the raid, the plotters moved the counters across the map table using croupier-like rakes; as in Ashmore's LADA, the arrows showing the track were colour-coded according to the colour on the face of the segmented clock in the operations room. Plots older than 15 minutes were removed from the table.

Patricia Robins was a WAAF plotter and explains the job first hand: "The information received by the plotters in the filter rooms from the coastal radar stations was processed by the filterers and relayed by an operator on the telephone to the ops room. From the map references relayed to the ops room the squadrons could be scrambled to deal with the approaching enemy aircraft. Speed was, therefore, essential, and the urgency of our work became even more apparent when the blitz started.

"I think there were about 30 around the table on a shift. We were an assorted bunch of young women from very varied backgrounds, but there was never any discord between us. We were all dedicated to our work and totally concentrated on what we were doing.

"On occasions we would receive SOS signals from one of our planes damaged so badly it was about to come down in the Channel. We were then able to plot its anticipated ditching position and the ops room could alert the necessary rescue craft." »

This is the receiver room of an AMES Type 2 CHL station. The plan position indicator and range consoles are to the right, with the air plotting board at centre.
RAF (AHB)/© UK MoD Crown Copyright 2015

Telephone operators, in the Sector 'G' Operations Room at Duxford, take reports from Observer Corps' posts. RAF (AHB)/© UK MoD Crown Copyright 2015

The Filter Room at Fighter Command HQ. RAF (AHB)/© UK MoD Crown Copyright 2015

Scramble!

Once his mind was made up, the controller at the responsible Group HQ would lift his phone and tell the switchboard operator to connect him to the relevant Sector station. The Sector controller's phone would ring and he would hear the Group controller's voice issuing instructions to scramble the relevant squadrons and confirming the altitude at which they should patrol, and the patrol area.

The orders were crisp and to the point, wasting few words. Thus, "Scramble 92 and 72, Patrol Canterbury, Angels 25," meant 92 and 72 Squadrons were to be sent into the air immediately, climb to 25,000ft and form a patrol line over the city of Canterbury.

The Sector controller repeated the words to ensure they were correctly understood and then put the phone down. He then turned to the phone connected directly to the squadron dispersal huts on the airfield. When the phones in the dispersal huts rang, every pilot lazing in the bunks in the hut, or outside in deck chairs, or on the grass, sat bolt upright and stared at the individual who lifted the receiver. As soon as he shouted "Scramble!" they ran towards their aircraft.

Parachutes would have been placed on the wing or the seat, and the ground crew, who never strayed far from their charges, helped the pilots buckle them on, slip into their cockpits and do up their straps. Then the engines all around the dispersal spluttered and roared into life, brakes were released and the fighters began to move, bouncing and rolling across the grass in a pell-mell race to get airborne.

Once the aircraft left the ground, the fighter leader called up the Sector controller for instructions. It was then the Sector controller's task to direct them towards the enemy via radio-telephone, his initial order being the course to steer, together with "Make Angels 25". As more information was received on the strength and direction of the raid, he would pass this to the squadrons and change the vectors as necessary to bring them over Canterbury or adjust their course to meet the enemy.

All tracking of raids that had crossed the English coast was the responsibility of the Observer Corps, since the radars looked out to sea, not inland. The margins for error were small, but the vital communications links between the component parts of the system allowed just enough time for the defences to react.

Talking about her work as a radar operator, former WAAF Yvonne Axon emphasised the importance of minimising errors for accurate interceptions: "We were connected directly to Fighter Command, telling them what to put on the table. In other words we said: 'I think we have an aeroplane…' Actually, it could be three, or a squadron, or might well be a group of 60 fighters. They all looked very much the same. You had to sound terribly confident. If what you said was right, then the fighter boys were sent up to that spot, or where that spot would be in five minutes' time. We were always there in the right place at the right time – that is, most of the time."

Thus the radars, Observer Corps and filter and operations rooms gathered, filtered, disseminated and displayed the information in usable form. But they made up only those elements of the air defence system designed to tell commanders what was going on. Moreover, while the commanders benefited immeasurably from this heightened situational awareness, they had still to decide what resources to use, despatch those forces to intercept, and manoeuvre them into contact with the enemy, which was no mean feat in a fast-moving, three-dimensional battle.

The result of successful detection, plotting, reporting and control was an engagement with the enemy, as far away from British targets as possible. Here Heinkel He 111 bombers are under attack. RAF (AHB)/© UK MoD Crown Copyright 2015