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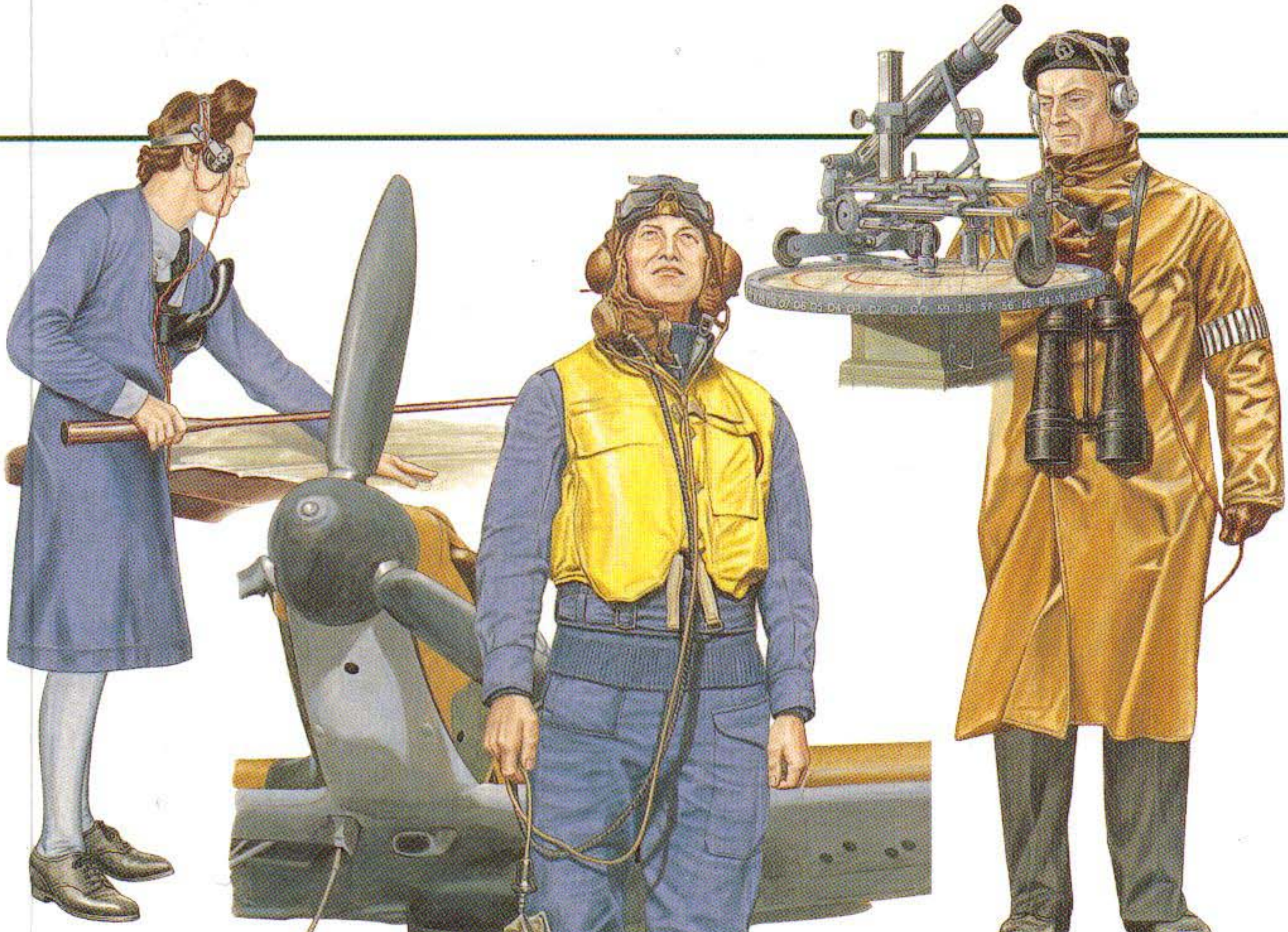
Britain's Air Defences 1939–45



Dr Alfred Price • Illustrated by Darko Pavlovic

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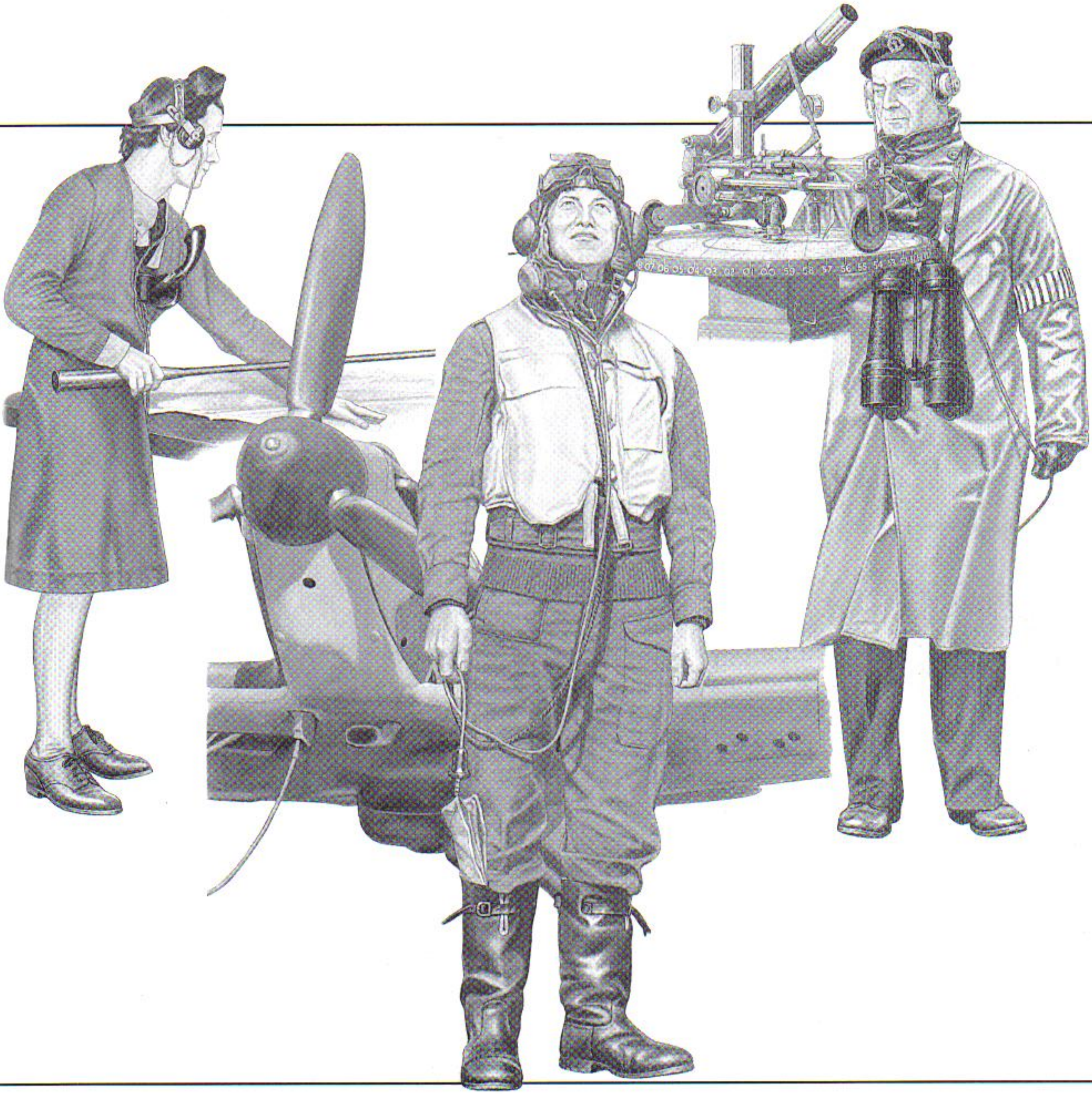

Dr Alfred Price • Illustrated by Darko Pavlovic

Consultant editor Martin Windrow

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Author's Note

In writing this book, my aim has been to describe the initial state and the subsequent evolution of Britain's air defences during World War II. I also show how each element of the defences – the fighter control organisation, the day and night fighters, the heavy and the light AA guns, the barrage balloons, the radio-jamming organisation – combined to produce a coherent and efficient system to blunt the enemy air attacks.

Air-to-air fighting tactics during World War II have been described in several other Osprey books, including three titles by this author: *Spitfire Mark I&II Aces*, *Spitfire Mark V Aces* and *Late Marque Spitfire Aces*. I have not gone over this ground again, though I have described the operation of the supporting fighter control system. Descriptions of aerial combats end when the fighter pilot makes visual contact with the enemy aircraft.

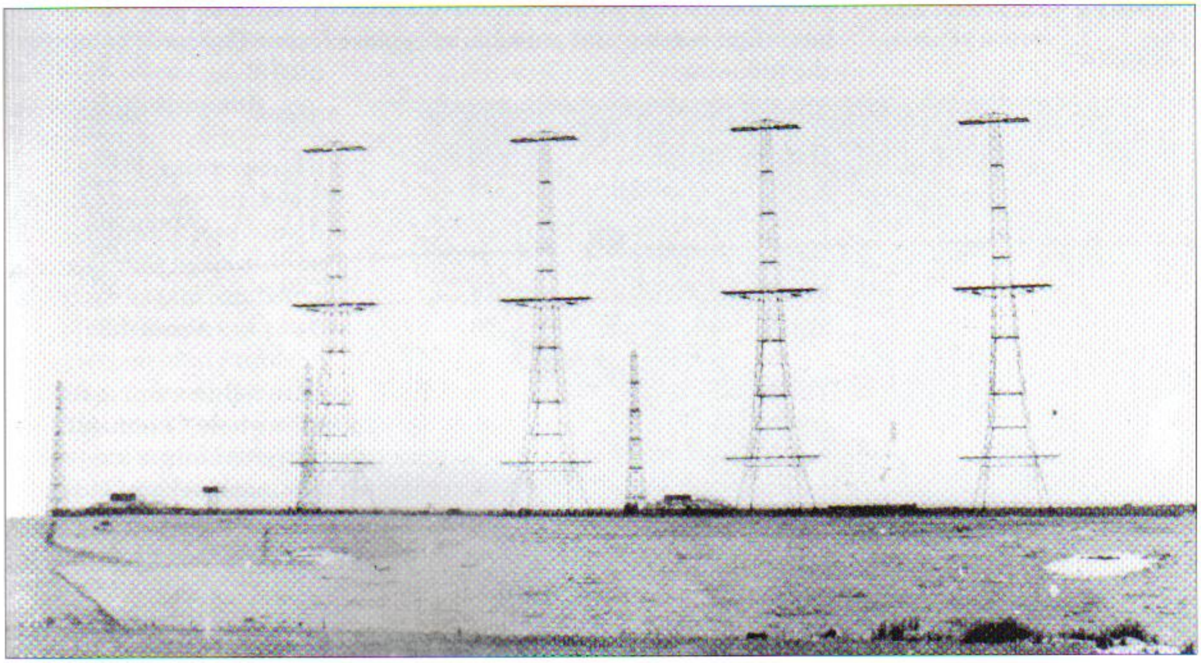
BRITAIN'S AIR DEFENCES 1939–45

PREPARING FOR WAR

In the spring of 1939, RAF Intelligence officers produced their assessment of the threat the Luftwaffe long-range bomber force posed to targets in Great Britain. They estimated that the force possessed about 1,600 modern bombers and, in the event of a war, these might attempt to deliver an aerial 'knock-out blow' on London. If there were no effective countermeasures, it was calculated that in the first two weeks of such an attack the capital would receive about 700 tons of bombs per day.

From German records, we know those RAF figures were unduly pessimistic. When World War II opened in September 1939, the Luftwaffe possessed only 1,180 twin-engined bombers – about a quarter less than the British estimate. Of those, about a thousand bombers were serviceable. The bulk of the bomber force, nearly 800 aircraft, comprised Heinkel 111s. Most of the rest were Dornier 17s.

An attack on London mounted from north-western Germany meant a round trip of 760 miles flying round neutral Holland, or 720 miles flying over it. With fuel allowances to cover formation assembly, route flexibility and safety margins, neither German bomber type could reach London carrying its full load of bombs. Nor could such an attacking force receive fighter protection.



The Chain Home long-range early warning radar, able to detect individual aircraft at ranges greater than 100 miles. The transmitter aerial wires were strung horizontally between the four 350ft high towers. The transmitter itself was housed in the small building to the right centre of the photograph. The smaller towers in the background carried the receiver, direction-finding and elevation-measuring aerials.

Chain Home Low radar scanner, mounted on top of a 185ft high tower. This radar entered service during the early months of the war, and partially filled the gap in the radar coverage at the lower altitudes. The CHL could detect aircraft flying at 500ft out to 18 miles, and aircraft flying at 2,000ft out to 35 miles.

In fact, the maximum bomb tonnage the Luftwaffe could deliver on the British capital was 400 tons, not 700 tons. Allowing for strays and bombs that failed to explode, that meant a realistic maximum of about 300 tons of exploding bombs on the target for a maximum-effort daylight attack. By night, when the proportion of stray bombs would have been substantially greater, that figure shrank to about 100 tons.

So much for the predicted maximum weights of the air attack that could be launched against London in 1939. From German records it is clear that Adolf Hitler had no intention of launching such an attack on London or any other British city for several months after the outbreak of the war. That did not stop him from extracting the maximum possible diplomatic mileage from the threat of such attacks, however.

In Defence of the Realm

Having looked at the weight of attack the Luftwaffe could deliver on London, let us examine the ability of the nation's air defences to parry such an blow. In September 1939 RAF Fighter Command possessed 39 front-line squadrons, with a total of 747 aircraft plus about 300 aircraft in reserve and available to replace losses. The force comprised the following:

Aircraft Type	*Squadrons*	*Strength*	*Reserve*
Hawker Hurricane	16	347	22
Supermarine Spitfire	10	187	71
Bristol Blenheim	7	111	About 40
Gloster Gladiator	4	76	126
Gloster Gauntlet	2	26	50
Totals	**39**	**747**	**About 309**

The Spitfire and the Hurricane were fast, modern fighters and as soon as production allowed they would equip almost the whole Command. The twin-engined Blenheim was a bomber type converted into a long-range fighter by the addition of a pack containing four machine guns mounted under the fuselage. The Gladiator and Gauntlet were obsolescent biplanes, scheduled to be replaced as soon as possible in the front-line home defence units.

The Spitfire and the Hurricane were each armed with eight .303in. Browning machine guns. The Blenheim carried five of these weapons firing forwards; it also carried a single machine gun in the rear turret for defence against attack from behind. The Browning had a rate of fire of 1,150 rounds per minute, and was effective against unarmoured aircraft (at the outbreak of the war German bombers did not carry armour).

The Commander-in-Chief Fighter Command, Air Chief Marshal Sir Hugh Dowding, calculated that he needed a minimum of 46 squadrons with 736 fighters to defend the entire spread of targets ranging from Portsmouth in the south to the River Clyde in the north. When the war began Dowding possessed not 46 fighter squadrons, but 39. And of these, he had to give up four squadrons immediately to go to France to provide air cover for the British Expeditionary Force.

In the months that followed, more fighter squadrons were formed. Also a new fighter type entered service, the Boulton Paul Defiant. This aircraft carried its armament of four machine guns in a power-operated gun turret mounted on top of the fuselage. The Defiant's unusual role is described in Box 1.

Against bombers flying from bases in Germany, and therefore without fighter escort, we now know that even Dowding's reduced fighter force could have dealt severely with bombers attacking England in daylight. By night it was another matter, however. Lacking airborne radar, the British fighters were virtually ineffective during the hours of darkness.

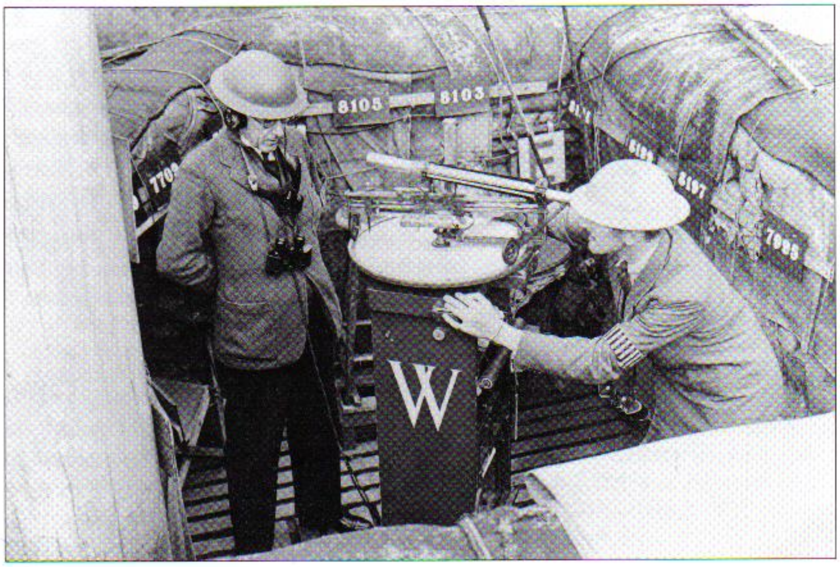
Fighter Command's Ace Of Trumps

The fighters were Fighter Command's 'teeth'. But scarcely less important were the Command's 'eye' and 'brain' organisations, and the 'nervous system' carrying information between the three, which enabled the 'teeth' to snap at raiders to greatest effect.

During the late 1930s, the RAF had built a chain of radar stations along the east coasts of England and Scotland. These were Fighter Command's long-range 'eyes', able to detect and track aircraft approaching at medium or high level more than 100 miles away. When the war began there were 18 such radar stations, code-named Chain Home (CH) equipments, covering the approaches to the eastern and southern coasts of Britain between Portsmouth and Aberdeen.

The CH radar worked well against aircraft flying at medium and high altitudes, but against those flying at 5,000ft or below the performance was poor. To overcome that problem, partially at least, the RAF introduced a new type of early-warning radar: the Chain Home Low or CHL. With its scanners mounted on towers up to 185ft high, the new radar could detect aircraft flying at 500ft out to 18 miles, and aircraft

For technical reasons, the CH radars could not track aircraft flying over land. That was the responsibility of the hundreds of Observer Corps posts dotted around the country, which fed reports to the Fighter Command filter room to assist in building up the air picture.



flying at 2,000ft out to 35 miles. The CHL radars were interspersed between the CH stations, providing useful additional cover to lessen the risk of surprise attack.

The Fighter Command headquarters at Bentley Priory near Stanmore, and the Group and Sector operations rooms, were the 'brains' of the system. The web of landlines linking every part of the organisation constituted the 'nervous system'. When radar detected approaching enemy planes, their grid position, altitude and estimated strength were passed by landline to the Filter Centre at Fighter Command Headquarters. There officers checked the radar plots against the known locations of friendly aircraft. If the plot was classed as 'hostile' or 'unidentified', it was passed to the Fighter Command operations room where it appeared as an appropriate marker on the situation map. That information was also relayed to the various fighter Group and Sector operations rooms, where it appeared on their situation maps also. Other recipients of the information were the anti-aircraft gun control rooms in the threatened areas, and the civil defence organisation which sounded the warning sirens.

At the fighter Group headquarters responsible for the defence of the area under threat, the controller ordered his fighter squadrons to 'scramble'. It was important to get them off as early as possible, to give them time to climb to the raiders' altitude.

For technical reasons, the Chain Home radars could not track aircraft flying over land. Once the raiders crossed the coast, tracking was the responsibility of the hundreds of ground Observer Corps posts that dotted the countryside. These posts passed their plots by landline to their own Group headquarters, which relayed them to the Fighter Command Filter room for onward transmission throughout the system.

Once a fighter squadron was airborne, it came under radio control from one of the Sector operations rooms. The ground controller guided the fighters to the point of gaining visual contact with the enemy force. When he had the enemy in sight the fighter formation leader called 'Tally Ho!', to indicate that no further assistance was required from the ground.

The Royal Air Force's comprehensive system of fighter control was without equal anywhere in the world at that time. Fighters would wait on the ground until a raiding force was observed on radar heading for the coast. Then there was time, just, to take off and climb into position to engage the raiders. The system therefore obviated the need to mount costly, wasteful and largely ineffective standing patrols, which would have inflicted much needless wear and tear on the force. It also enabled ground controllers to manage the air battle, to concentrate their forces where they would inflict maximum harm on the enemy. In the forthcoming air actions over Britain, that ground control system would be Fighter Command's ace of trumps.

The Anti-Aircraft Guns

Anti-aircraft (AA) gun batteries were another important aspect of Britain's air defence system. Although Anti-Aircraft Command belonged to the army, its forces came under the operational control of RAF Fighter Command.

The guns were deployed for the point defence of potential targets. To protect a potential target from raiders at high level (above 10,000ft)

Box 1: The 'Defiant' Turret Fighter

In March 1940 No. 264 Squadron became operational with the Boulton Paul Defiant two-seat fighter. This unusual machine carried its armament of four .303in. machine guns in a powered turret that trained through 360 degrees horizontally and elevated almost to the vertical. When the turret pointed forwards, however, cut-outs prevented the guns depressing below 17 degrees from the horizontal to prevent the rounds striking the propeller. Thus the only direction from which the fighter could not engage a target was when it was directly in front.

In view of what later happened to the Defiant, it is important to appreciate its intended role. In the 1930s there were fears that the defensive crossfire from a formation of bombers might massacre normal-type fighters attacking from behind. To meet that possibility, the RAF commissioned the design of a turret fighter. The resultant aircraft, the Defiant, was intended to engage unescorted enemy bomber formations which, at the beginning of the war, constituted the only threat to Great Britain. The turret fighters were to formate on the enemy bomber formation by flying below, ahead or to one side of it, in sectors where the bombers' defensive guns provided little or no protection. Once he was in firing position, the Defiant's gunner could open a withering fire from an angle where the bombers could not reply effectively. If the turret fighters inflicted damage on bombers and forced them to leave the formation, these could be finished off by conventional fighters.

Against unescorted bomber formations, there is little doubt that the Defiant would have proved highly effective. However, during the Battle of Britain the Luftwaffe rarely sent unescorted bomber formations to attack targets. Moreover, conventional fighters proved able to engage bombers effectively despite the defensive crossfire.

When German single-seat fighters caught up with Defiants, the latter suffered heavily. Some commentators, ignorant of the fighter's intended role, have criticised it because it lacked forward-firing guns. These would have added nothing to the Defiant's proposed mode of operation, and their additional weight would have made the relatively slow and unwieldy fighter even slower and more unwieldy.

An early action demonstrated the vulnerability of Defiant two-seat fighters to attack from enemy single-seaters. On 19 July 1940, nine Defiants of No. 141 Squadron were scrambled to intercept a force of dive-bombers attacking a convoy off Folkestone. Near the convoy, escorting Messerschmitt Bf 109s pounced on the Defiants, and one after another the two-seaters were shot down. Only the arrival of Hurricanes of No. 111 Squadron saved them from complete annihilation. As it was, six Defiants were destroyed and one more suffered serious damage. For most of the remainder of the Battle, the Defiants would be confined to areas where they were unlikely to encounter enemy single-seaters.

or low level (below 500ft), separate types of gun defence were necessary. The heavy AA guns and their predictor systems could not traverse rapidly enough to engage low-flying aircraft, while the light AA guns lacked the reach to engage high-flying raiders.

The most numerous type of heavy anti-aircraft weapon deployed in the United Kingdom in 1939 was the 3.7in. gun. This fired 28-pound shells at a maximum rate of about ten per minute to an effective engagement ceiling of 25,000ft. On exploding, the time-fused shell hurled out hundreds of red-hot splinters that were lethal against any aircraft within about 45ft.

The newer and heavier 4.5in. gun, deployed in smaller numbers, fired a 55-pound shell at a maximum rate of about eight per minute, to an effective engagement ceiling of 26,000ft. This round was lethal against aircraft up to about 60ft from the point of detonation.

In addition to these modern weapons, there were 270 of the lower performance 3in. guns left over from World War I, with an effective engagement ceiling of 14,000ft.

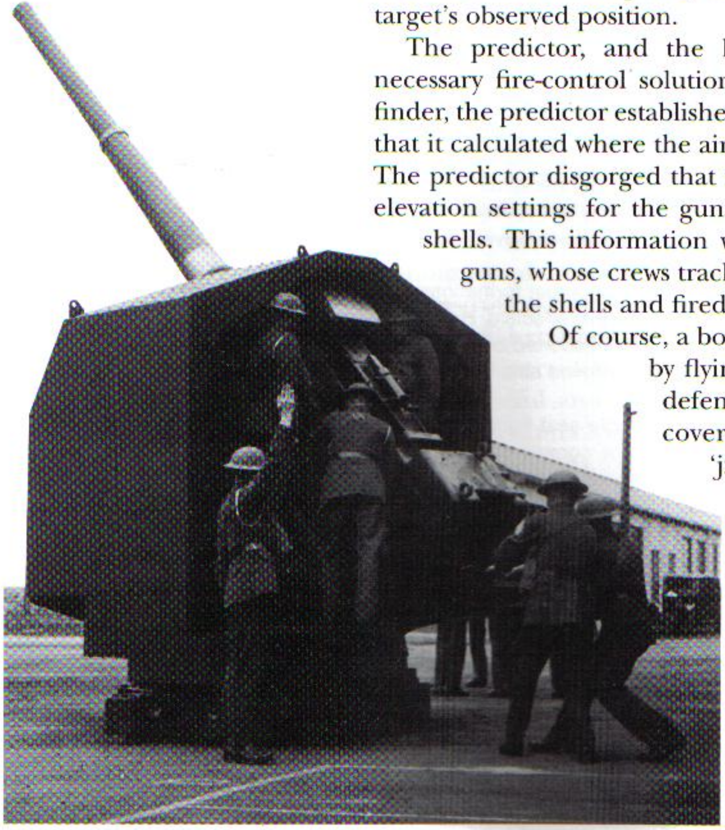
Heavy anti-aircraft guns were usually deployed in half-batteries of four (see box 2). However, sites with two, six or even eight guns were not uncommon. Each site had its own height-finder and predictor, essential for engaging enemy aircraft at long range. In the case of the 3.7in. weapon, the shell took about ten seconds to reach an aircraft at a slant range of 17,000ft from the gun. During those ten seconds, a bomber flying at 180mph covered exactly half a mile. Thus to inflict damage on that aircraft, the gunners needed to aim their weapons, and fuse their shells to explode, at a point exactly 880 yards in front of the target's observed position.

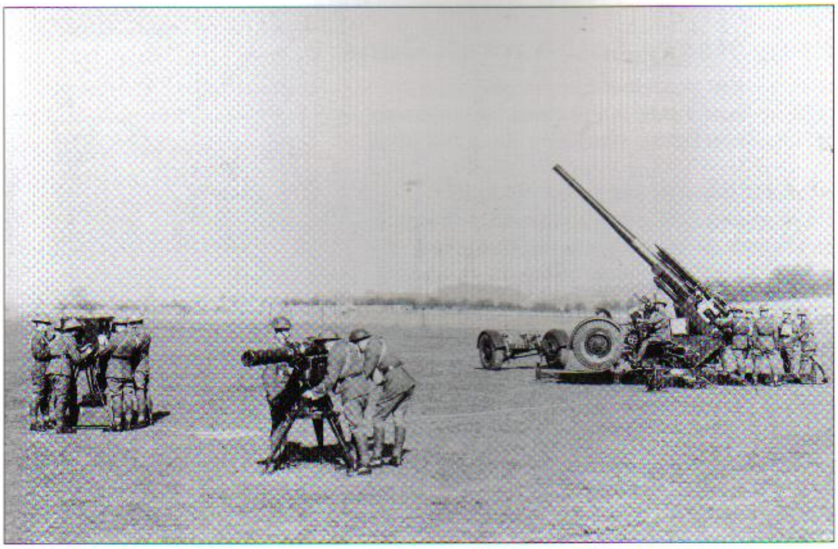
The predictor, and the height-finder beside it, produced the necessary fire-control solution. Taking information from the height-finder, the predictor established the aircraft's previous flight path. From that it calculated where the aircraft *would be* when the shells reached it. The predictor disgorged that information in the form of azimuth and elevation settings for the guns and time-of-flight fuse settings for the shells. This information was passed electrically to the individual guns, whose crews tracked the target's predicted position, fused the shells and fired their weapons.

Of course, a bomber crew could upset the gunners' aim by flying a meandering path through the gun-defended area. But the guns were sited to cover the approaches to targets, so any 'jinking' during the bombing run would cause the bombs to impact well clear of the target. The prevention of accurate bombing was the most important role of the anti-aircraft gunners.

At the beginning of the war, heavy anti-aircraft gun batteries relied on sound locators to detect the approach of bombers at night. The drawback of the sound locator for this purpose was that its capabilities fell far short of the performance of modern bombers. The

The 4.5in. AA gun was the heaviest anti-aircraft weapon in general use. Fired from a static mounting, it fired 55-pound shells at a rate of about eight per minute. The primary purpose of the shield around the gun was to protect the crew from the powerful back-blast when the weapon was fired. (IWM)





The Vickers 3.7in. Mark 1 AA gun was the mainstay of Britain's heavy gun defences throughout the war. This weapon fired 28-pound shells at a rate of about ten per minute. In this staged photograph the gun was shown with its associated Stroud No 1 Mark IV height-finder, centre, and Vickers-Armstrong Predictor No 1 Mark III, left. The normal deployment was in a half-battery of four guns, using targeting information from the same height-finder and predictor. Since the gun sites were themselves liable to come under air attack, protective walls of sandbags or concrete usually surrounded the height-finder, the predictor and the individual guns. (IWM)

standard locator had a maximum range of about 3½ miles. From that distance it took 18 seconds for the aircraft's engine noises, travelling at the speed of sound, to reach the instrument. However, during that time an aircraft flying at 180mph covered 1 mile. So the sound locator's bearing lagged the aircraft's actual bearing by that amount. During peace-time trials it had seemed that the sound locators might provide an approximate position for the enemy plane, to serve as a starting point from which searchlights could commence their search. We shall observe their actual effectiveness in war in a later chapter.

Once searchlights had illuminated an enemy plane, fighters or guns could engage it visually. The searchlight was an effective form of air defence in its own right, however. If one or more searchlight beams held a bomber in their glare, that obscured the target and forced the crew to take violent evasive action to escape.

Against low-flying raiders the most capable weapon was the 40mm Bofors gun. Designed in Sweden, this excellent weapon fired 2-pound impact-fused high-explosive shells at a maximum rate of 120 per minute. It was effective against targets up to about 10,000ft, and it was particularly dangerous against dive bombers. During the early part of the war Bofors guns were usually fired over open sights. In 1939 the only thing to be said against this weapon was that there were far too few of them. At the outbreak of war only 253 were available, against a requirement of 1,860 to defend the full range of potential targets.

The final element of the defence was the barrage balloon, of which 624 were available at the beginning of the war against a requirement of 1,450. The LZ (Low Zone) balloon was just over 62ft long and 25ft in diameter, and had a hydrogen capacity of about 19,000 cubic feet. The operation of the LZ balloon, and the clever double parachute link system which it made highly effective against aircraft, are described on Plate D and its associated commentary.

That, then, was the line-up of the potential attackers and the defenders during the months immediately following the outbreak of World War II. Yet when the attack finally came it would be quite different, both in its size and its shape, from that envisaged before the conflict.

Box 2: Principles of Siting Heavy Anti Aircraft Guns

A high-level raiding force could approach a target from almost any direction, so heavy AA guns were deployed to provide all-round cover. In this case, the vulnerable point to be protected was an important munitions factory measuring about 500 yards by 500 yards.

Typically, German twin-engined bombers of the early war period delivered horizontal attacks from around 16,000ft at an airspeed of about 180mph. Although a main purpose of heavy AA gunfire was to shoot down enemy planes, their main effect was to disrupt attacks and thereby reduce their accuracy. The raiders were vulnerable to AA fire during the final minute and a half before bomb release when, to achieve accuracy, they needed to fly straight and level for the bombing run of about 2 miles and preferably longer.

The most likely type of attack against a pin-point target of this type was the pattern bombing attack. As they entered the bombing run, the bombers tightened formation. The bomb aimer in the leading aircraft directed the flight path of his aircraft, and the other bombers followed him. When he released his stick of bombs, the other planes in the formation released theirs to produce a pattern of hits on the target. In that way the most experienced bomb-aimer aimed the bombs of the entire formation. In recognition of its importance, therefore, the formation leader's aircraft was the aiming point for defending AA gunners during an engagement.

To counter such an attack four heavy AA gun troops, each with four guns, were sited in a square pattern around the target and about a mile from it. Against an aircraft flying at 16,000 feet, the 3.7in. AA gun had a maximum range of 5½ miles. The limit of the gun engagement zone was, therefore, the circumference of a near circle of radius 6½ miles centred on the target – the 5½ mile range of the gun, plus the 1 mile separation between the gun sites and the target (see opposite). As the raiding force approached the target, while still outside gun range, the height finder and predictor operators at each gun site tracked the leading aircraft and the gunners trained their weapons on the predicted aiming point ahead of it.

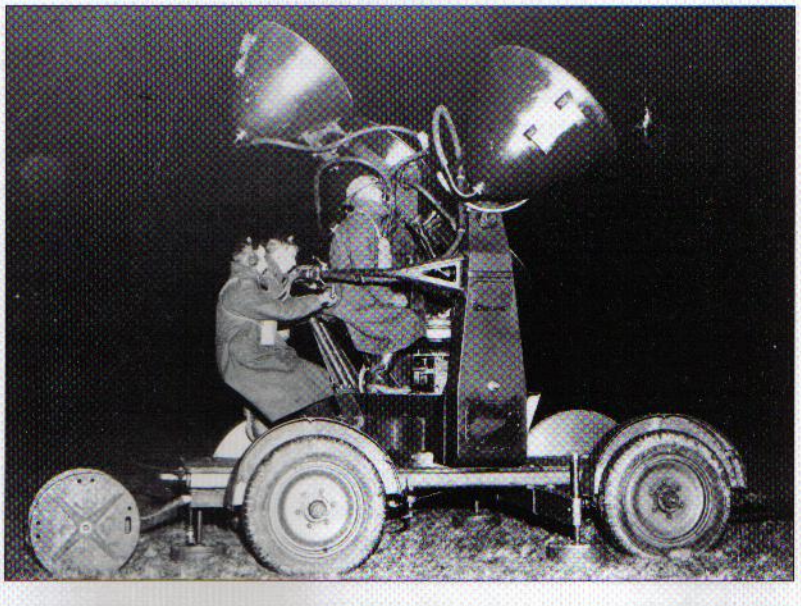
As the leader crossed the 6½-mile circle and came within range of the nearest gun site, it commenced firing. By the time the leader commenced his bombing runs, all four gun sites had him in range and were engaging him with continuously aimed predicted fire.

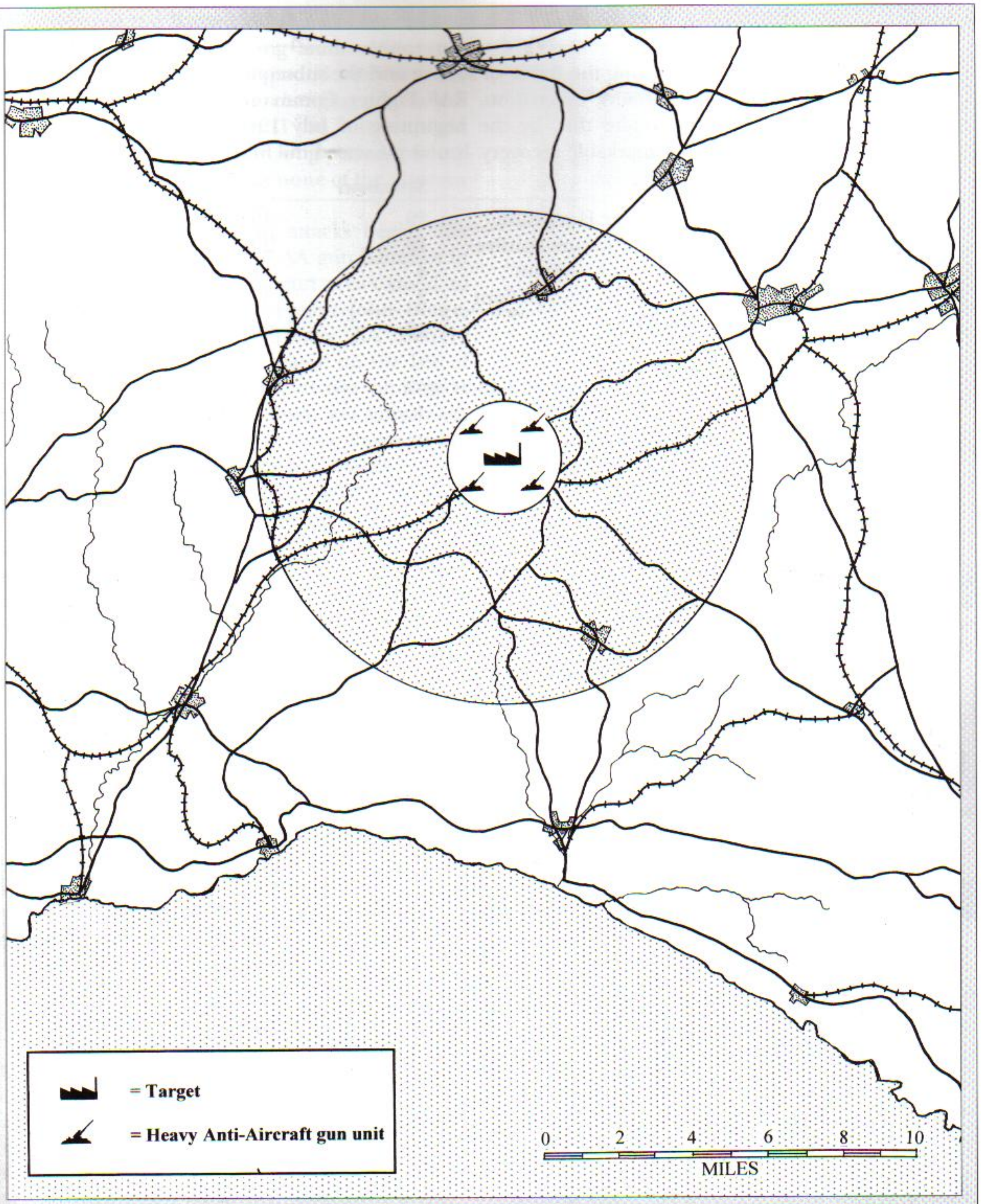
If their fire was accurate , it took a brave and determined flyer to maintain a straight flight path in the face of that degree of harassment.

Bombs released from 16,000 feet at 180mph had a forward throw (the distance they travelled forward, between release and impact) of about 1½ miles. Thus, a circle of radius 1½ miles from the target marked the line of bomb release. Once the bombers had crossed that line and released their bombs, no further disruption of their attack was possible. If another formation of bombers followed the first, the gunners now shifted their fire to engage the leading aircraft in the second formation.

If there was only one formation, the gunners engaged these bombers for as long as they remained within range. However, once it had released its bombs, a formation could confuse the predictors and reduce the accuracy of gunfire by flying an irregular weaving path and varying its altitude.

Prior to the introduction of radar to direct searchlights and AA guns, ground defence units had only sound locators to assist them to locate and track enemy aircraft at night. The Mark V Sound Locator, the most modern type available at the beginning of the war, was barely effective when tracking the engine noises from a single aircraft. If more than one plane was present in its area, a sound locator became swamped and produced little usable information.




= Target
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MILES

THE BATTLE OF BRITAIN

During the Battle of France and the subsequent operation to cover the Dunkirk evacuation, RAF Fighter Command lost about 300 aircraft. Despite this, by the beginning of July 1940 the force had made a remarkable recovery. It now possessed the following aircraft:

Type	*Squadrons*	*Strength*	*Reserve*
Hawker Hurricane	29	462	170
Supermarine Spitfire	19	292	97
Bristol Blenheim	8	114	About 50
Boulton Paul Defiant	2	37	20
Totals	**58**	**905**	**About 337**

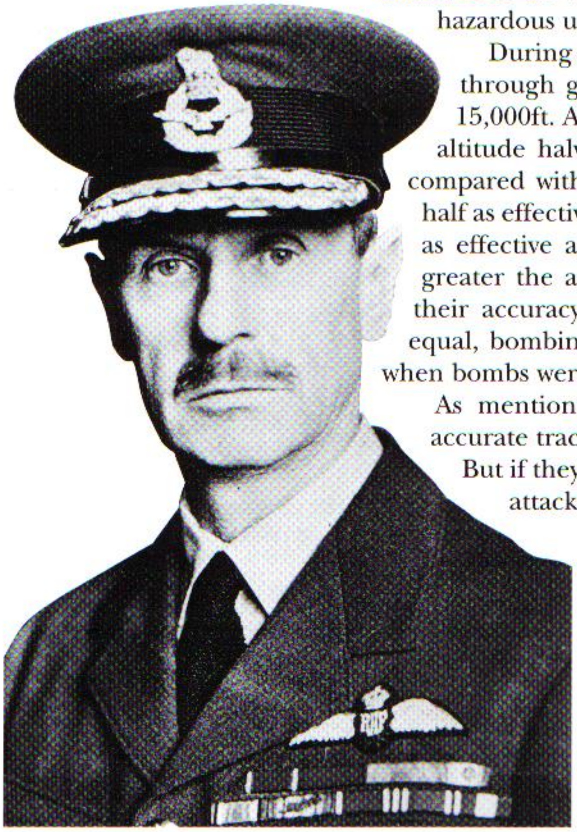
The fighters and their ground control system constituted the main element of the defences during the Battle of Britain, and these have been described in detail in many other accounts. Another important part, often neglected in published accounts of the Battle, was that played by the anti-aircraft gun batteries. Although the gunners' primary aim was to destroy enemy aircraft, only rarely were they able to achieve that desirable objective. If they were deployed in sufficient numbers, however, they were consistently successful in protecting targets from accurate attack. To achieve accurate bombing, raiding aircraft would have liked to fly straight and level bombing runs by day, in clear skies, at altitudes around 5,000ft. The heavy guns and prediction systems available at the beginning of the war would make that an extremely hazardous undertaking, however.

During their attacks in 1940, Luftwaffe bombers flying through gun-defended areas usually did so at altitudes above 15,000ft. As a rough guide, each 5,000ft increase in an aircraft's altitude halved the accuracy of anti-aircraft fire. That is to say, compared with their effectiveness at 5,000ft, the guns were about half as effective against aircraft at 10,000ft and only about a quarter as effective against aircraft at 15,000ft. On the other hand, the greater the altitude from which bombs were released, the lower their accuracy. Again as a rough guide, and other things being equal, bombing errors from 15,000ft were about twice as great as when bombs were dropped from 5,000ft.

As mentioned in the previous chapter, bomber crews facing accurate tracking fire could throw the gunners off aim by jinking. But if they did that during a bombing run, the accuracy of their attack was greatly reduced.

To sum up: accurate iron going up will prevent accurate iron coming down. In the narrowest sense every German bomber that attacked from 10,000ft or higher, or which jinked when flying through the target area, represented a minor victory for British anti-aircraft gunners. Moreover, any target that lacked effective AA gun protection was liable to suffer concentrated devastation.

Gunner Peter Erwood, who served with the 75th Heavy AA Regiment at a 3.7in. gun site near Dover,



Air Chief Marshal Sir Hugh Dowding, Commander in Chief RAF Fighter Command during the Battle of Britain.

remembered the Battle of Britain as 'one almost continuous grind of carrying ammunition (two 56-pound cartridges in a 28-pound steel box, 140 pounds in all, one per man), changing gun barrels when they were worn down (1 ton between eight men, lifted nearly 5 feet) and long periods of duty. We worked bloody hard, with none of the glamour enjoyed by the fighter pilots.'

Once the German night attacks began, life became even harder for the AA gun batteries in the south of England, with gun crews stood to almost round the clock. Sergeant John Burge, serving with the 163rd Heavy AA Battery equipped with 3.7in. guns located on the Isle of Grain, recalled: 'During the Battle of Britain sleep was always on a cat nap basis. We stayed with the guns, we ate with the guns, and if there was a lull in the fighting we slept with the guns.'

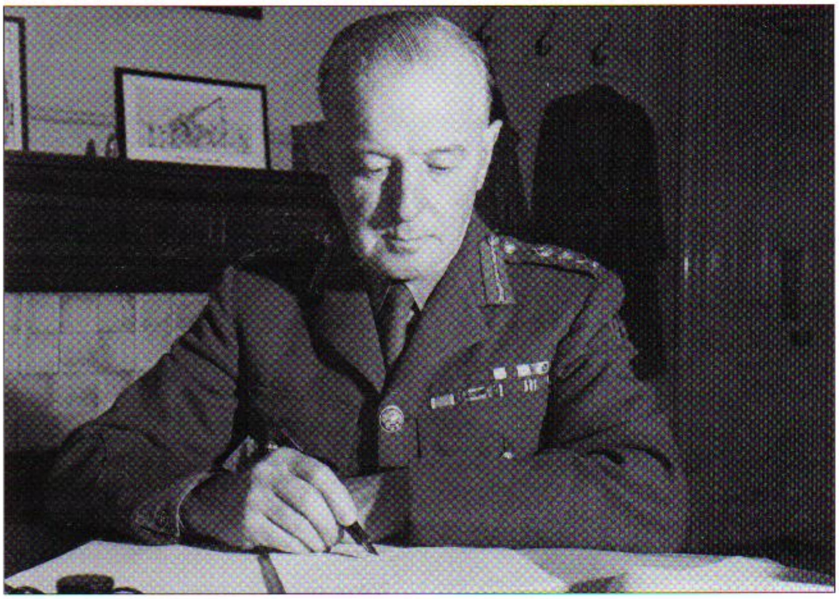
There have been numerous day by day accounts of air combats during the Battle of Britain, and it is not intended to repeat those stories here. In this account it is necessary to show the working of the air defence system, however. For that purpose we shall examine the defenders' reaction to three representative types of daylight attack during the summer and autumn of 1940: the low-altitude attack on Kenley airfield on 18 August, the large-scale attack aimed at dock areas to the east of London on 15 September, and the fighter-bomber attack on London on 15 October.

A Heinkel 111 releasing a stick of 110-pound bombs.

Low-Altitude Attack on Kenley Airfield on 18 August

On Sunday 18 August, nine Dornier Do 17s of the 9th Staffel of Kampfgeschwader 76 set out to deliver an attack on the important Fighter Command airfield at Kenley. The unit specialised in low-altitude attacks, and each aircraft carried a 20mm Oerlikon cannon in the nose to engage ground targets.

The Staffel took off from its base at Cormeilles-en-Vexin north of Paris and headed out over the English Channel, descending to 60ft above the sea to remain below the British radar cover. Near Beachy Head the bombers crossed the coast and headed for Burgess Hill, where the seven tall chimneys of a brickworks provided a dis-



General Fredrick Pile, commander of Anti-Aircraft Command throughout the war. Although an army formation, this came under the operational control of RAF Fighter Command. (IWM)

tinctive landmark. From there the Dorniers headed almost due north, for much of the way following the main London to Brighton rail line which ran past Kenley.

Although as yet there had been no serious defensive reaction, the low-flying Dorniers had not passed unnoticed. Observer Corps Post K3, situated on top of Beachy Head, had reported the raiders' strength, heading and other details to its headquarters at Horsham. From there, the report was relayed to the Fighter Command Filter Room, then to the various Group and Sector operations rooms. As the bombers headed inland, other posts passed reports of their progress.

Dornier 17 of KG 76 pictured low over Sussex, on its way to bomb Kenley airfield on 18 August 1940. The proximity of the shadow indicates that the aircraft was flying at about 70ft.

In the operations room at Kenley the station commander, Wing Commander Thomas Prickman, had been watching his station's fighter squadrons being vectored to intercept high-altitude raiding forces coming in from the south-east. Then another marker appeared on the plotting table, showing the low-flyers heading across Sussex. The only fighters in his sector that were not yet committed were No. 111 Squadron's 12 Hurricanes, waiting at readiness at Croydon. Prickman ordered the unit to scramble and patrol over Kenley at 3,000ft.

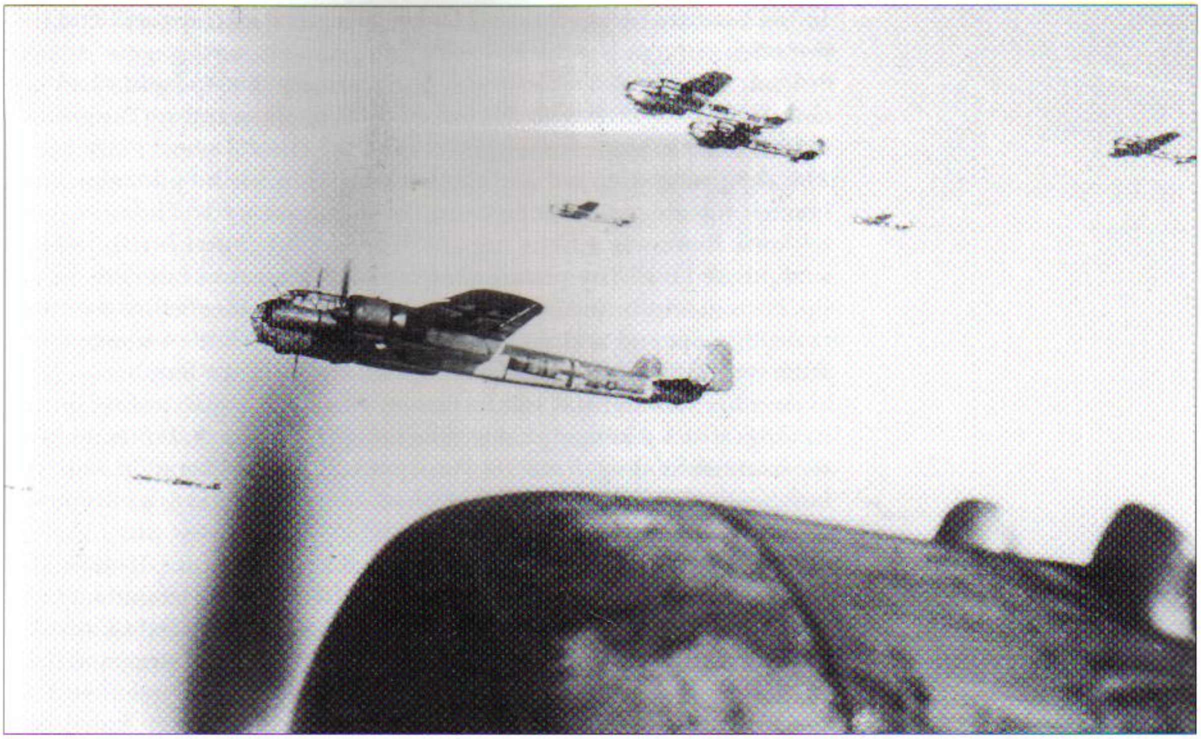
After a flight of 40 minutes over enemy territory, the Dorniers arrived just south of Kenley. As they pulled up to clear the North Downs, the men on board caught their first glimpse of the airfield's buildings poking up above a line of trees. Each crew picked out its assigned target, and commenced its bombing run. At first it seemed the raiders had achieved complete surprise, but this was not so.

Thanks to the efficient plotting of the low flyers' progress by the Observer Corps, Kenley's ground defences were at full alert. The gun defences comprised four 40mm Bofors guns, two obsolete 3in. anti-aircraft guns and about twenty Lewis .303in. machine guns. Also, along the northern edge of the airfield, there was a line of parachute-and-cable launchers; this unconventional 'secret weapon' had yet to be used in action.

As the Dorniers swept in towards the airfield, Kenley's gunners opened fire. Unteroffizier Guenther Unger, piloting one of the bombers, saw strings of tracer rounds flash past his cockpit. He pushed the aircraft yet lower and headed for his targets, two of the hangars. Moments later,

Box 3: The Parachute-and-Cable System

Launched vertically into the path of low-flying enemy aircraft, this unconventional weapon was fired in nine-round salvoes from a row of launchers on the ground. The weapon comprised a 480ft length of steel cable suspended from a parachute which opened automatically when the rocket reached the top of its climb at about 600ft. When an aircraft struck the cable and started to carry it forwards, the shock of the impact caused the opening of a second drag parachute attached to the bottom end of the cable. If the contraption snagged on the wing or any other part of an aircraft, the combined drag from the two parachutes imposed a violent deceleration that was usually sufficient to cause the machine to stall and fall out of the sky in an uncontrollable dive.



Dornier 17s of Kampfgeschwader 76 climbing to altitude during the Battle of Britain.

machine-gun rounds thudded into his right engine and brought it to a smoking stop. Unger feathered the propeller and struggled to hold the Dornier straight, as his navigator released the bombs in one long stick.

Unteroffizier Schumacher, piloting another Dornier, watched the bombs from the leading aircraft ram into the hangers: 'Other bombs were bouncing down the runway like rubber balls. Hell was let loose. Then the bombs began their work of destruction. Three hangers collapsed like matchwood. Explosion followed explosion, flames leapt into the sky. It seemed as if my aircraft was grabbed by some giant.'

Machine-gun rounds rammed into that bomber too, leaving a smell of phosphorous and smouldering cables with several of the plane's instruments smashed. Then Schumacher's left engine was hit and started to lose power.

In another Dornier a machine-gun round hit the pilot in the chest. As his body slumped forwards, the navigator, Oberfeldwebel Wilhelm Illg, leaned over the unconscious man and grabbed the controls to prevent the aircraft smashing into the ground.

Having releasing their bombs on the hangars and other buildings on the south side, the bombers skimmed low over the landing ground to make good their escape. Ahead of them lay the line of nine parachute-and-cable launchers intended to counter just such an attack. As the operator saw three enemy bombers coming straight for him, he pushed the firing button. With a united 'Whoosh!', nine rockets soared vertically into the sky in a salvo, each one leaving a dense trail of smoke.

Feldwebel Wilhelm Raab, at the controls of one of the Dorniers, described the strange sight that unfolded in front of him: 'Suddenly red-glowing balls rose up from the ground in front of me. Each one trailed a line of smoke about 1 metre thick behind it, with intervals of

10 to 15 metres between each. I had experienced machine-gun and flak fire often enough but this was something entirely new.'

Raab had no idea what it was, but obviously that spectacle had not been laid on for his health. He jerked the aircraft away from the ground to give room to manoeuvre, then hauled the control wheel to the right. The right wing dropped and the left wing rose, as the pilot aimed his bomber for the gap between two adjacent smoke trails. The next thing he knew there was a hefty tug and his machine yawed briefly, then it straightened out. The plane's wing had struck a cable, but close to the tip. Fortunately for the crew, the cable slid off the wing before the lower parachute opened and took effect. Once past the line of smoke trails, Raab returned to low altitude and sped away from the target.

Another Dornier was less fortunate. Already hit and on fire, one of its wings struck a hanging cable. The device functioned as intended and the combined drag from the two parachutes on one side sent the bomber down out of control. It crashed into the ground just outside the airfield boundary.

The line of cables also threatened the leading Dornier. Its pilot also eased the aircraft up to give room for manoeuvre, then wound on bank to avoid the threat. At that moment a Bofors shell exploded against the left wing, blowing a gaping hole in the structure. Petrol streamed from the shattered fuel tank, then caught fire. The pilot struggled to hold the blazing Dornier in the air while three rear crewmen baled out. Then he took the bomber down and made a crash landing. The pilot and navigator both suffered burns as they fought their way out of the blazing plane.

As the seven surviving Dorniers pulled away from Kenley they came under repeated attack from No. 111 Squadron's Hurricanes, until the

The Hawker Hurricane equipped about two-thirds of Fighter Command's single-seat fighter squadrons in the summer of 1940. It had a maximum speed of about 315mph in Battle of Britain configuration. This example belonged to No 17 Squadron.

latter exhausted their ammunition. As they left the coast, most of the raiders were in poor condition. Two Dorniers, each struggling to maintain height on a single damaged engine, ditched in the English Channel. Two more got back to France, but crash landed soon after crossing the coast. Two further Dorniers made normal landings at airfields near the coast to offload wounded or dead crewman. Only one Dornier returned to Cormeilles without having suffered major damage or a seriously wounded crewman.

Of the 40 men on the Dorniers, nine were killed, three were wounded and five taken prisoner. The attack on Kenley came close to destroying the 9th Staffel, and never again would it operate in the low-level attack role over Britain. The action provides an object lesson on the dangers that face low-flying raiders, if they have lost the element of surprise and their target has effective ground defences.

A few minutes later 27 Dorniers delivered a high-altitude attack on Kenley. Together, the two attacks destroyed three out of Kenley's four hangars, and several other buildings. They destroyed four Hurricanes and a Blenheim fighter on the ground, and inflicted damage on two Hurricanes and a Spitfire. The attack put the airfield out of action, but not for long. Repair teams quickly filled in the craters in the grass runway with rubble, and rolled them flat using a steamroller. Within a couple of hours of the bombing the airfield resumed limited operations. By the following day, Kenley was again fully operational.

Large-Scale Attack on London on 15 September

So much for the defenders' reaction to a small-scale low-altitude attack. At the opposite end of the scale was the large-scale attack on the afternoon of 15 September. Then a force of 114 Dornier 17s and Heinkel 111s set out to bomb dock areas to the east of London: the Royal Victoria and West India docks to the north of the Thames, and the Surrey Commercial Docks to the south of the river.

Escorting the bombers were about 450 Messerschmitt Bf 109s. About one-third of these flew on a large free-hunting patrol to clear the path ahead of the raiders. A similar number of escorts provided open cover for the bomber formations, while the remaining one-third split into five units to provide a close escort for each of the five bomber formations.

Soon after the incoming German force appeared on

Air Vice Marshal Keith Park, a New Zealander, commanded No. 11 Group of Fighter Command during the Battle of Britain. His Group was responsible for the defence of the capital and targets in the important south-eastern sector of Great Britain. (IWM)

The Supermarine Spitfire was the highest performing fighter type in the RAF in the summer of 1940, with a maximum speed of about 350mph in Battle of Britain configuration. This example belonged to No 72 Squadron.

his plotting table, Air Vice Marshal Keith Park scrambled four squadrons of Spitfires and eight squadrons of Hurricanes. These fighters were ordered to climb to fighting altitude and patrol over Sheerness, Chelmsford, Hornchurch, Northolt and Kenley, to await developments. In the minutes to follow, the other squadrons were scrambled to join them.

After it crossed the coast of Kent at Dungeness, the vanguard of the raiding force wheeled on to a north-north-westerly heading. The bombers were arrayed in five separate Gruppe-sized formations, the smallest with 18 and the largest with 29 aircraft, stepped up in altitude from 16,000ft. The three leading Gruppen flew in line abreast, 3 miles apart; the remaining two Gruppen flew, respectively, 3 miles behind the left and the right Gruppen flying in the lead.

Soon after the bombers crossed the coast the three forward-deployed Spitfire units, No.s 41, 92 and 222 Squadrons with a total of 27 fighters, went into action. The escorting Messerschmitts quickly moved into position to block the attacks and the action developed into a series of swirling combats between the opposing fighters.

As the first of Keith Park's fighters went into action, the last of his day fighter units were getting airborne. No. 11 Group possessed 21 squadrons of Spitfires and Hurricanes, and every one of these was now committed. From No. 12 Group in the north, Squadron Leader Douglas Bader moved on the capital at the head of his five-squadron 'Big Wing'. From No. 10 Group in the west, a squadron of Spitfires and one of Hurricanes were also on their way to engage the raiders. Fighter Command was committing all 276 of the Spitfires and Hurricanes based close enough to the capital to assist in its defence.

Although No. 11 Group and the units based in adjacent sectors in No.s 10 and 12 Groups were at full stretch, it should not be imagined that Fighter Command as a whole was fully committed. Air Chief Marshal Dowding's safety-first strategy was to commit during each action sufficient fighters to give the enemy a bloody nose, but not to risk the bulk of his units in a single do-or-die battle. At airfields spread throughout the rest of the country, more than 500 serviceable Spitfires and Hurricanes stood ready to meet attacks in their areas or replace hard-hit units in the south.

Meanwhile, Keith Park fed more fighters into the running battle. Five minutes after the three forward-deployed Spitfire squadrons went into action, two squadrons of Hurricanes engaged the raiders. Five minutes after that, two more squadrons of Hurricanes were vectored in to attack. Those engagements maintained a continual pressure on the raiding force as it flew across Kent.

The raiders' route took them close to the important Royal Navy base at Chatham, defended by 20 4.5in. and eight 3.7in. guns. Oberleutnant Peter Schierning, navigator in a Heinkel of Kampfgeschwader 53, saw series of black lumps suddenly appear in the sky around him and blasts from the exploding shells rocked the bomber. Within seconds the smoke puffs had been left behind, but by then the damage had been done. Schierning recalled: 'One of the first salvoes knocked out our right motor. We felt no shock, but the motor slowly wound down. The pilot shouted "Get rid of the bombs! Get rid of the bombs! I can't hold it!" I jettisoned the bombs over farm land.' Unable to keep up with the formation, the wounded bomber made a steep diving turn and its pilot headed for the protection of a bank of cloud. Another German bomber suffered a similar fate, and it too left the formation and sought safety in cloud.

When the AA gunners had opened fire, several British fighters were still engaging the bombers. German bomber crews were impressed with that, and the official Luftwaffe report on the action later commented: 'The [enemy] fighters pressed home their attacks either singly or in pairs, without regard for the flak…' The British side of the story is rather different. When friendly fighters attacked the enemy planes, AA gunners should have ceased fire. That did not happen. Flying Officer B. MacNamara of No. 603 Squadron was one of those who afterwards complained,

Bomb damage at Austin Friars in the city of London.

'Throughout this attack I was troubled by heavy AA fire, which did not cease despite the fact that I had commenced an attack on the enemy, and shells were continually bursting very close to my aircraft.' Later, the offending anti-aircraft batteries would receive stern reprimands.

Meanwhile, Keith Park had assembled the bulk of his fighter units immediately in front of London: 19 squadrons of fighters, with 185 Spitfires and Hurricanes. He chose to fight his main engagement there, deep inside home territory where he knew the escorting Messerschmitt 109s would be running short of fuel and near the limit of their combat radius of action.

On the way to the target defending fighters and AA guns knocked down, or forced to turn back, 13 German bombers. Yet all five German bomber formations reached the outskirts of London more or less intact. When they arrived their crews were dismayed to find that banks of cloud protected the targets far more effectively than any human-mounted form of defence: nine-tenths cumulus and strato-cumulus, with tops extending to 12,000ft. None of the dock areas earmarked for attack was visible, though there were clear skies over West Ham. Two Gruppen of Heinkels and one of Dorniers re-aligned their attack runs on the borough and the Bromley by Bow gasworks nearby, causing widespread damage in those areas. The two other Dornier Gruppen dropped their bombs on targets of opportunity in Kent on the way home.

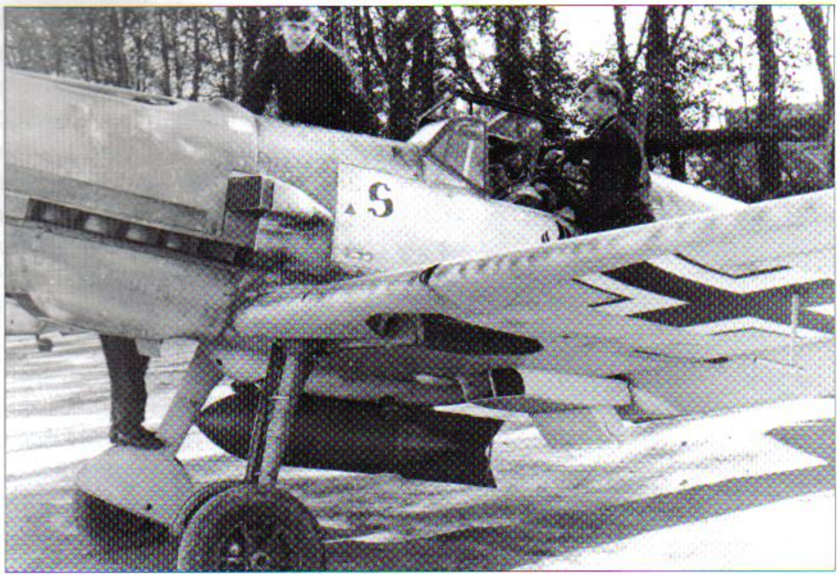
Over Kent, those German bombers forced out of formation engaged in a deadly game of hide-and-seek with the defending fighters. Peter Schierning's Heinkel, limping home with one engine wrecked by AA fire, was one of these. Suddenly both the cloud and the crew's luck ran out, and the Heinkel came under attack from a couple of Hurricanes and a Spitfire. They quickly finished it off, and the bomber crash-landed near Staplehurst.

During this action the RAF system of fighter control performed almost faultlessly. Twenty-eight squadrons of fighters had been scrambled, and every one engaged the enemy. In the course of that action, and another earlier in the day, the Luftwaffe lost 56 fighters and bombers. RAF Fighter Command lost 29 aircraft.

After the day's fighting, Fighter Command issued an exaggerated claim that fighters and AA guns had destroyed 185 German planes. That error would not be corrected until some time after the war, when the official German loss records became available.

Wrecked Magister training aircraft, in one of the bombed hangars at Manston. This airfield was attacked the most often and the most severely during the Battle.

Fighter-Bomber attacks on London on 15 October



Messerschmitt Bf 109E fighter-bomber of JG 26 carrying a 550-pound bomb under the fuselage. During the final phase of the Battle of Britain, these aircraft made several high-altitude attacks on London. With the small bomb loads and poor bombing accuracy, however, the raids had little effect.

Following the action on 15 September, the Luftwaffe wound down its programme of large-scale daylight attacks on Britain using twin-engined bombers. Yet the Battle of Britain still had one further phase to run. From mid-September the Luftwaffe attacked London using small forces of fighter-bombers. The bulk of these attacks were by Messerschmitt Bf 109s, each carrying one 550-pounder or a similar weight of smaller weapons; sometimes Messerschmitt Bf 110s took part, each carrying 2,200 pounds of bombs.

In contrast with the attacks by twin-engined bombers, the Luftwaffe fighter-bombers and their escorts ran in to attack at higher speeds, around 240mph, and at higher altitudes, between 26,000ft and 33,000ft. Their escorts had no need to zigzag to maintain station on their charges, so they could reach the capital with relative ease. At those altitudes the Bf 109 had an edge in performance over the Spitfire, and a considerable edge in performance over the Hurricane. Moreover, since at a distance it was impossible to distinguish the fighter-bombers from their escorts, the RAF fighter pilots had to treat all the raiders as fighters and approach them with caution.

The new form of attack presented Fighter Command with a difficult interception problem. With the greater speed and altitude of these raiders, radar gave less warning time than previously. If the RAF fighters scrambled on the first radar warning of an incoming attack, they could not reach the raiders' altitude and intercept the fighter-bombers before the latter reached the capital and dropped their bombs. So Fighter Command was forced to resort to an inefficient system of standing patrols. Fighters took off and patrolled at altitudes around 10,000ft, the highest they could go without pilots needing to use their limited supply of oxygen. On the approach of raiders the fighters resumed their climbs, hoping to intercept the enemy formations and force the fighter-bombers to jettison their bombs short of the targets.

The attacks on 15 October were mounted by Bf 109s only. A force of about 30 fighter-bombers and escorts reached London at about 9am and attacked Waterloo station and rail lines there and at Vauxhall. Three quarters of an hour later came a second wave, this time with some 50 fighter-bombers and escorts, which bombed the area around Tower Bridge. At 11.30am yet another formation of Messerschmitts attacked the Southwark area.

This phase of the Battle saw relatively few combats, with light losses on both sides. On that day the Luftwaffe lost five Bf 109s, while the RAF lost four Spitfires and eight Hurricanes. On a straight count, therefore, victory went to the attackers. Yet these attacks achieved little of military value. The fighter-bombers carried small bomb loads, which they released in shallow dives from around 18,000ft. Pilots had only their gunsights for aiming, and accuracy was poor. Usually the bombs fell over a wide area and caused little damage. In truth, these raids served merely to provide a token Luftwaffe presence by day in the skies over southern England. The nuisance raids tapered off during October, and ceased altogether in the following month.

The Battle Summed Up

When the Battle petered out from the end of October, Fighter Command was as active as ever. During its attempt to knock out the Command as an effective fighting force between 10 July and 31 October, the Luftwaffe lost 1,733 aircraft. Fighter Command lost 915 fighters. More to the point, for the first time during the conflict the German war machine had set itself a major objective and patently failed to achieve it. Great Britain was not yet strong enough to switch over to the offensive, but her military strength would grow with each month that passed. Yet, as we shall observe in the next chapter, at first Britain's air defences could do little to counter the damaging night attacks on the nation's cities.

COUNTERING THE NIGHT RAIDER

The Luftwaffe launched its first large-scale night raid on Great Britain on 28 August 1940, when 160 bombers attacked Liverpool. The raiders returned to the port in similar strength on the next three nights, and again on the nights of 4, 5 and 6 September. These raids ran in parallel with the daylight attacks described in the previous chapter. So began the

The morning after the night before ... Bomb damage at Tottenham Court Road following a heavy night attack on the capital.

long-running 'Night Blitz' on Britain, which would cause enormous damage and large numbers of casualties.

Initially Britain's defences against night attacks were woefully inadequate, and the raiders suffered minimal losses. During 1940 and the early part of 1941, the Luftwaffe lost far more planes in flying accidents than to the fighter and AA gun defences combined.

On 7 September the Luftwaffe shifted the focus of its attack to the dock areas to the east of London, with a large-scale daylight raid followed by another after dark. Together, the two raids involved more than 600 bomber sorties. The attacks started huge fires among the warehouses, many of which were still burning when dawn broke. Firemen fought desperate battles during the daylight hours of 8 September to control the fires, but several resisted their efforts. Thus there was light aplenty to guide the 207 bombers which returned to the city after dark. The raiders extended the previous fires, and kindled new ones.

The bombers would return in force to the capital on the following night and, with one exception due to bad weather, on each of the 65 nights that followed.

Box 4: Types of Heavy Anti-Aircraft Gun Engagement

When engaging aircraft, Heavy AA Gun batteries usually employed one of three methods: continuously pointed fire, predicted concentration fire or a box barrage.

Continuously Pointed fire was the most dangerous type of AA fire. Each gun unit tracked the target aircraft, usually the formation leader, at a predicted distance in the sky in front of it. The guns fired at maximum rate, for as long as the target aircraft remained within range or until it crossed the bomb release line. For this type of fire the predictors and height finders needed to have the aircraft continuously in view to allow visual aiming, either by day or at night illuminated by searchlights. Or they needed high quality radar information (i.e. from the GL Mark III radar) on the target's track.

Predicted Concentration fire was less effective than continuously pointed fire. It was used when darkness or cloud prevented visual fire control, or when radar information was of low quality (i.e. from the GL Mark I radar with the Elevation Finding attachment, or from the GL Mark II radar). The gunners fired short barrages at points in the sky through which it was predicted the target aircraft would pass.

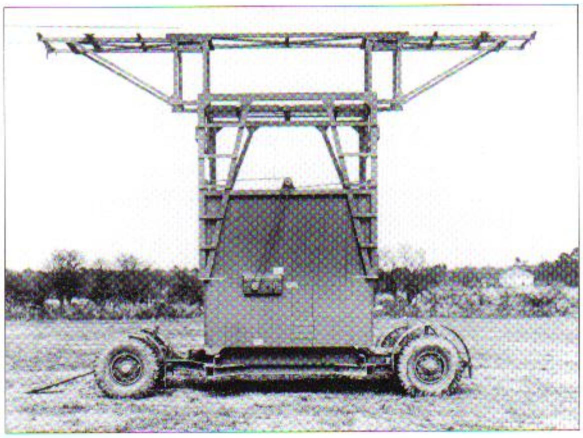
Box Barrage fire was the least effective and the most wasteful type of AA fire. It was used when darkness or cloud prevented the use of other fire-control methods, and good information was not available on the location of targets. The gunners fired into a box of sky just in front of the bomb release line in front of the bombers' supposed target. The so-called 'London Barrage' involved this type of fire.

Weak Defences

Initially the night bombers operated over Britain at will. The searchlight batteries relied on sound locators to guide their beams on to the bombers, but with little success. The locators gave only an imprecise indication of the whereabouts of an enemy plane; if several planes were present in the area, the engine noises swamped the locators.

Earlier in the war, the first Gunlaying Mark I (GL I) radars went into service at AA gun batteries. The new equipment operated on frequencies in the 54 to 84 MHz range. Strictly speaking the term 'Gunlaying' was a misnomer when applied to this equipment, for it had not been designed to perform that task. 'Gun-Assisting Radar' more accurately described its capabilities. Although it gave accurate ranges on enemy aircraft, the azimuth indications were imprecise and it could not measure elevation. By itself the radar was, therefore, incapable of directing anti-aircraft fire with even a low degree of accuracy. Those limitations were recognised at the time, but it was important to get the radar into service so AA gunners could gain experience with the device ready for when better equipment became available.

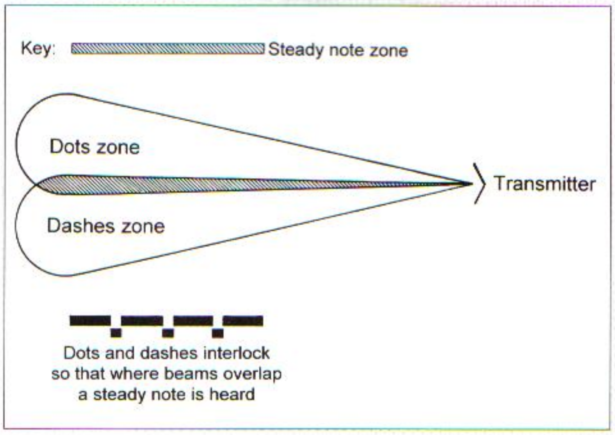
On occasions searchlights working independently were effective in illuminating bombers



The Gunlaying Mark I radar in its original form, with no elevation-measuring capability.

Box 5: The Battle of the Beams

Initially, Luftwaffe bomber crews used the so-called *Knickebein* (bent leg) radio beam system to assist them to locate targets at night. In Germany and occupied France, Holland and Norway, 11 powerful transmitters were in position to project the guiding beams over Great Britain. In the Luftwaffe bomber, the pilot heard a series of Morse dots if he was to the left of the beam, or a series of Morse dashes if he was flying to the right of it. The Morse dots and dashes interlocked, so that when the aircraft was in the centre of the beam the pilot heard a steady note. To mark a target for attack, one *Knickebein* beam guided the aircraft along the approach path, while a second beam crossed the first at the bomb release point. *Knickebein* was a simple system that could be used by all German twin-engined bombers.


Key:
Steady note zone
Dots zone
Dashes zone
Transmitter
Dots and dashes interlock so that where beams overlap a steady note is heard

The British Intelligence service soon discovered the working of *Knickebein*, and recognised the grave threat it posed to Britain's cities. Briefed by his scientific advisors of the seriousness of the menace, Winston Churchill ordered the immediate formation of a suitable radio-jamming organisation.

By the autumn of 1940 the jamming organisation, designated No. 80 Wing, was ready to begin operations. Under the command of Wing Commander Edward Addison, the unit rapidly built up to strength of 180 men and women.

At the Telecommunications Research Establishment at Swanage, Dr Robert Cockburn headed the small team which built jamming transmitters code-named 'Aspirins'. The Aspirin radiated Morse dashes on the beam frequencies. These Morse dashes were not synchronised with the beam signals, rather they were superimposed on top of them. The idea was that when a German pilot entered the dash zone, he would turn in the required direction. But when he arrived in what should have been the steady note lane, he continued to hear dashes. When he reached the dot zone, he heard dots and dashes which did not resolve into a clear note.

Both during and since the war there have ben stories that the RAF deliberately 'bent' the beams. These stores are untrue. The normal method of jamming *Knickebein* was to radiate unsynchronised Morse dashes on the beam frequencies. It is possible that on occasions British dashes and German dots came together to produce some sort of 'bent' beam. But there was never any deliberate 'beam aiming'.

Even when the Aspirin jamming failed to blot out the *Knickebein* beam signals, it still had a useful effect. It showed that the defenders were aware of the beams' existence and their location, and the word got around the Luftwaffe bomber force that RAF night-fighters flew along the beams to pick off the bombers. Bomber crews became so concerned about this possibility that they refused to use the beams while over enemy territory. As a result, *Knickebein* passed out of general use. Later the Luftwaffe introduced two further beam systems to locate targets at night, *X-Geraet* ('X-Device') and *Y-Geraet*. These systems, too, were jammed by No. 80 Wing.

ABOVE OPPOSITE
The *Knickebein* beam.

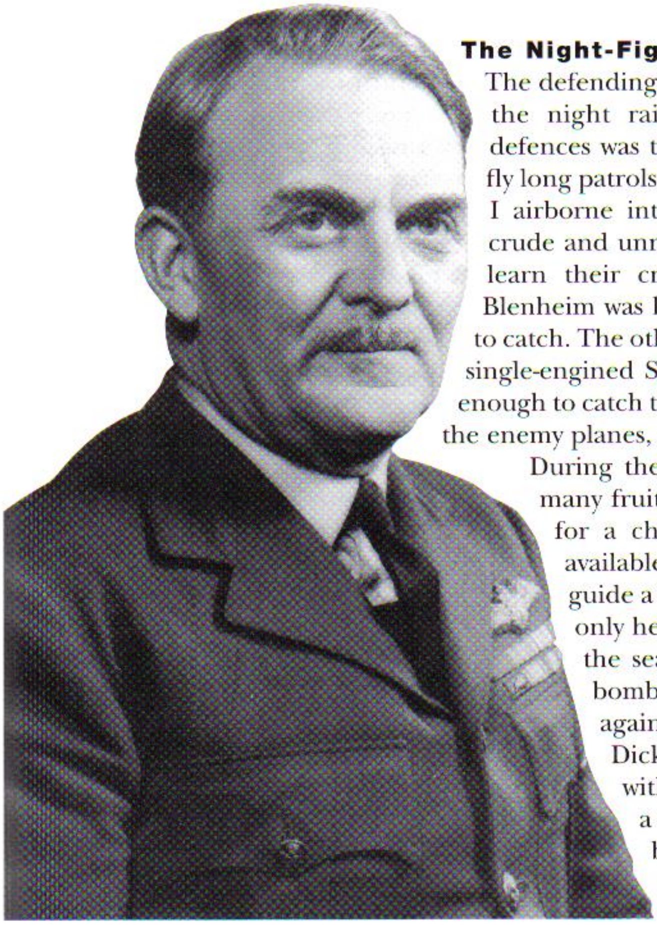
BELOW OPPOSITE
***Knickebein* beam transmitter situated at Stollberg in Schleswig Holstein. The aerial array was about 100ft high and 315ft wide. It rested on railway bogies running on a circular rail track, to allow the beam to be aligned on the target.**

for attack by guns or night fighters, but they spent most of their time sweeping the sky in vain searches. The main types of heavy anti-aircraft fire are outlined in Box 4.

General Frederick Pile, commanding the AA gun and searchlight units, came under strong political pressure to 'do something' about the night raiders. He therefore ordered his gunners to maintain a steady rate of fire while night raids were in progress, even if that meant firing unaimed shells into the sky. Even if the gunners could not provide an effective air defence, they could at least provide the sounds of one. Huddled in their shelters, the capital's citizens could not tell the difference. Later Pile would write: 'The volume of fire which resulted, and which was publicised as a 'barrage', was in fact largely wild and uncontrolled shooting. There were, however, two valuable results from it: the volume of fire had a deterrent effect upon at least some of the German aircrews … there was also a marked improvement in civilian morale.'

During September 1940, AA gunners loosed off a quarter of a million shells at night, most of them into thin air. Their efforts accounted for less than a dozen enemy planes.

At this time No. 80 Wing of the RAF became increasingly prominent in the nightly air actions, with its jamming of the Luftwaffe radio navigation systems. The so-called 'Battle of the Beams' is described in Box 5.

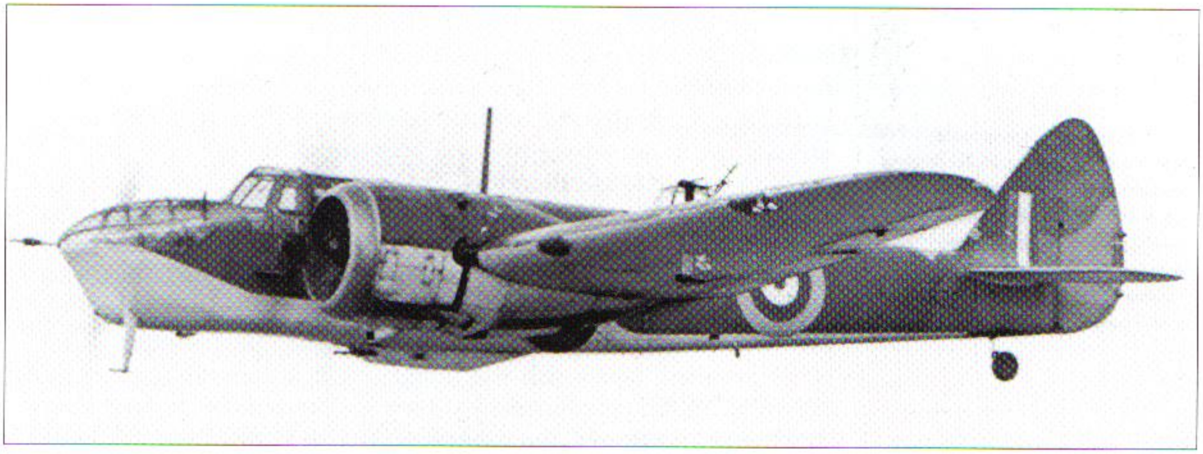


Wing Commander Edward Addison commanded No 80 Wing, which conducted the jamming and spoofing of German radio navigation systems and radio beacons.

The Night-Fighters' Problems

The defending fighter force was no better able to deal with the night raiders. The mainstay of the night-fighter defences was the twin-engined Blenheim. This type could fly long patrols at night, and a few were fitted with the Mark I airborne interception (AI) radar. The equipment was crude and unreliable, and the ill-trained operators had to learn their craft from first principles. Moreoever, the Blenheim was little faster than the enemy bombers it tried to catch. The other RAF fighter types flying night patrols, the single-engined Spitfires, Hurricanes and Defiants, were fast enough to catch the bombers. Yet they lacked the radar to find the enemy planes, and they could not spend long on patrol.

During the final months of 1940, RAF fighters spent many fruitless hours cruising in the darkness, hoping for a chance sighting on an enemy aircraft. The available ground radars were not precise enough to guide a night-fighter into an intercept position. The only help from the ground came occasionally from the searchlights. Yet even when the lights held a bomber in their beams, the odds were stacked against a successful engagement. Pilot Officer Dick Haine, who flew Blenheim night-fighters with No 600 Squadron, recalled: 'It might seem a simple matter for night fighter crews to see bombers which had been illuminated by searchlights, but this was not the case. If the raiders came on bright moonlit nights,



The Bristol Blenheim bore the brunt of the night-fighting patrol effort up to the spring of 1941. With a maximum speed of 266mph and a forward-firing armament of five .303in. Browning machine-guns, it lacked the speed to catch enemy bombers and the firepower to engage them effectively. Moreover, the AI Mark I radar carried in the Blenheim (see the transmitter aerial on the extreme end of the nose) had a poor performance and was unreliable.

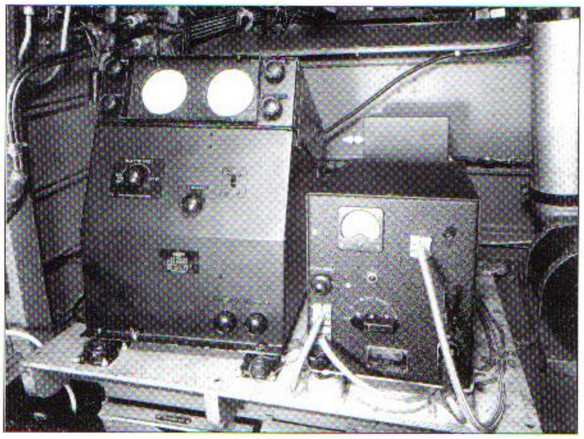
which was usual during this time, the beams from the searchlights were not visible at heights much above 10,000 feet. If the searchlights were actually on the enemy bomber the latter could be seen from some way away, but only if the fighter was underneath the bomber and one could see its illuminated underside; if the fighter was higher than the bomber, the latter remained invisible to the fighter pilot. If there was any haze or cloud it tended to diffuse the beams so that there was no clear intersection to be seen, even if two or more searchlights were accurately following the target.'

Effective New Fighters and Radars

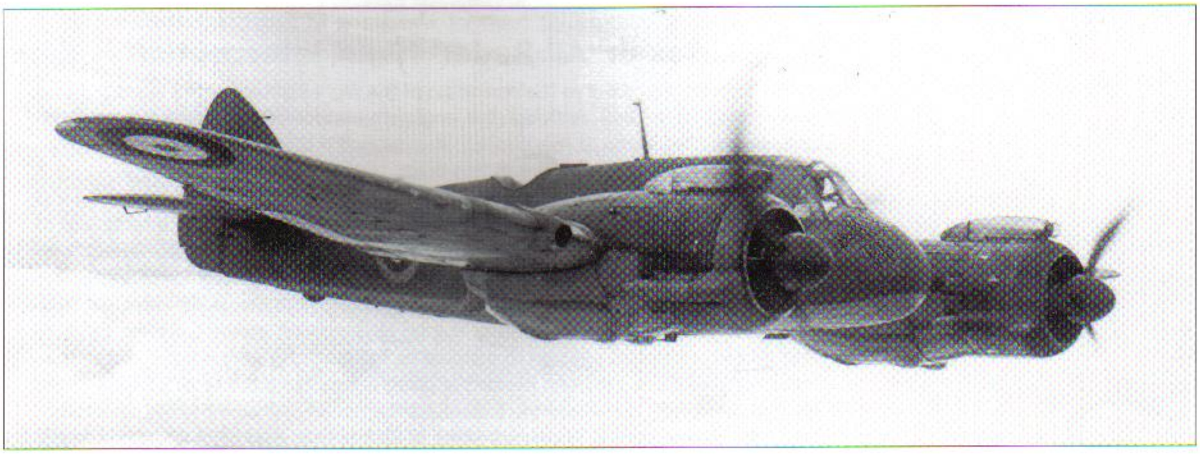
Fighter Command's hopes for the future centred on the twin-engined Bristol Beaufighter, which entered service in September 1940. It was fast, had a good endurance, it was powerfully armed with four 20mm cannon and six machine guns and it carried the more effective AI Mark IV radar. The fighter had been rushed into production, however, and initially it suffered serious teething troubles. Several months would pass before it was available in sufficient numbers to pose a serious threat to night raiders.

In another important innovation, the prototype of the purpose-built Ground Controlled Interception (GCI) radar was up and running at the end of 1940. This medium-range radar was the first to employ the plan position indicator type of display employing the rotating timebase. Nowadays that 'rotating clockface' type of display is familiar to everyone, but at the time it represented a considerable technological advance. The new display allowed a ground controller to see the relative juxtaposition of the night-fighter and the enemy bomber, and so could direct the former into position to engage the latter.

AI Mark I radar installation in the fuselage of a Blenheim night fighter.



By the close of 1940 the main building blocks were in place; and night interception became a structured business. Long-range, low-precision Chain Home radar alerted the defences, enabling the night fighters to scramble in time to reach the bombers' altitude. Medium-range, medium-

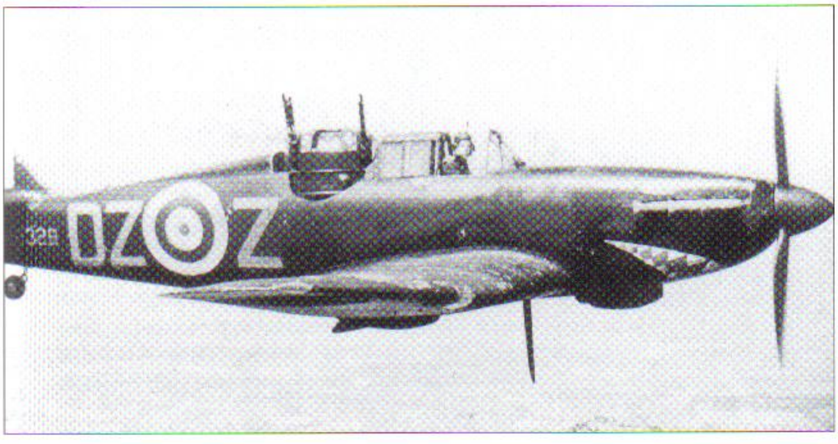


With a maximum speed of 321mph, and an armament of four 20mm Hispano cannon and six .303in. Browning machine guns, the Bristol Beaufighter had the speed to catch enemy bombers and the firepower to knock them down. With the new AI Mark IV radar it became an effective night-fighter. The Beaufighter entered service in the summer of 1940 but suffered from initial teething troubles. When these were overcome, early in the following year, it became a formidable hunter in the night skies over Britain.

precision GCI radar then guided the fighter into position behind the enemy bomber (for a typical interception, see Box 6) and to within range of its short-range, high-precision AI radar. The AI operator then guided the pilot to within visual range of the bomber. Dick Haine described a typical commentary from the radar operator to the pilot, as the former directed the latter to match the night-fighter's altitude, track and speed to those of the bomber before moving in to engage: 'I've got a contact, 3 miles, below and to the right… Come down a bit and go right… Go more right… Steady now… Hold that… Hold that… Right a bit more… OK, hold that… Steady… Steady… Hold that… You're going a bit too fast, slow down… range 2 miles now, closing nicely… He's turned to the right, go right… keep coming round… now reduce your turn… Hold that… Hold that… Range closing nicely… Steady… look up now and you should see him in front of you about 600 yards away and a little above.'

As the pilot looked up from his instruments, it took a few seconds to re-focus his eyes outside the cockpit and see his prey. He then closed on the bomber and engaged in it in the normal way.

The radar-guided fighter interception was, beyond dispute, the most effective means of engaging enemy planes at night. Yet it would take time to manufacture the necessary equipment, and train crews to operate it and technicians to maintain it. While it was waiting, the RAF



A Defiant of No. 151 Squadron operating in the night-fighter role. With two pairs of eyes to search for targets, the Defiant was the most successful RAF single-engined fighter type used during night operations.

Box 6: 'All Radar' Night Interception

In this section, we observe the operation of the night-fighter control system during an interception in 1943. Although the engagement took place later in the war and outside the time frame of this chapter, the method employed was developed in 1941 and so warrants inclusion at this point.

At 22.45 hours on 15 October, Flying Officer H. Thomas, with Warrant Officer C. Hamilton as radar operator, scrambled from West Malling in Kent in a Mosquito of No. 85 Squadron. Fifteen Junkers 188 bombers of Kampfgeschwader 6 had bombed London and were heading for home, all continually varying their speeds, headings and altitudes to make interception difficult. The Mosquito crew (radio callsign 25) contacted the GCI radar station at Sandwich (called Sw here, but note that it used a different callsign to conceal its location). An edited transcript of the radio conversations between the two is given below. Note the brevity of the exchanges, which conveyed the essential information and acknowledgements but no unnecessary chatter. Those are signs of well-trained and disciplined operators:

22.57	25, Sw	Bandit [enemy aircraft, range] 40 miles, 12 o'clock [dead ahead].
	Sw, 25	OK
	25, Sw	Angels [altitude, of enemy plane] 20 [thousand feet]
	Sw, 25	OK
	25, Sw	What are your Angels?
22.58	Sw, 25	Angels 13, going up.
	25, Sw	Make it 15.
	Sw, 25	Are you sure that is enough?
	25, Sw	Yes, that will do for the present. Range 20, 12 o'clock, he's coming towards you.
	Sw, 25	OK
22.59	25, Sw	[Go] Starboard [heading] 090, [target] range 20, 12 o'clock
	Sw, 25	OK
23.00	25, Sw	Bandit 13,000, speed 150.
	Sw, 25	Speed again?
	25, Sw	Speed 170
	Sw, 25	OK
	25, Sw	Range 12, 1 o'clock
	Sw, 25	OK
	25, Sw	Starboard 100.
	Sw, 25	OK
23.02	25, Sw	Starboard 140.
	Sw 25	OK, thank you, 140

The Ju 188 was heading almost due east, and during the next few minutes the Mosquito was given a series of major heading changes to bring it into position behind its quarry.

23.09	25, Sw	Starboard 160, speed up, range 3
	Sw, 25	Any Angels?
	25, Sw	What [are your] Angels now?
	Sw, 25	19
	25, Sw	Keep it there for present, [head] 190 [almost due south]
	Sw, 25	OK
	25, Sw	Starboard 230
	Sw, 25	OK
	25, Sw	You are very close now, any joy? [Have you AI contact?]
	Sw, 25	OK, thank you.

From the tone of Hamilton's voice, it was clear that he needed no further help from the ground. He now had the enemy aircraft on AI radar, about 4 miles away in front of him. The radar operator now passed a stream of instructions, as he directed Jones into position to make visual contact with the Ju 188. At about the same time as Thomas caught sight of the bomber, the bomber crew sighted the Mosquito. The bomber dived steeply to port, with the night-fighter following. Throughout the manoeuvre, Hamilton reported on the relative position of the Junkers. Eventually Thomas closed to within 300 yards of the raider and fired four short bursts with his 20mm cannon. With both engines on fire, the bomber crashed near Margate. Only the pilot parachuted to safety and was taken prisoner.

resorted to unconventional methods to destroy enemy bombers. One such device, the Long Aerial Mine, is described in Box 7.

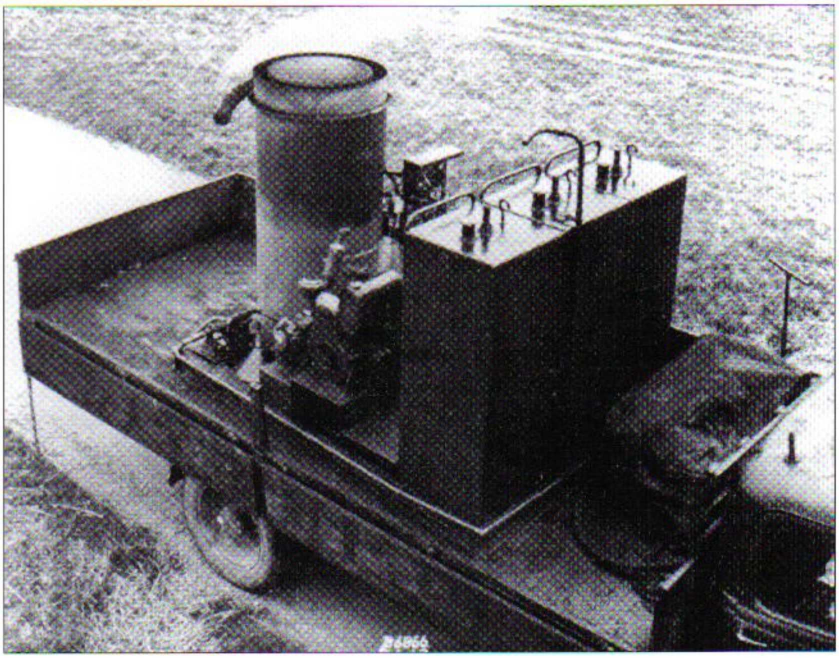
The Gunners' Problems

By the summer of 1940, Anti-Aircraft Command had about 200 Gunlaying Mark I radars in service. By then a purpose-designed radar for AA fire control, the Gunlaying Mark II, was undergoing trials. It suffered teething troubles, however, and was not yet ready to enter production. At the request of General Pile, engineers at the Cossor company modified a GL I radar to improve azimuth accuracy and provide a limited elevation-measuring capability. The modification, officially designated the Elevation Finding or EF Attachment, gave the Mark I a rudimentary fire-control capability against targets at night, and made possible the use of Predicted Concentration Fire (see Box 4).

With Britain's cities under nightly attack, General Pile demanded the conversion of the rest of his radars as quickly as possible. Cossor turned out the necessary modification kits as fast as it could. Such was the urgency of the operation, as each kit was completed it was rushed to the radar site allocated to receive it. With it went a team of technicians to make the conversion, then the Army operators received a crash course in how to use the modified equipment.

As more GL I radars became operational with the EF Attachment, the accuracy of the elevation measurements was found to vary greatly from site to site. For technical reasons, the gun-laying radar was sensitive to siting. The surrounding ground needed to be flat with even electrical conductivity – in other words, the ideal site was one that rarely existed. That problem was overcome by covering the ground under the radar receiver aerials, out to a radius of 80 yards, with a mat of chicken wire. Of this modification General Pile later wrote: 'Experiments with a trial mat were a complete success and the principle was adopted universally. What I had not realised was that the project would involve using the whole of the country's stock of wire net for the first 300 mats.'

Compared with the unaimed firing methods employed earlier, the modified GL I radar gave a significant improvement in the accuracy of anti-aircraft fire at night. However, the ideal of continuous accurately predicted fire was still some way off. The indications from the first-generation radar were too coarse for that. The operators could provide only an approximate position of an enemy


A smoke-screen generator, used to protect important targets, mounted on a lorry. The device employed an oil-burning furnace which superheated and vaporised the two smoke ingredients, water and fog oil. The hot vapours were then ejected through nozzles, and when they came into contact with the cool surrounding air, they condensed into a dense white smoke cloud.

Box 7: The Long Aerial Mine

In the desperate days of 1940, no air defence scheme was too outlandish to merit consideration. One such system was to use aerial 'minefields' to trap raiding aircraft.

In December 1940, No. 93 Squadron was formed with Handley Page Harrow bombers. The obsolescent planes took about 40 minutes to climb to 20,000ft, and their maximum speed was 200mph. Each Harrow was modified to carry 120 special aerial mines.

The weapon used, officially known as the Long Aerial Mine, weighed 14 pounds and was housed in a small cylindrical drum. After the drum was released, a parachute opened, slowing the fall of the warhead which weighed 1-pound and was about the size of a half-pint beer can. Attached to the base of the bomb was 2,000ft of piano wire with a second, furled, parachute at the bottom end.

Operating under control of GCI radar, the aircraft released its mines at 200ft intervals to produce a curtain about 4¼ miles long and nearly half a mile deep, in front of incoming raiders. Released at around 20,000ft, the mines descended at about 1,000ft per minute. They therefore remained effective for about 10 minutes, before they fell below the level where they might encounter enemy aircraft.

The weapon contained an 8-ounce explosive charge, sufficient to inflict lethal damage to an aircraft if it detonated in contact. The warhead was detonated by a pressure plate on its base. The weapon carried no self-destruct mechanism, so it was important that they were released only in areas where they would not come down on land.

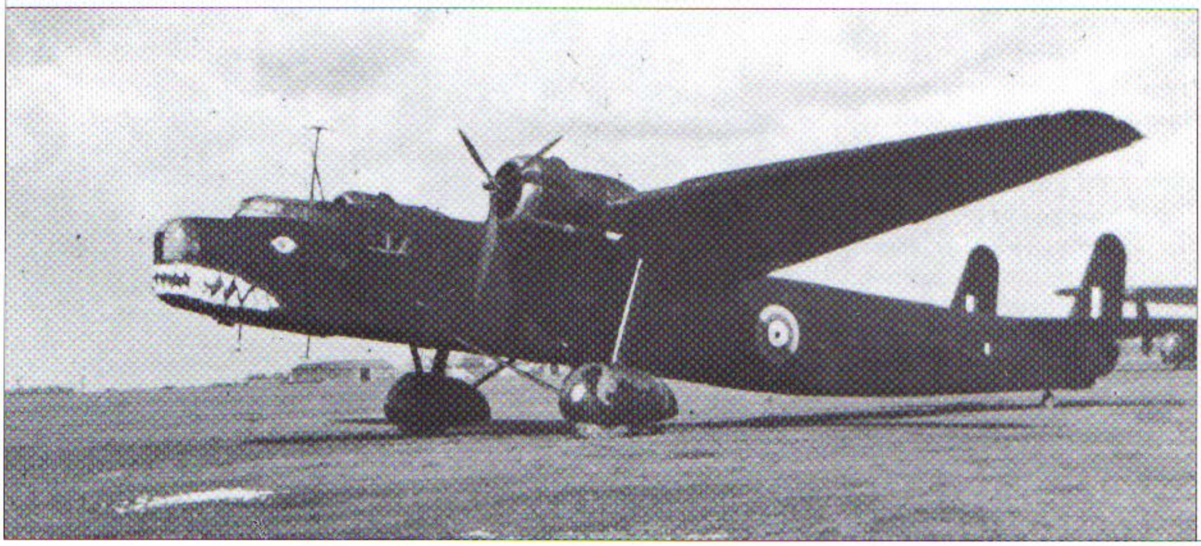
When an enemy aircraft struck the piano wire, the shock of impact severed a weak link which released the upper parachute. As that parachute fell clear, it pulled from its bag a small parachute which stabilised the bomb in its fall. The impact shock also unfurled another parachute, at the bottom of the wire. As it opened, the lower parachute swung into position behind the target aircraft and pulled the bomb sharply down on the plane. The warhead exploded when it came into contact with a hard surface.

Harrows began flying minelaying sorties at night in December 1940. On the 22nd, a Harrow released a string of mines in front of two enemy aircraft observed approaching the coast. One aircraft was seen to enter the 'minefield', where its radar echo suddenly faded. That aircraft was assessed as 'destroyed'. On 13 March, another German bomber was claimed 'probably destroyed'.

During the months to follow, the Long Aerial Mine barrier served as the first of many lines of defence that raiders had to cross to reach their targets. The device appears to have scored no further successes, however, and in November 1941 the scheme was abandoned.

Each Long Aerial Mine unfurled to create one element of a barrier spread across the sky. It comprised, from top to bottom, a medium-sized parachute, a 1-pound bomb, 2,000ft of piano wire and a parachute in its container. The 120 mines carried by a Harrow bomber, released at 200ft intervals at right angles to the track of the incoming German bombers, produced a slowly descending barrier about 4¼ miles long and nearly half a mile deep. Released from 20,000ft, the mines descended at about 1,000ft per minute. If an aircraft struck the wire, the shock of impact released the upper parachute and at the same time unfurled the parachute at the bottom of the wire. The lower parachute rapidly took up a position behind the aircraft, and pulled down the bomb which exploded on impact.

Handley Page Harrow bomber of No. 93 Squadron, modified to lay curtains of Long Aerial Mines. This obsolescent bomber had a maximum speed of 200mph.



aircraft, sufficient to enable gunners to put up a box-barrage into the sky in front of it.

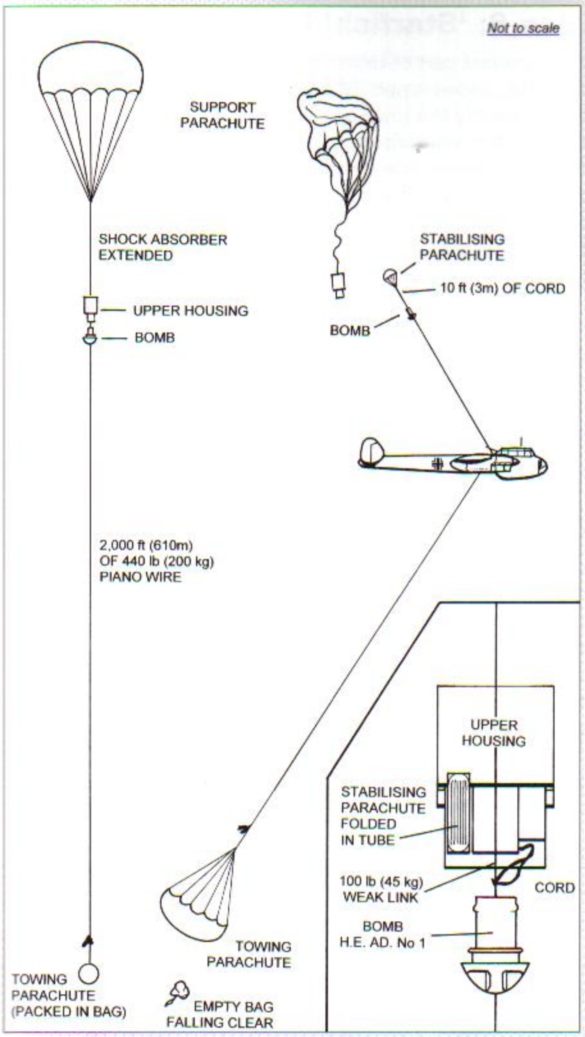
Early in 1941 the Gunlaying Mark II radar entered service, producing more-accurate azimuth and elevation information. Its arrival, coupled with improving serviceability of the radars as troops became more familiar with their equipment, led to further improvements in accuracy.

To improve the ability of searchlights to find and track enemy planes, another type of radar, code-named 'Elsie', was introduced at this time. Fitted on a searchlight projector, the set gave a maximum detection range of about 8 miles for a bomber-type aircraft. The radar allowed crews to align their projector accurately on the aircraft before they switched on the light, and hold their beam on it even if the plane took evasive action. Once an enemy bomber was illuminated, it could be engaged visually by AA guns or fighters.

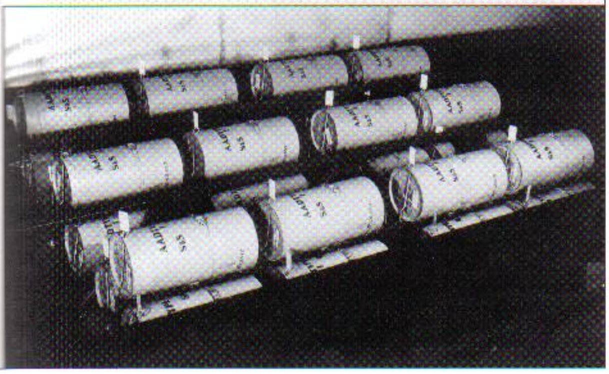
At the end of 1940 a more powerful searchlight, the 150cm, came into service. This gave a beam of 510 million candlepower, more than twice that of the earlier 90cm type. A 150cm light fitted with Elsie radar served as 'master' for a section of three lights. It illuminated the enemy aircraft first, then the other two lights would 'cone' the machine.

The 3.7in. and 4.5in. heavy AA guns remained effective weapons throughout the war. Production of these complex weapons was slow, however, and during the earlier years there were insufficient to defend of the huge number of potential targets. To supplement them, the 3in. rocket projectile entered service in 1941. Each rocket was 6ft 4in. long and weighed 54 pounds. These fin-stabilised rockets did not rotate in flight, and for that reason were called 'Unrotated Projectiles', 'UPs' for short. The UPs were fired in salvoes of 128, on the indications from GL radar, to produce a 'shotgun' effect. After launch each rocket accelerated to about 1,000mph in 1½ seconds, then coasted on to its maximum engagement altitude of 19,000ft. The 22-pound warhead was fused to explode at a pre-set time after launch.

In combat, the UP proved a poor substitute for heavy AA guns. They were considerably less accurate and, because of the long time to reload all 128 projectors, only one salvo could be launched at a passing aircraft. The weapon saw only limited deployment.


Not to scale
SUPPORT PARACHUTE
SHOCK ABSORBER EXTENDED
UPPER HOUSING
BOMB
STABILISING PARACHUTE
10 ft (3m) OF CORD
BOMB
2,000 ft (610m) OF 440 lb (200 kg) PIANO WIRE
UPPER HOUSING
STABILISING PARACHUTE FOLDED IN TUBE
100 lb (45 kg) WEAK LINK
CORD
BOMB H.E. AD. No 1
TOWING PARACHUTE
TOWING PARACHUTE (PACKED IN BAG)
EMPTY BAG FALLING CLEAR

Interior of the Harrow's bomb bay, with its load of 120 Long Aerial Mines in their containers.



If night-fighters, gunners, and No. 80 Wing's jamming (see Box 5) failed to prevent enemy bombers reaching the target area, one further method remained to make the bombs go astray. The operation of the fire decoy sites ('Starfish') is described in Box 8.

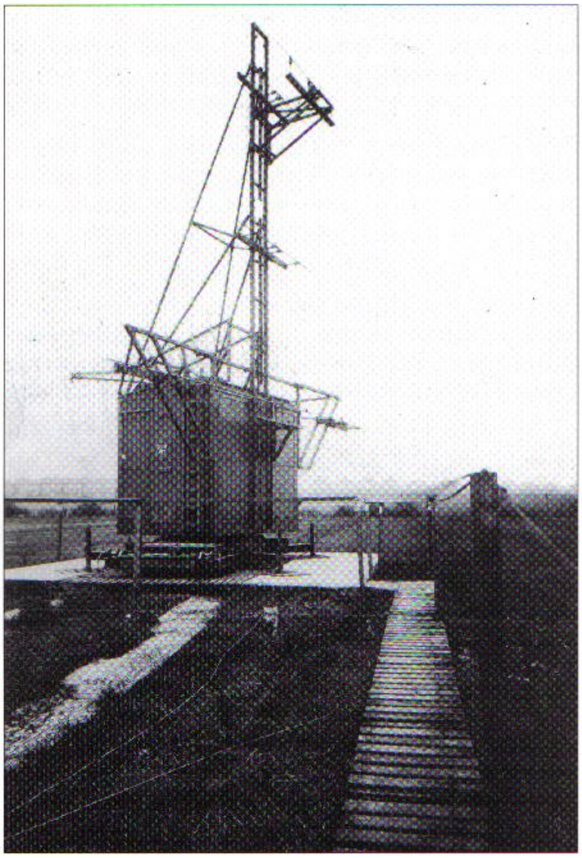
Box 8: 'Starfish' Fire Decoy Sites

An important part of Britain's air defences were the decoy fire sites, code-named 'Starfish'. Designed to burn and look plausibly like town or city targets under air attack, the 'Starfish' comprised a cluster of fires in open countryside at least 4 miles from the target it was intended to protect. The decoy was ignited electrically from a concrete control post about 600 yards away, the operator being in telephone contact with a command post at the real target.

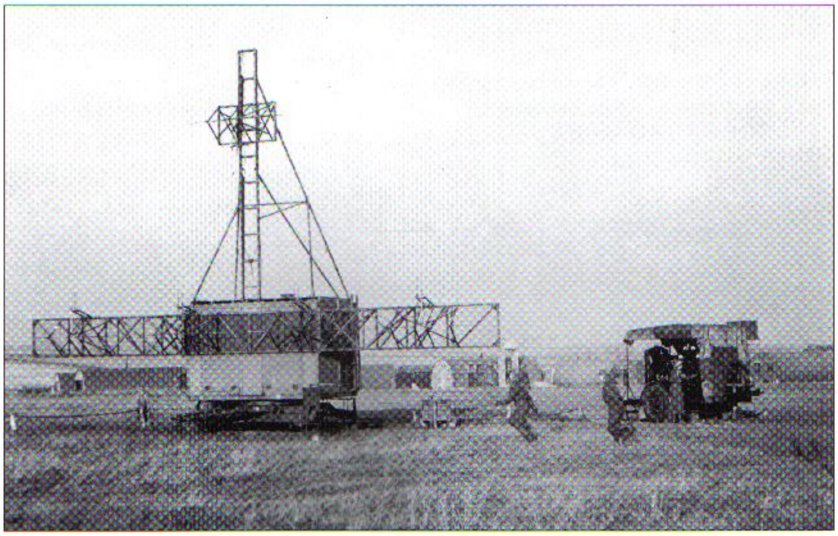
As soon as the real target came under attack, fire fighters made every effort to extinguish the initial fires as quickly as possible. At the same time, the fire decoys in the area were ignited. The fastest-burning type of decoy comprised several building-shaped structures made of steel and asbestos, covered in tarred roofing felt. The felt burned rapidly, and to keep the blaze going additional rolls of felt were attached to the roof. As the fire burned through the strings holding the extra rolls in position, the latter unrolled at intervals to renew the supply of combustible material. The decoy 'buildings' were clad in asbestos sheeting and could be used several times. Other types of decoy, intended to burn more slowly, used coal, paraffin or creosote to provide variety to the size, colour and intensity of the fires and their smoke. Each 'Starfish' comprised a number of decoy fires of different types.

The selection of sites for 'Starfish' posed a major problem. Each site needed to be at least a mile from the nearest habitation. Obviously, nobody wanted a decoy 'in his back yard'. To avoid wrangling and delays, once a location was decided the local Agricultural Officer had either to agree to it, or provide a suitable alternative within 24 hours.

At the beginning of March 1941, 108 'Starfish' sites were in operation around Great Britain. These often drew large numbers of bombs away from their intended targets.

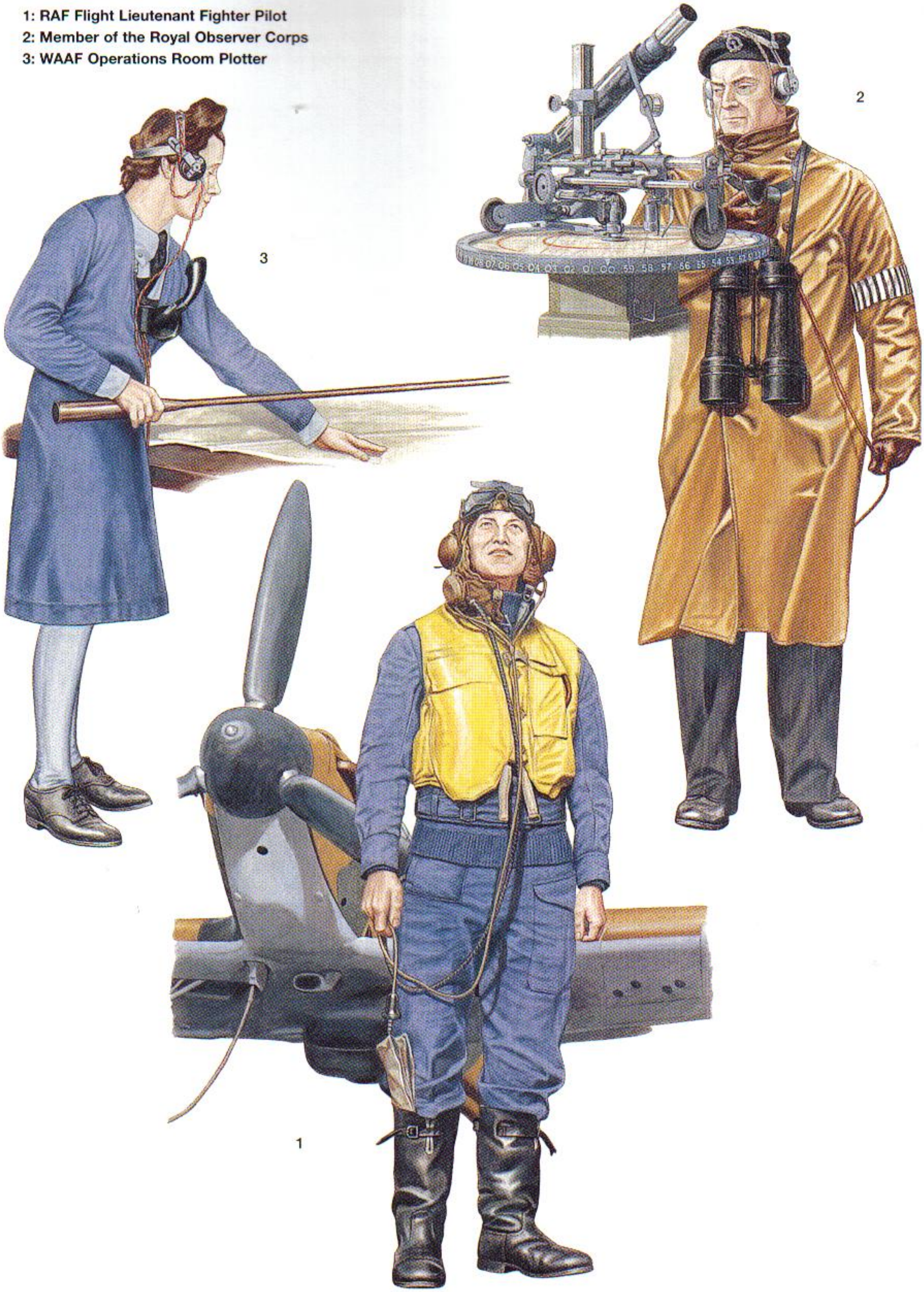


Receiver unit of the Gunlaying Mark II radar. Note the staked down mat of chicken wire in the foreground. This gave an area of uniform.electrical conductivity to remove irregularities in the aerial lobe patterns and assist height finding. (IWM)



The separate transmitter unit for the Gunlaying Mark II radar. (IWM)

1: RAF Flight Lieutenant Fighter Pilot
2: Member of the Royal Observer Corps
3: WAAF Operations Room Plotter



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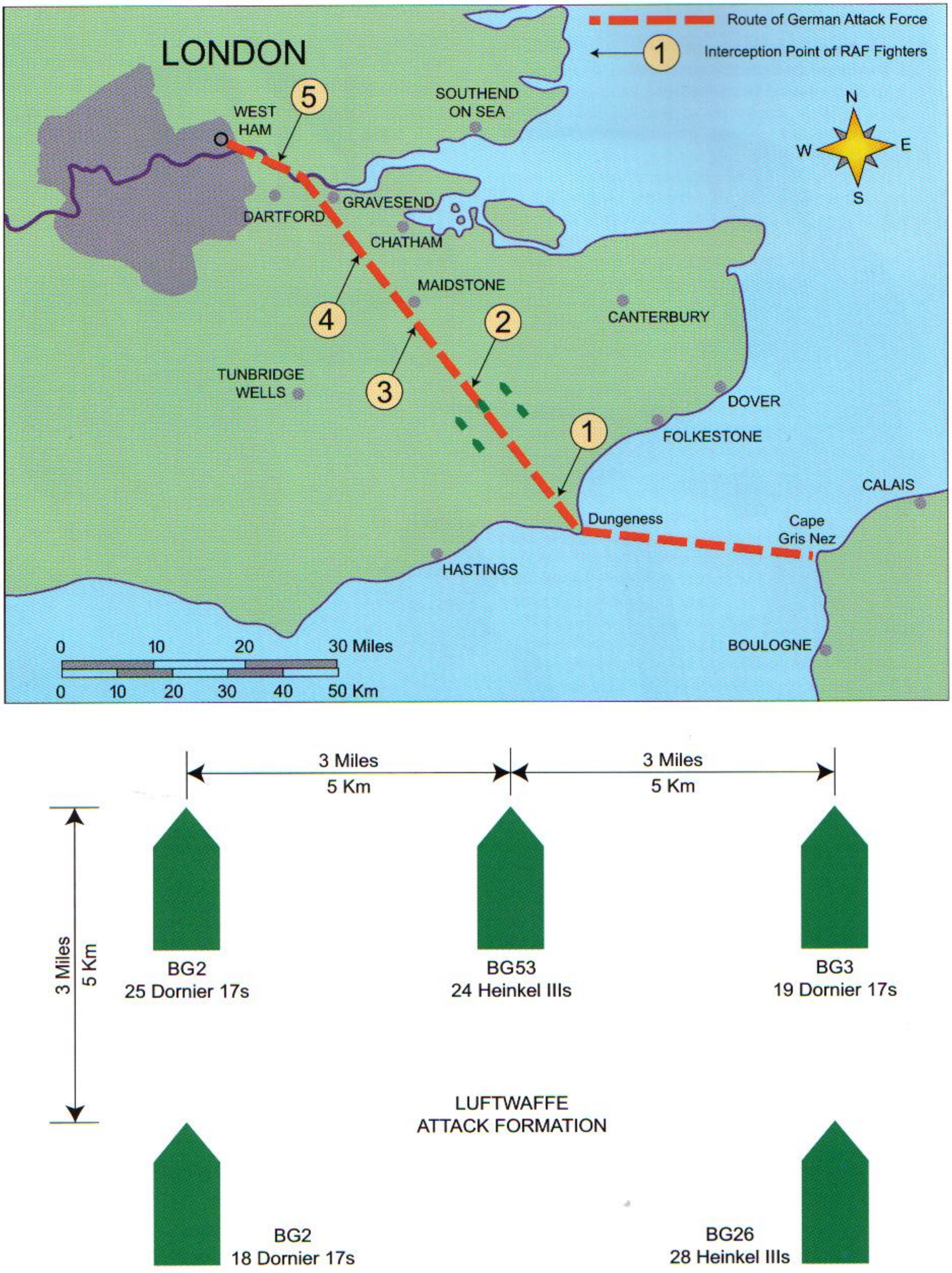
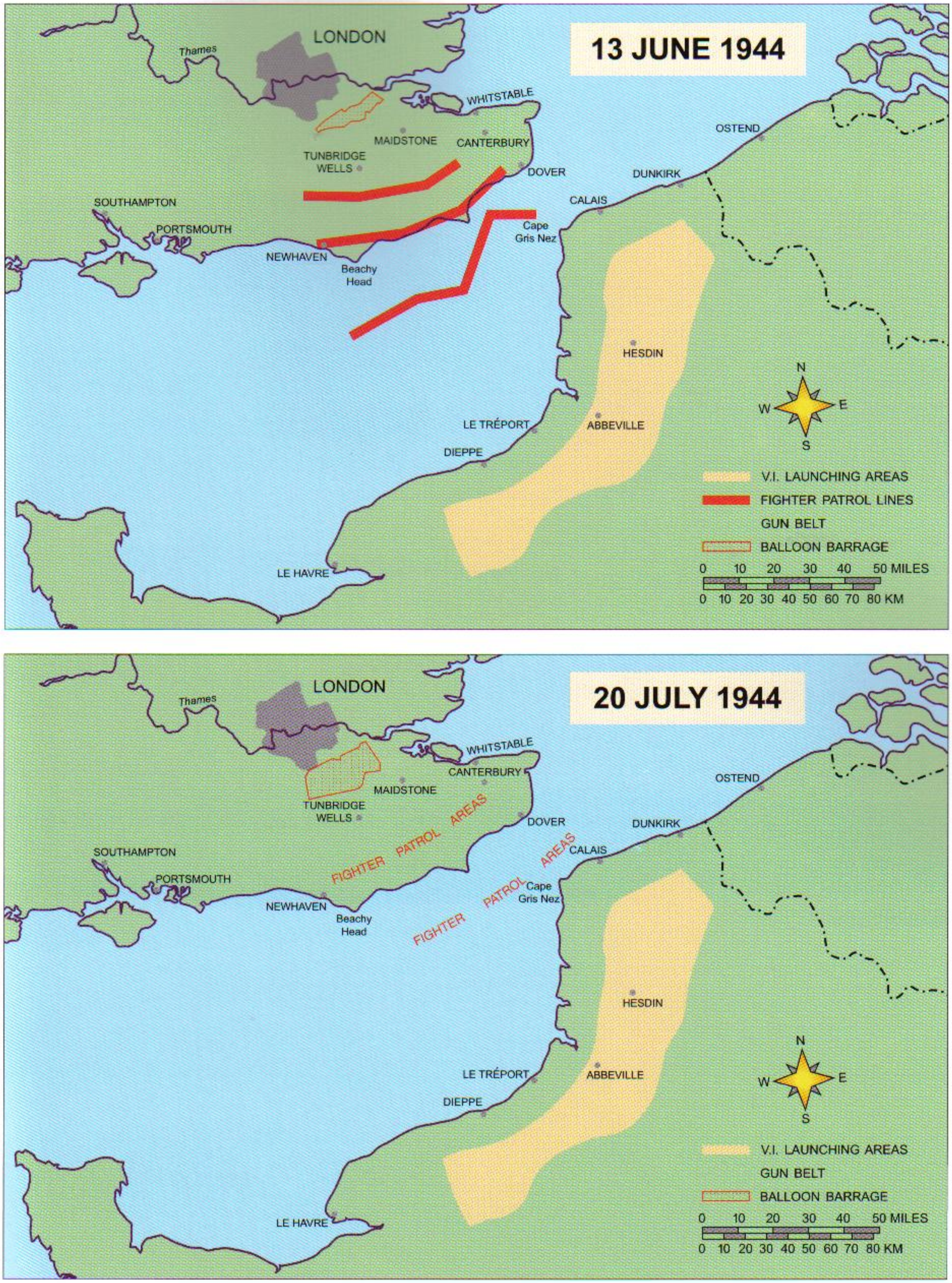
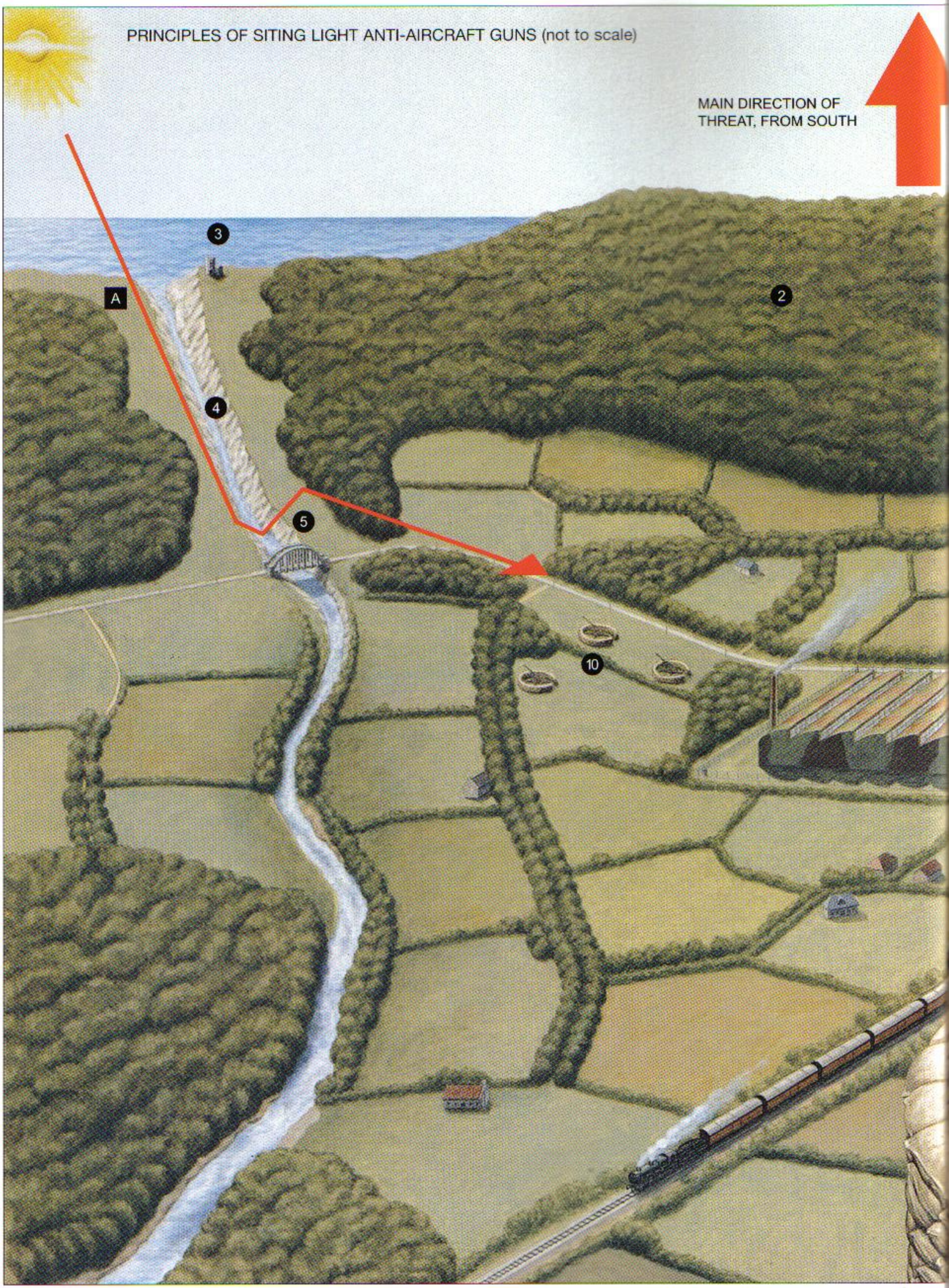

Route of German Attack Force
1
Interception Point of RAF Fighters
LONDON
N
W
E
S
WEST HAM
5
SOUTHEND ON SEA
DARTFORD
GRAVESEND
CHATHAM
4
MAIDSTONE
CANTERBURY
2
3
TUNBRIDGE WELLS
DOVER
FOLKESTONE
1
CALAIS
Dungeness
Cape Gris Nez
HASTINGS
BOULOGNE
0
10
20
30 Miles
0
10
20
30
40
50 Km
3 Miles
5 Km
3 Miles
5 Km
3 Miles
5 Km
BG2
25 Dornier 17s
BG53
24 Heinkel IIIs
BG3
19 Dornier 17s
LUFTWAFFE ATTACK FORMATION
BG2
18 Dornier 17s
BG26
28 Heinkel IIIs

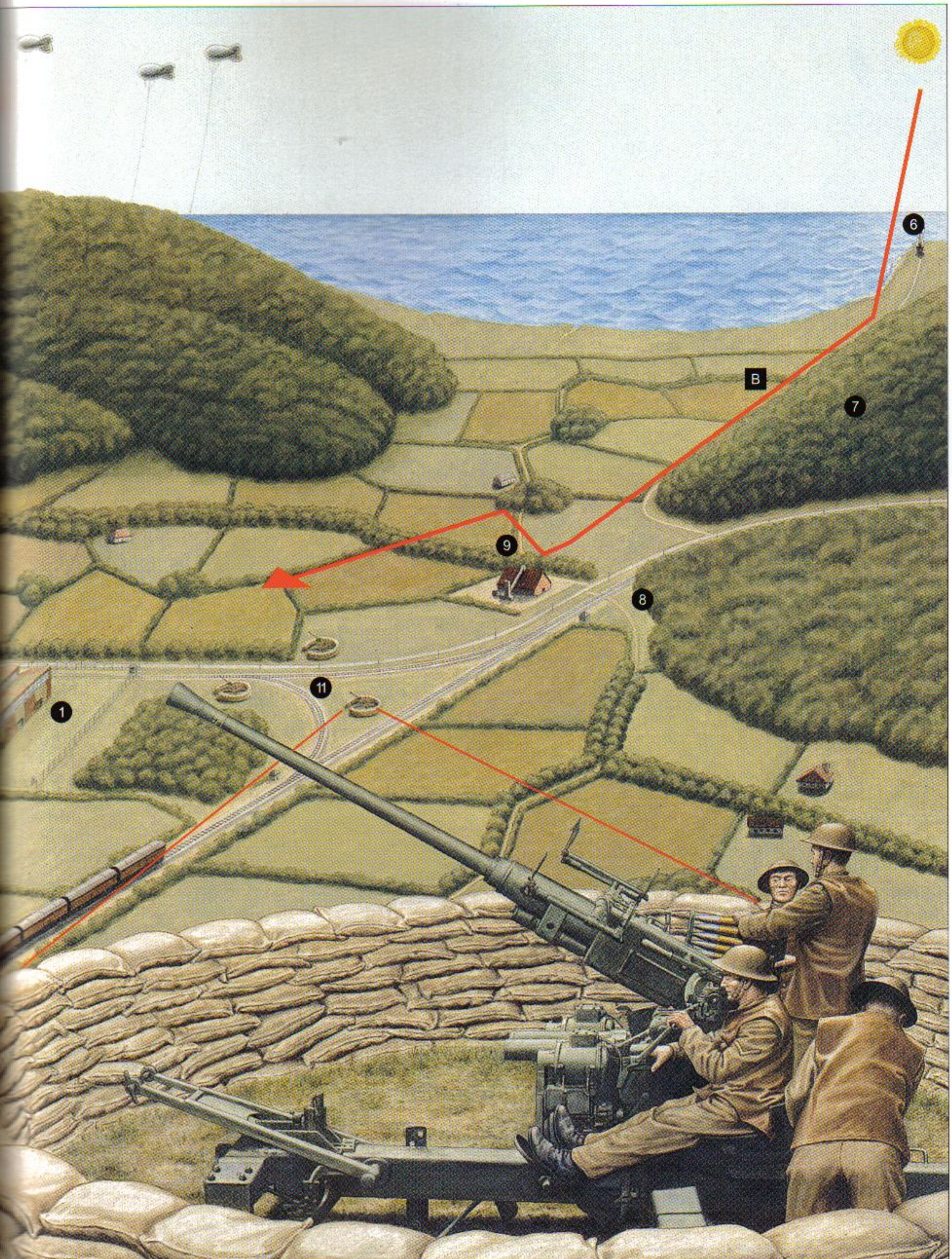
B FIGHTER COMMAND'S RIPOSTE TO THE ATTACK ON LONDON ON THE AFTERNOON OF 15 SEPTEMBER 1940.


13 JUNE 1944
LONDON
Thames
WHITSTABLE
MAIDSTONE
CANTERBURY
TUNBRIDGE WELLS
DOVER
SOUTHAMPTON
PORTSMOUTH
NEWHAVEN
Beachy Head
Cape Gris Nez
CALAIS
DUNKIRK
OSTEND
HESDIN
ABBEVILLE
LE TRÉPORT
DIEPPE
LE HAVRE
N
W
E
S
V.I. LAUNCHING AREAS
FIGHTER PATROL LINES
GUN BELT
BALLOON BARRAGE
0 10 20 30 40 50 MILES
0 10 20 30 40 50 60 70 80 KM
20 JULY 1944
LONDON
Thames
WHITSTABLE
CANTERBURY
MAIDSTONE
TUNBRIDGE WELLS
DOVER
SOUTHAMPTON
PORTSMOUTH
NEWHAVEN
Beachy Head
FIGHTER PATROL AREAS
FIGHTER PATROL AREAS
CALAIS
Cape Gris Nez
DUNKIRK
OSTEND
HESDIN
ABBEVILLE
LE TRÉPORT
DIEPPE
LE HAVRE
N
W
E
S
V.I. LAUNCHING AREAS
GUN BELT
BALLOON BARRAGE
0 10 20 30 40 50 MILES
0 10 20 30 40 50 60 70 80 KM

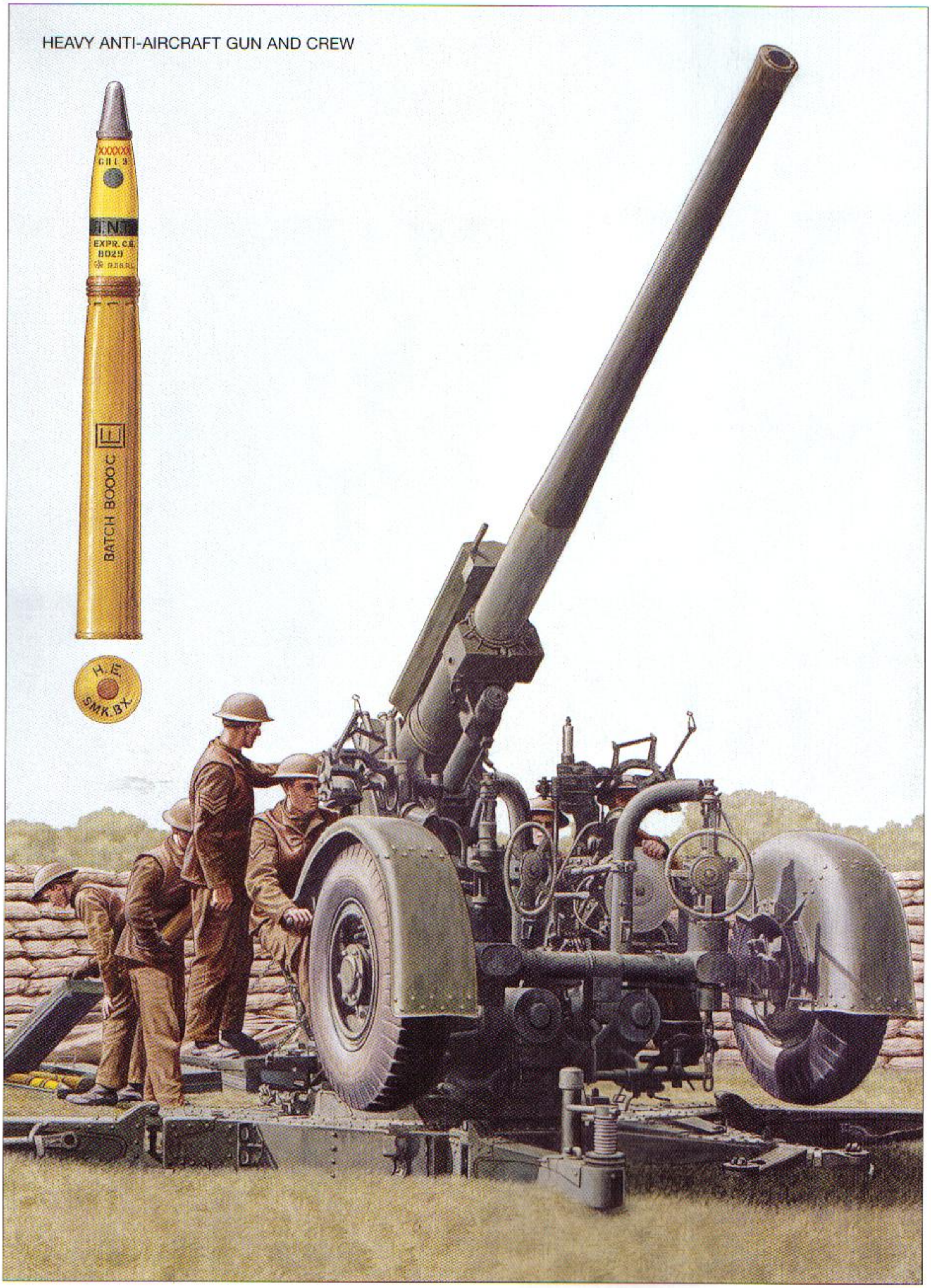
DISPOSITION AND RE-DISPOSITION OF DEFENCES TO COUNTER THE V.1 FLYING BOMB ATTACK ON LONDON, 1944.


PRINCIPLES OF SITING LIGHT ANTI-AIRCRAFT GUNS (not to scale)
MAIN DIRECTION OF THREAT, FROM SOUTH
3
2
A
4
5
10

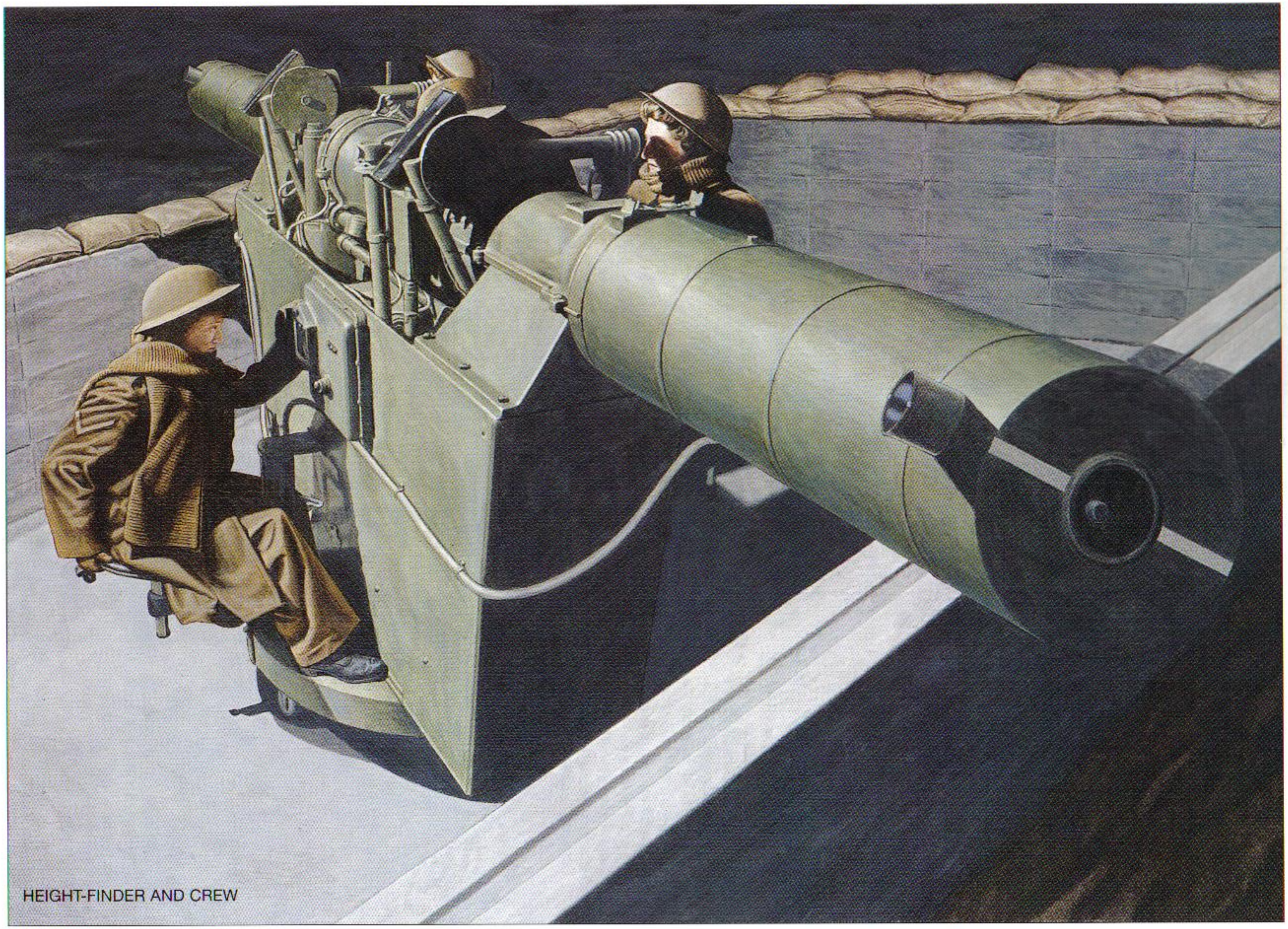
D


6
B
7
9
8
11
1

HEAVY ANTI-AIRCRAFT GUN AND CREW

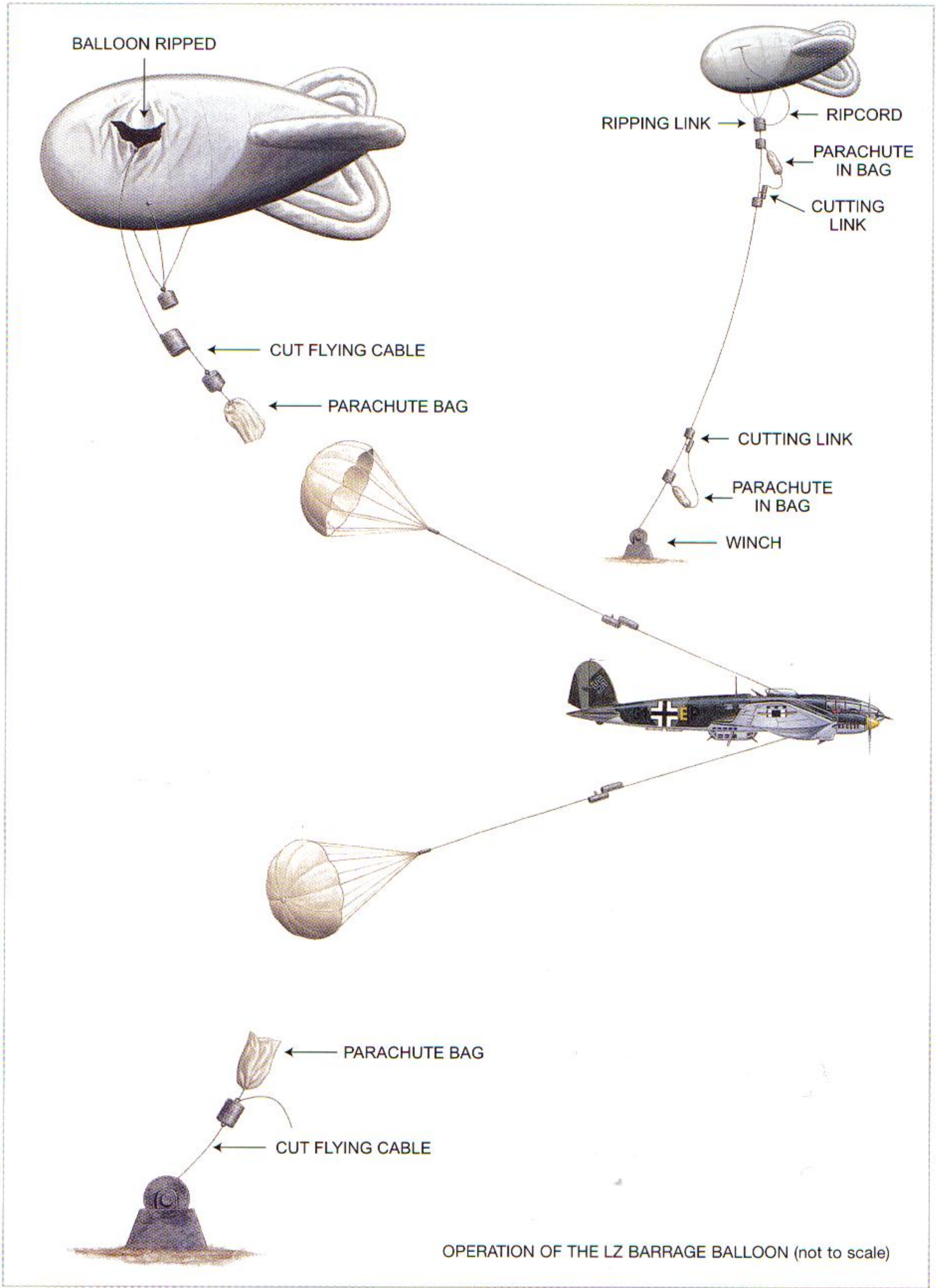

XXXXX
T.N.T.
EXPR. C.E.
8029
E
BATCH BOOOC
H.E.
SMK.BX.

F

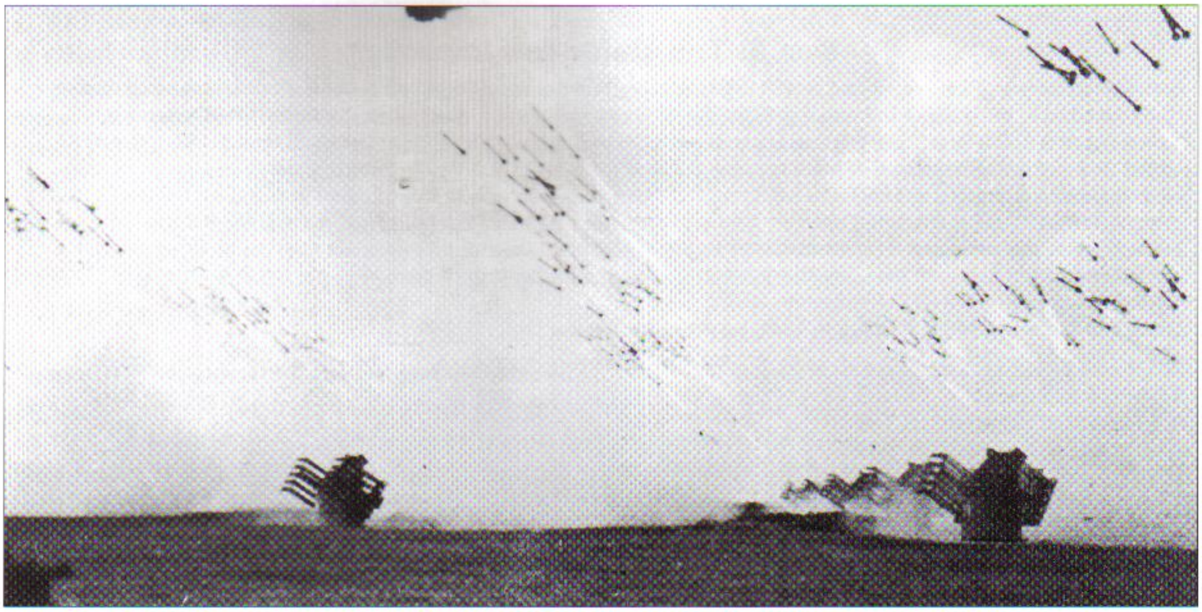


HEIGHT-FINDER AND CREW

G


BALLOON RIPPED
RIPPING LINK
RIPCORD
PARACHUTE IN BAG
CUTTING LINK
CUT FLYING CABLE
PARACHUTE BAG
CUTTING LINK
PARACHUTE IN BAG
WINCH
PARACHUTE BAG
CUT FLYING CABLE

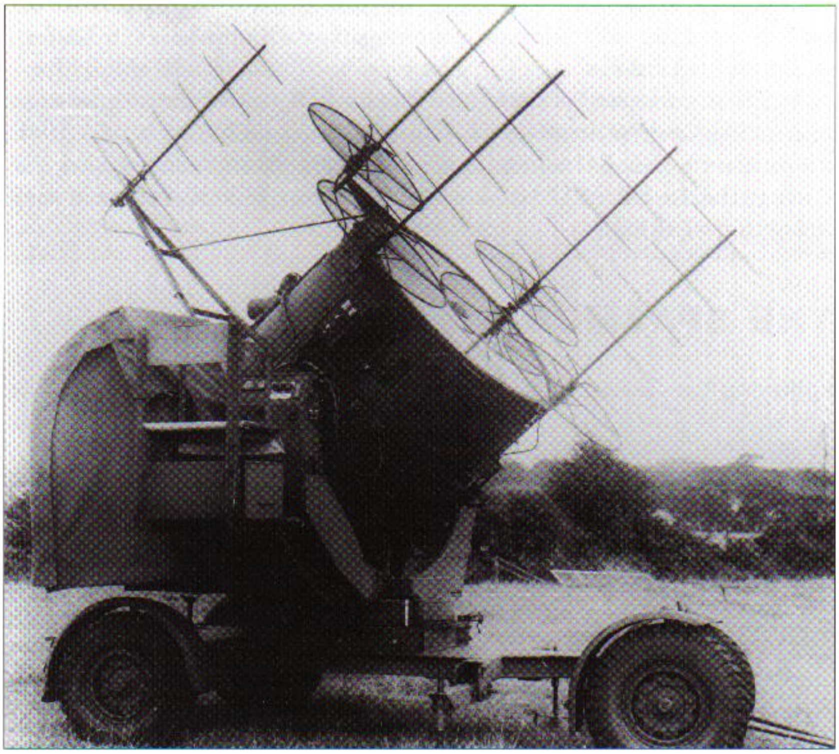
OPERATION OF THE LZ BARRAGE BALLOON (not to scale)



A rocket battery launching a salvo of 128 Unrotated Projectiles, usually called 'UPs'. Able to engage aircraft at altitudes up to 19,000ft, each rocket carried a 22-pound warhead. The rocket batteries proved less effective than conventional heavy AA guns, however, and were not deployed in large numbers. (IWM)

End of the Beginning

By the late spring of 1941, Britain's night air defences had undergone a complete transformation, compared with those of the previous summer. The radar-equipped and GCI-controlled night-fighter was now the most effective element of the defence. This demonstrated a growing ability to find and destroy its prey. At the same time, the introduction of radar-controlled AA guns and rockets contributed to the raiders' discomfort



A 150cm Searchlight Projector Mark 3, fitted with the 'Elsie' radar. The radar enabled the operators to align their projector on the target aircraft before they turned it on, and made it easier to hold the beam on the aircraft if the latter took evasive action.

Box 9: The Defences Improve

Between January and the end of May in 1941, Britain's night air defences improved beyond all recognition. Many things came together to bring about this change. From the beginning of January, six Ground Controlled Interception (GCI) radars became operational, covering the whole of southern and eastern England. At the same time the fast, heavily armed Beaufighter, with the new AI Mark IV radar, became available in quantity. In February, only two squadrons were fully equipped; by the end of May there would be six. There were also new radars to assist in laying AA fire, and to direct searchlights. In addition, there had been a massive effort to instruct those operating and maintaining the new equipment to use it effectively and keep it serviceable. The losses in May 1941 were more significant than the table suggests, for half way through that month the Luftwaffe ceased its large-scale attacks on Britain.

Losses of Luftwaffe Night Raiders in 1941, by Probable Cause

Probable Cause	*February*	*March*	*April*	*May*	*Total*
Twin-Engined Fighters[1]	2	9.5	13.5	25	50
Single-Engined Fighters[2]	2	2 5	13.5	11	31.5
AA Guns	0.5	2.5	4	10	17
Balloons	0.5	1	1	2	4.5
Accident or Technical Failure	Nil Recorded	1	Nil Recorded	67	
Cause Unknown[3]	6	8	13	13	40
Total	**11**	**27**	**45**	**67**	**150**

Notes: 1. Except for one victory by a Blenheim in March, all victories were by Beaufighters.

2. The majority of these victories by Defiants, the rest by Hurricanes.

3. Most 'Cause Unknown' losses were due to AA fire, accidents or technical failures.

when they flew straight and level on their bombing runs. Also, radar-controlled searchlights found and held enemy planes in their beams, to illuminate them for attack by AA guns or fighters.

Yet as these various moves approached maturity, the defenders' battle to contain the raiding forces suddenly underwent a profound change. By the late spring of 1941, Adolf Hitler's plans to attack the Soviet Union were in an advanced stage. As part of those preparations, the bulk of the Luftwaffe bomber force began moving to bases in Eastern Germany and Poland.

In a final concerted effort before that move became general, there was one further large-scale attack on London. On the night of 10 May 1941, the Luftwaffe flew 541 sorties against the capital, and caused extensive damage for the loss of 11 bombers. Never again would it operate in such strength over Britain.

THE SPASMODIC WAR

Following the German invasion of the Soviet Union in June 1941, the Luftwaffe retained about 200 bombers in the west to mount spasmodic attacks on targets in Great Britain. These raiding forces suffered heavy proportionate losses from the steadily improving British night defences. Also during this period, Luftwaffe fighter-bombers flew small-scale daylight 'tip and run' attacks on coastal targets, usually causing little damage and few casualties.

In April 1942 an effective new night-fighter type became operational, the de Havilland Mosquito. Carrying four 20mm cannon and four .303in. machine-guns, the Mosquito II had a maximum speed of 370mph. Initially it carried AI Mark V radar, similar to the Mark IV but with an additional screen for the pilot.

The major development in airborne radar at this time was the so-called 'centimetric' radar. The experimental AI Mark VII worked on a wavelength of about 10cm, considerably shorter than the earlier types. Use of the shorter wavelength brought the advantages of a greater effective range, less trouble from unwanted ground reflections and a more precise indication of the target's location and movements. The AI Mark VII radar went into limited production in the spring of 1942. Later in the year the mass-produced and fully engineered version, the Mark VIII, became available. Both types were fitted in Beaufighters and Mosquitos.

Searchlight Control for Night Fighters

Also at this time there was an important change in night-fighting tactics. Using GCI radar to direct a single fighter on to a single bomber was the most efficient method of engaging the latter. Yet if there were several bombers in the same patch of sky, these swamped the system, for only one bomber could be engaged at a time. To counter that threat, Fighter Command introduced an alternative system using radar-directed searchlights to guide fighters to intercept enemy aircraft.

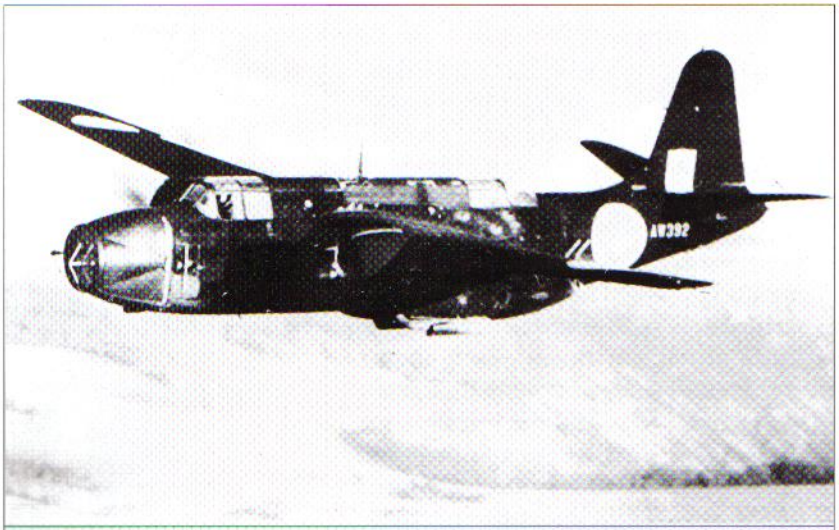
Code-named 'Smack', the new method operated in parallel with, but separate from, GCI control. Almost the whole of southern England and the Midlands was divided into a series of 'Fighter Boxes', each about 32 miles deep and 14 miles wide, arranged in front of potential targets. Most searchlights were now fitted with 'Elsie' radar, and the rest were to receive it when production allowed. The first 12 miles of each Box was the Indicator Zone, with searchlights deployed singly at 10,000-yard intervals. In the middle of each Box, a searchlight pointing vertically served as a beacon which the fighter orbited while waiting for an enemy plane to appear.

When an enemy aircraft entered the Indicator Zone, individual searchlights illuminated it or pointed out its path. Simultaneously, the searchlight that had served as orbit beacon depressed to 20 degrees, then swung round to point towards the raider. As the fighter pilot manoeuvred into position to engage the bomber, the latter entered the rear 20 miles of the Fighter Box, the so-called Killer Zone. In that zone,

The Mosquito Mark XIII entered service in 1943, and had a maximum speed of 391mph. This variant carried the very effective AI Mark VIII microwave radar. (IWM)

searchlights were deployed at 6,000-yard intervals, providing continuous illumination of the enemy aircraft so the defending fighters could engage it. The basic patterns of the GCI and 'Smack' night-interception tactics came into use early in 1942, and they remained effective for the remainder of the war.

Another interesting innovation that appeared during this period was the 'Turbinlight' device, an airborne searchlight to guide fighters without radar on to enemy bombers. The operation of Turbinlight is described in Box 10.



Douglas Havoc fitted with the Turbinlight searchlight installation and AI Mark IV radar. For night intercept missions, it was intended that this type of aircraft would lead a Hurricane into position behind the enemy bomber. The Havoc pilot then switched on the searchlight to illuminate the enemy plane, so the Hurricane would pull out in front and deliver its attack. When tested in action, the cumbersome method achieved little. It accounted for few enemy planes before it was abandoned.

Box 10: The 'Turbinlight'

To enable fighters without radar to engage enemy night bombers with greater effect, Fighter Command introduced a small number of Douglas Havoc bombers converted to carry airborne searchlights, 'Turbinlights'. The powerful searchlight occupied the nose of the aircraft, which also carried AI radar. The bomb bay of the Havoc was filled with a large number of batteries to provide the electrical power required to run the searchlight. Together the searchlight, the batteries and the radar weighed so much that the Havoc was able to carry no armament.

The idea was that GCI radar would vector the Havoc, accompanied by a Hurricane fighter, to the vicinity of the enemy plane. The Havoc closed to within about 300 yards of its quarry, and illuminated it with the searchlight. The Hurricane then pulled ahead and delivered its attack.

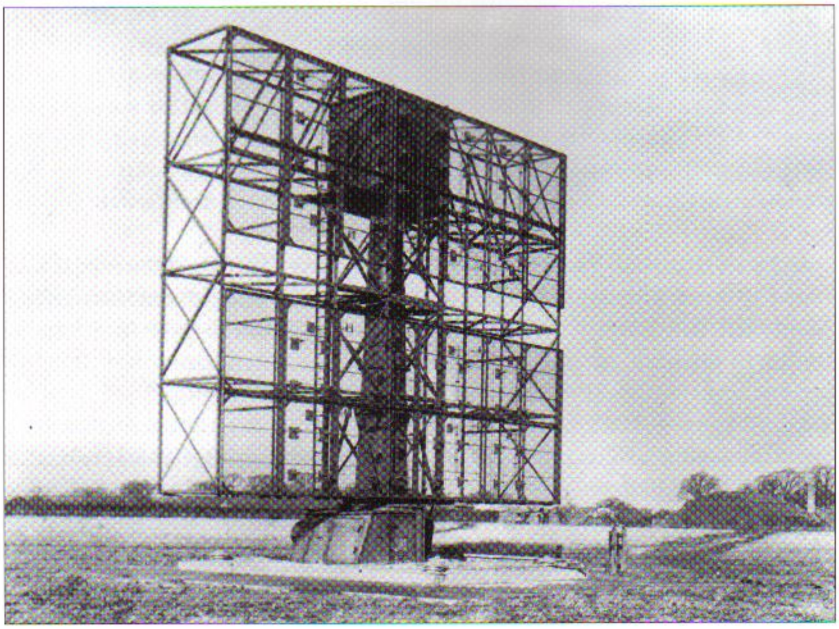
A Turbinlight team achieved a rare success on the night of 1/2 May 1942. Flight Lieutenant C. Winn in the Havoc, and Flight Lieutenant D. Yapp in the accompanying Hurricane, were vectored on to a Heinkel 111 off the coast near Flamborough Head, North Yorkshire. Before the searchlight was turned on, Yapp sighted the raider visually. As he moved in to engage, he asked that the light be left off. He closed to within 100 yards and was about to open fire when the bomber entered a violent turn to starboard. Yapp followed the bomber and fired several bursts, scoring hits on the engines and the fuselage before it entered cloud. Shortly afterwards a bright glow lit the cloud from below, the bomber's wreckage burning on the sea.

In the months to follow the Turbinlight teams accounted for one further enemy bomber, and inflicted damage on two more. But this cumbersome method compared unfavourably with the powerfully armed and radar-fitted Beaufighters and Mosquitoes, now available in useful numbers. The scheme was abandoned in January 1943.

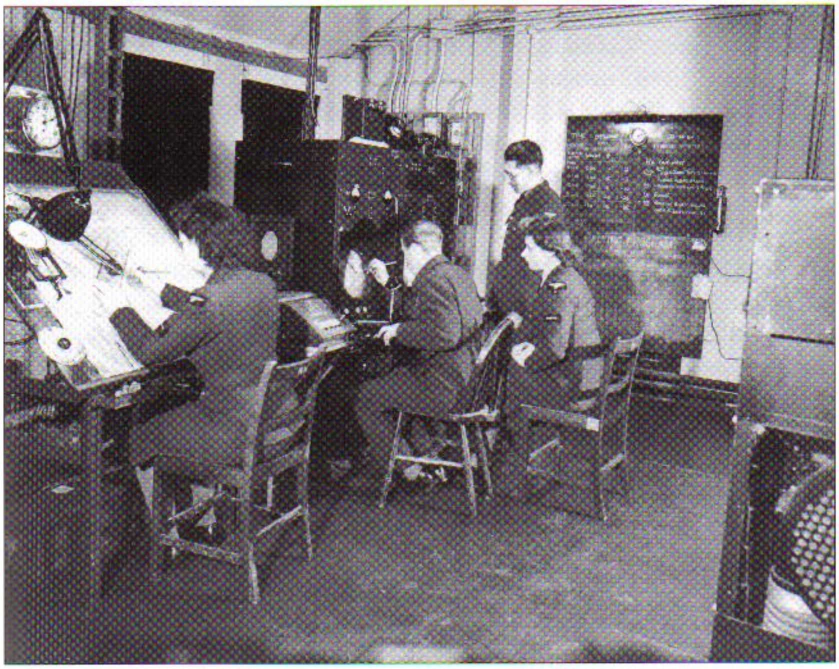
Improvements in AA Gunnery

At the beginning of 1942, Britain's heavy gun defences comprised 1,400 guns of 3.7in. calibre, 416 guns of 4.5in. calibre and 144 obsolescent 3in. guns. The GL Mark II radar was deployed in large numbers and night-firing accuracy, though still worse than by day when using optical fire control, was a great improvement over that in the summer of 1940.

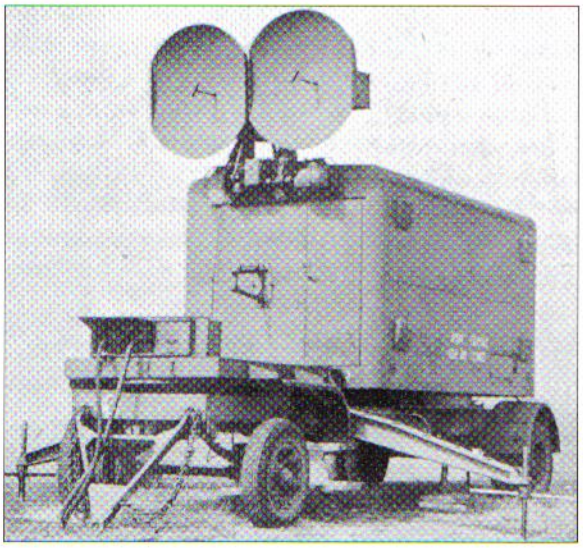
At this time, General Pile faced continual pressure to give up batches of able-bodied gunners for service in the field forces. Pile later wrote of



Scanner of the Type 7 Ground Controlled Interception (GCI) radar. The camouflaged operations room can be seen in the background, to the right of the photograph. (IWM)



Interior of a GCI cabin. The officer seated in the centre, plotting the aircraft tracks on the screen with a wax crayon, was conducting the interception. The WAAF seated, nearest the camera, was recording the tracks flown for later analysis.



The Gunlaying Mark III radar, designed and built in Canada, brought a major improvement in the accuracy of guns firing at night or through cloud. For the first time, guns could employ continuously pointed fire under these conditions.

a conversation he had on this matter with Mr Churchill: 'I told him that I would not agree to leaving guns out of action. If he gave me the guns I would find some means of manning them, whether it was with whole-time soldiers, ATS [Auxiliary Territorial Service women] or Home Guard. This greatly appealed to Churchill and he said that could it be achieved it would be at least as valuable as a major victory. The Prime Minister had rapidly added up in his mind the figures involved. "Forty thousand men saved," he said, "equals a major victory for this country"'

Those 40,000 men represented about one-sixth of Pile's total manpower. Yet in spite of the influx of untrained men and women to fill the gaps in the ranks, the desultory nature of the attacks allowed ample time for the newcomers to train for their tasks.

Also at this time there was a major improvement in the accuracy of night gunnery, brought about by the introduction of the Gunlaying Mark III 'centimetric' radar. The new radar, developed in Canada, made it possible to employ continuously pointed fire (See Box 4) against aircraft at night or above cloud.

Throughout 1942 and 1943 the German bomber force mounted occasional sharp raids on targets in Great Britain, though never with the strength or destructiveness of those in 1940 and 1941. The air defences coped with each move by the raiders, and exacted due retribution. At the end of 1943, however, the Luftwaffe girded itself for a new campaign against the old enemy.

Operation *Steinbock* – The 'Baby Blitz'

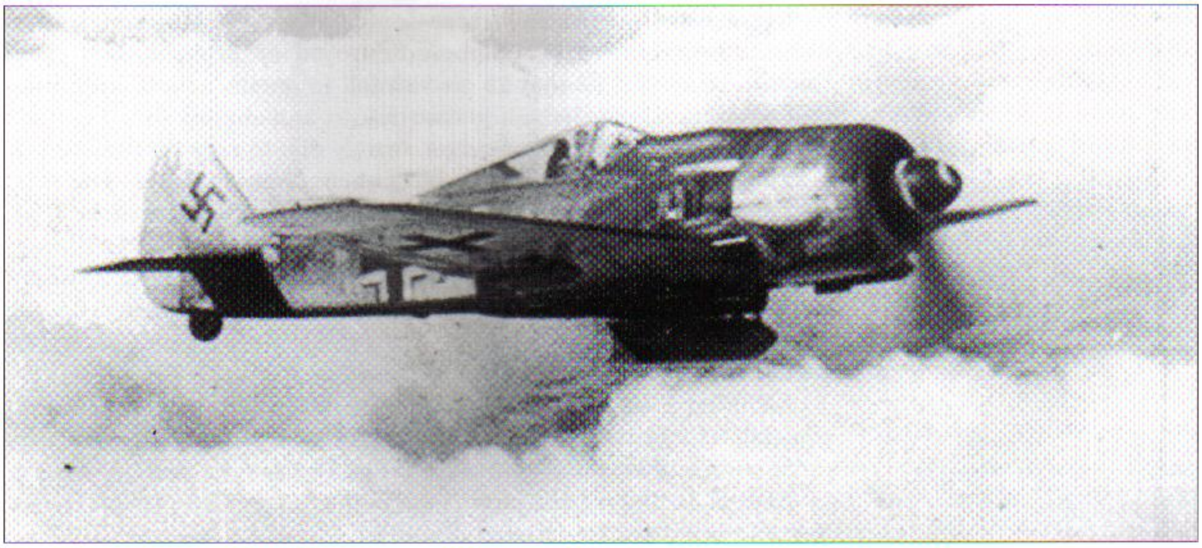
Following increasingly devastating attacks on their homeland by Allied heavy bombers, Germany's leaders sought revenge. Luftwaffe bomber leaders received orders to resume large-scale bomber operations against Great Britain. Code-named Operation Steinbock (Ibex), final preparations for the new attacks were well advanced by mid-January 1944. The attack force comprised more than 500 bombers: Junkers 88s and 188s, Dornier 217s, Messerschmitt 410s, Heinkel 177s and a few Focke-Wulf 190 fighter-bombers.

In mid-January 1944, the night-fighter defences of southeast England comprised six squadrons of Mosquitos with a total of 113 aircraft. These aircraft all carried centimetric wavelength radar, either the AI Mark VIII or the even more effective AI Mark X.

During the third week in January, bomber units allocated to *Steinbock* began moving to forward airfields in France, Belgium and Holland. On the afternoon of 21 January, there was a flurry of activity as ground crews prepared the bombers for action.

That evening the initial raiding force, comprising 227 aircraft, headed across the English Channel. The bombers crossed the coast on a narrow front near Dungeness, and headed for London.

To confuse radar plotting, each bomber released bundles of radar reflective metal foil (German code-name *Dueppel*). With concentrations



Focke-Wulf 190 fighter-bombers made numerous daylight tip-and-run attacks on targets in southern England during 1943.

of *Dueppel* confusing the air picture, only a small proportion of the night-fighters received GCI control. Others resorted to freelance tactics, using radar-guided searchlights to guide them to the bombers. Representative of the latter was the Mosquito XIII of No. 96 Squadron, piloted by Flight Lieutenant N. Head and with Flying Officer A. Andrews as radar operator. The crew received permission to conduct a freelance hunt for raiders running in across Kent, and afterwards Head reported: 'Several searchlight intersections were investigated without result and height was reduced to 15,000 feet. An intersection was seen with an aircraft illuminated and the observer obtained contact at about 6,000 feet range. The aircraft was identified as a Ju 88 and was taking evasive action in searchlights, and opened fire on the Mosquito at about 1,000 feet range. The evasive action of the enemy aircraft became much more violent and each time the Mosquito attempted to get its sights on, the enemy aircraft turned into the attack. Finally, I got in a good burst at 4/600 feet range, strikes being seen on the fuselage and the port wing root, height of combat 12,000/15,000 feet. Enemy aircraft turned to port, Mosquito overshot and enemy aircraft went on to its back with the port engine well alight, and as aircraft was falling away it partially recovered and then went on to its back again and disappeared from sight.'

Some minutes later the same crew investigated another searchlight intersection, and sighted a Ju 88 taking violent evasive action. Head fired several deflection shots, aiming at a point ahead of the target to allow for its forward travel, and saw strikes on the starboard engine which then caught fire. The enemy plane fell away and dived into the ground.

South of London, Pathfinder Ju 88s and Ju 188s laid out lines of white flares pointing towards the city and white and green flares to mark the target, Waterloo station. After releasing their bombs, the raiders withdrew eastwards down the Thames Estuary. On returning to base, bombers that were serviceable were quickly refuelled and rearmed. Others that had not taken part in the first attack joined them, and during the early morning darkness 220 aircraft made a repeat attack on London.

To meet the two attacks Fighter Command flew 96 Mosquito sorties, whose crews claimed 16 bombers destroyed or probably destroyed. German records state that 25 aircraft fell to enemy action, indicating that some or all of the other nine fell to anti-aircraft fire. Eighteen bombers fell to non-combat causes, mainly due to crews getting lost or crashing when attempting to land at their dimly lit bases. The total loss amounted to almost 10 per cent of the sorties dispatched, an unsustainable rate for the Luftwaffe.

Considering the scale of that first attack, London suffered remarkably little damage. There were 245 incidents reported on the ground, but only 44 of those were in the London defence area. The remainder occurred in Kent, Sussex and Essex.

Following a week of poor weather, the next raid on London was on the night of 29 January. The 285 bombers attacked in a single wave, with more success than the previous raid. The bombers caused 343 fires in the capital, including one large blaze at the Surrey Commercial Docks. Some 14 bombers were lost to all causes.

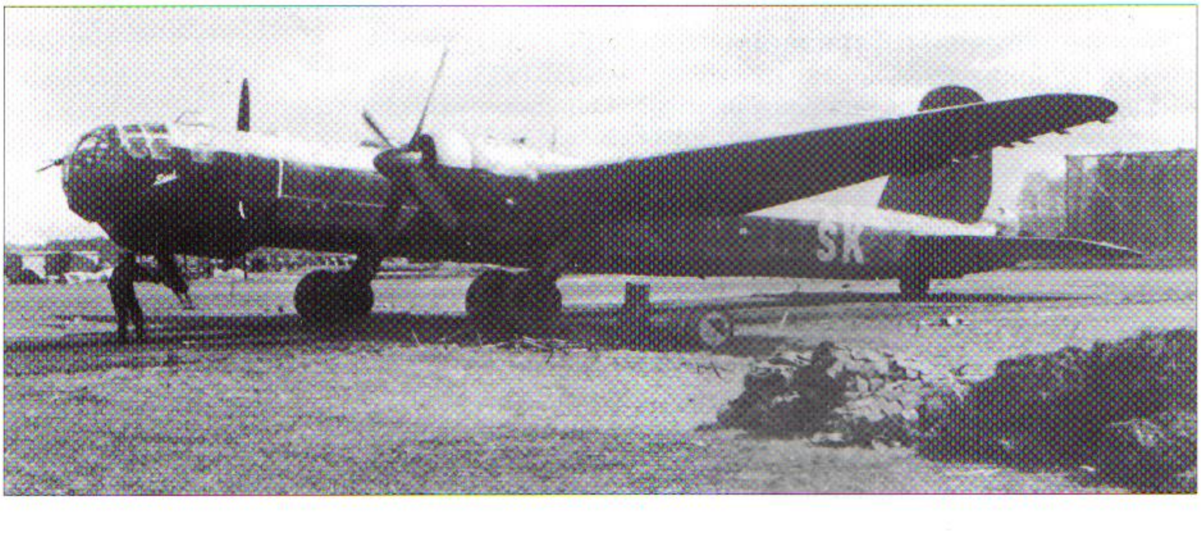
During February, the Luftwaffe mounted seven raids on London. Some of the later attacks caused considerable damage and casualties, with 961 people killed and 1,712 seriously injured during the month. In achieving this, however, the Luftwaffe lost 72 bombers and crews.

March saw four attacks on London, followed by unsuccessful raids on Hull and Bristol. The first two weeks in April were quiet. Then, on the 18th, came the final manned bomber attack against the capital. In the final days of the month, bombers attacked Hull, Bristol, Portsmouth and Plymouth.

Steinbock Reviewed

Operation *Steinbock* was the last attempt by the Luftwaffe to mount large-scale attacks with bombers on Britain's cities. Many of the bomber crews lacked experience and this, coupled with the harassment from the defences, usually led to bombs being scattered over large areas. Only about two-fifths of the bombs intended for London landed within its boundaries. Air-raid casualties in Britain during the first five months of 1944 totalled 1,556 killed, with 2,916 seriously injured.

The Heinkel He 177 heavy bomber was first employed over Britain in January 1944. This example, belonging to Kampfgeschwader 100, took part in Operation *Steinbock*. Although it had the appearance of a twin-engined aircraft, the bomber's four engines were coupled in pairs and each pair drove a single airscrew via a gearbox. In service the arrangement gave considerable trouble, however.



Steinbock cost the Luftwaffe more than 300 planes. For every five people killed on the ground, the raiding force had lost about one bomber and four crewmen killed, wounded or captured. The defending night-fighter squadrons and gun batteries ensured that although the bomber force could inflict serious losses, it suffered almost equally heavy losses itself.

Steinbock petered out at the end of April 1944. Then came a pause, before London suffered a further massive assault from two completely new types of weapon.

THE ROBOT ATTACK

During the early morning darkness of 13 June 1944, a V.1 flying bomb rumbled off its camouflaged launching ramp near Hesdin in the Pas de Calais and headed away to the north-east. The attack on Great Britain had entered a new phase. Whether the Hesdin missile was the first one launched against England is not known with certainty – four out of the initial salvo of ten flying bombs crashed soon after launch, in most or all cases because they failed to reach flying speed. However, there is no doubt that the Hesdin V.1 was the first of these weapons to come within the view of Britain's defences.

For the first three minutes after launch the missile flew straight ahead, climbing at a shallow angle and gradually building up speed. Then the compass took control and, with a small correction to allow for the predicted wind, the missile's nose edged round until it pointed towards its designated target: London. About six minutes after launch the missile reached its cruising altitude around 3,000ft, and levelled off. The V.1 crossed the coast near Le Touquet and headed out to sea. Soon afterwards, radar operators at Swingate radar station near Dover had their first unknowing glimpse of the new form of attack. For a few sweeps of their scanner they watched the approaching 'aircraft', then lost it. A few minutes later a Royal Navy motor torpedo boat in mid-Channel reported seeing a 'bright horizontal flame' moving north-west from the French coast.

Box 11: The V.1 Flying Bomb

At launch the V.1 weighed 4,858 pounds, of which 1,185 pounds was fuel (75-octane petrol) and 1,988 pounds was warhead. The version used during the initial phase of the attack on London had a maximum range of 160 miles. Its designed flight time was between 20 and 25 minutes, and the cheaply produced pulsejet engine would not run for much longer than that. The engine developed about 600 pounds of thrust at launch, reducing to about 550 pounds after 25 minutes' running.

V.1s were not manufactured to normal aircraft tolerances, and their performance varied greatly. The majority of flying bombs flew at speeds around 350mph, though the fastest was tracked at 420mph and the slowest came in at around 230mph. There were similar variations in altitude. Although most crossed the coast at between 3,000ft and 4,000ft, the highest was recorded at 8,000ft and the lowest came in at treetop height (which usually resulted in their early demise).

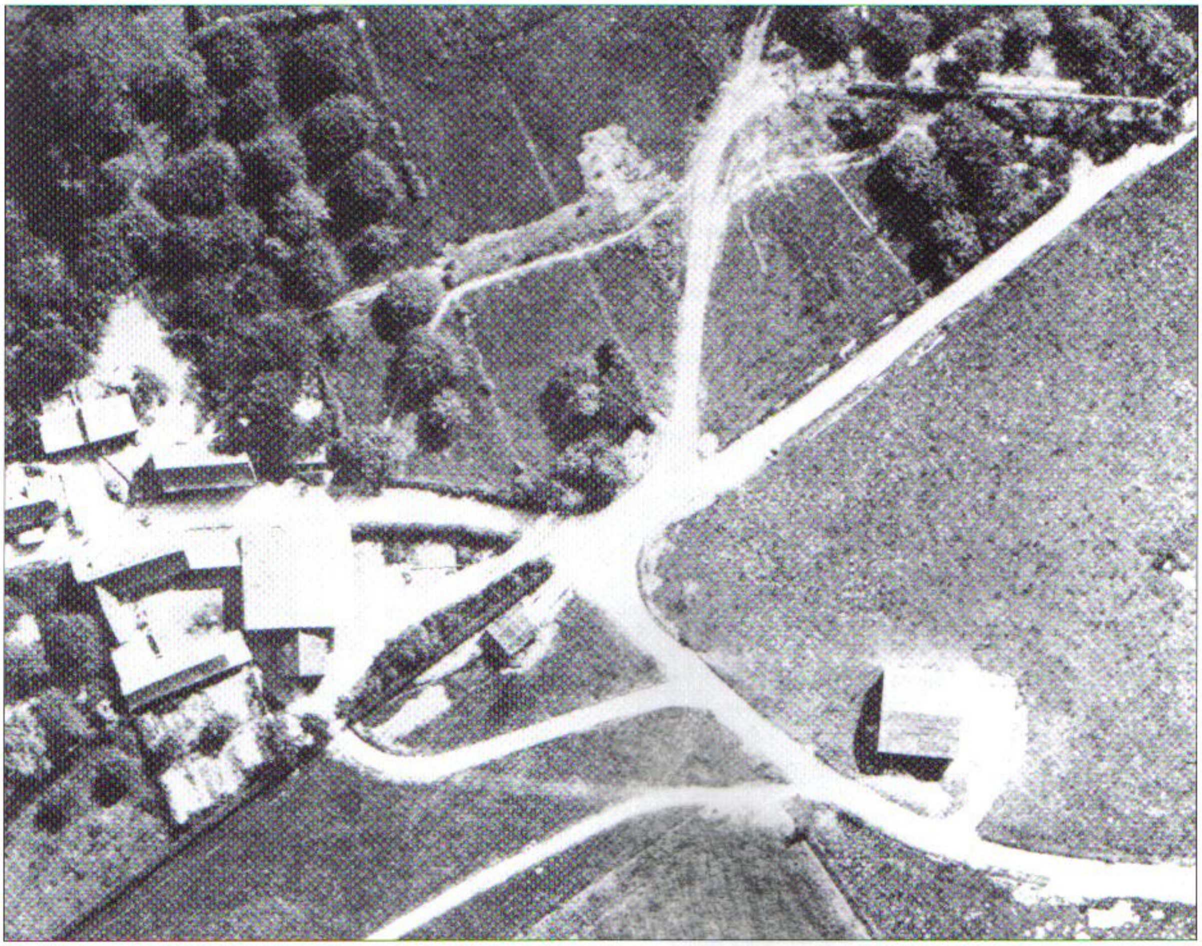
The missile crossed the English coast near Dymnchurch and sped across Kent at about 260mph, tracked by a succession of Royal Observer Corps posts along its path. Listeners likened the distinctive rumble of its pulsejet engine to 'a motor boat' or 'a two-stroke motorcycle without a silencer'.

On the nose of the V.1, a small wind-driven propeller drove a counting mechanism to measure the distance flown. When the mechanism reached the previously set figure to end the flight, two electrical detonators fired to lock the elevators and rudder in the neutral position. Simultaneously, a couple of spoilers flipped down on the underside of the tailplane, lifting the tail and forcing the missile into a steep dive. That bunting manoeuvre hurled the remaining petrol to the top of the almost-empty tank, uncovering the feed pipe. Starved of fuel, the motor flamed out. The engine roar ceased, and about ten seconds later the weapon crashed on open land at Stone near Dartford. The detonation of the 1,870-pound high-explosive warhead blew out a shallow crater and caused blast damage over a large area, but there were no casualties.

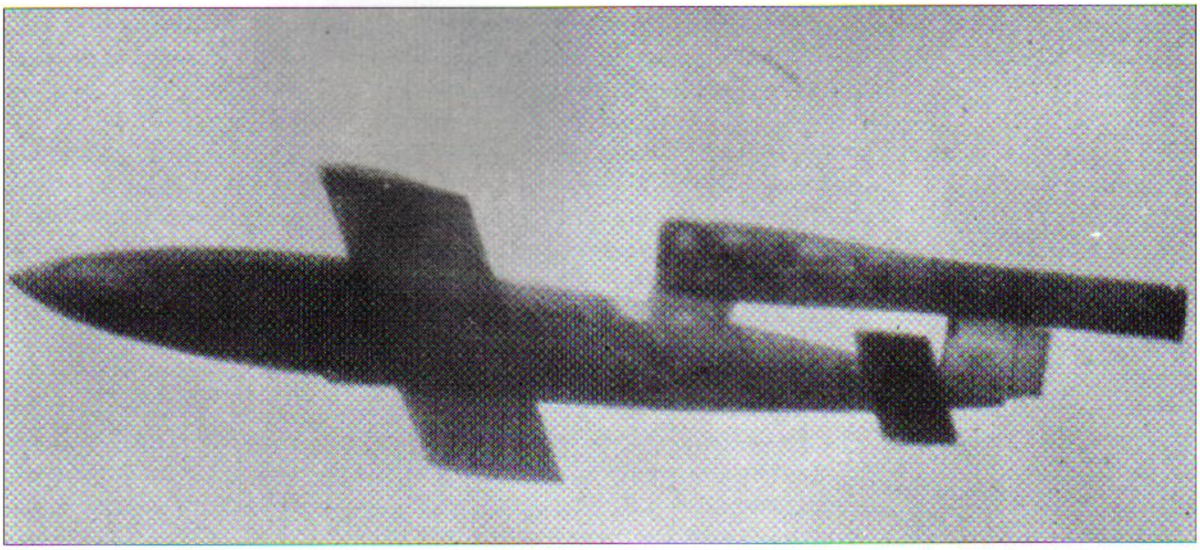
Two missiles from the initial salvo appear to have crashed into the sea. Of the remaining three flying bombs that crossed the coast of England, two crashed on open land without causing casualties. The third missile fell on a built-up area in Bethnal Green, killing six people and injuring nine. The robot bombardment had claimed its first victims.

Following the Allied landings in Normandy on 6 June a week earlier, the V.1 launching sites in the Pas de Calais area were kicked into frenzied activity. Although the preparations for the bombardment of London were well advanced, they were still several days from completion. The firing units received orders to push ahead with the preparations with all speed, aiming to commence firing on London after dark on the 12 June.

The launch crews did their best, but it was an impossibly tight schedule. Working round-the-clock, they toiled to install the necessary equipment at the 64 V.1 firing sites. At that time the Allied air forces were



Camouflaged V.1 launching site at Vignacourt near Abbeville in France. With the seemingly innocent collection of farm buildings, the 'give away' was the launching ramp aligned on London, in the top right corner of the photograph.



V.1 flying bomb in flight. At launch this weapon weighed just over two tons, of which half a ton was 75-octane petrol and just under a ton was warhead.

systematically pounding the French rail network, and when the deadline passed many sites still lacked essential items of equipment or supplies. As we have seen, the initial attack went off at half cock: instead of a concerted salvo, only ten missiles set out and six of those never got as far as the coast of England. Following that initial debacle, there was a three-day pause in firings to allow all launching units to come to full readiness.

Defenders React

During the lull following the initial attack, the RAF and the Army redeployed fighter, anti-aircraft gun and balloon units to south-eastern England to meet the new threat. The first line of defence comprised the fighters: nine squadrons of Spitfire, Typhoon and Tempest day fighters, and two squadrons of Mosquito night-fighters. These flew standing patrols on three lines: one some 20 miles off the coast, one along the coast and one about 15 miles inland. Behind the fighter patrol lines came the gun zone, with 192 heavy guns and a similar number of light AA weapons deployed across an area 20 miles deep. If a fighter was in hot pursuit of a flying bomb, gunners were ordered to withhold fire to allow the fighter to complete the engagement. Behind the gun zone, serving as a backstop close to London itself, was the balloon zone with 480 LZ barrage balloons.

Following the resumption of the V.1 bombardment on the evening of 15 June, the results were more gratifying from the German point of view. Between then and the end of June, 2,442 flying bombs were launched. Of those, roughly one-third crashed or were shot down before reaching the English coast. A further one-third crashed or were brought down over southern England, short of the Greater London area. The remaining third, about 800 missiles, crashed into the capital. On average, 153 missiles were launched each day.

People living in the threatened areas quickly learned to recognise the distinctive rumble of the flying bomb's pulsejet. They also learned they were safe so long as the pulse-jet engine kept running, and if it stopped they had about ten seconds to reach cover (the writer well remembers those exciting times, as a nine-year-old living in Ewell).

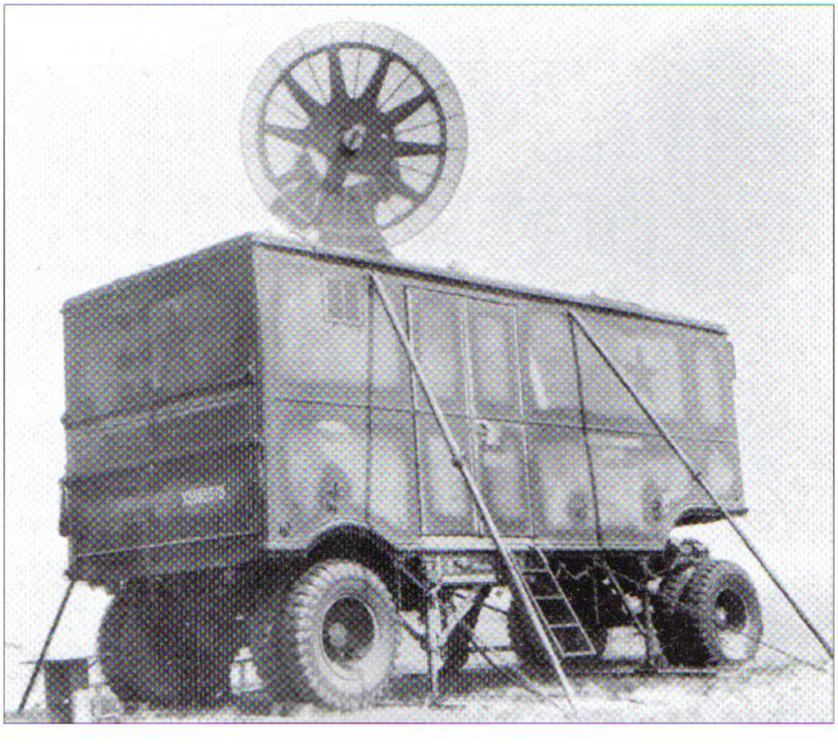
When Allied reconnaissance aircraft located a V.1 launching site, the latter came under repeated attack. Yet these sites were well camouflaged. Few suffered serious damage, and usually they could be repaired. The Allied Air Forces' systematic onslaught against the French rail system, mounted in support of the Normandy invasion, proved far more effective in limiting the scale of the bombardment than the attacks on the launchers. Once a site had fired its stock of missiles, it sometimes had to wait days for the next batch to arrive. Throughout the bombardment, the ability of the German logistics organisation to deliver missiles fell far short of the sites' capacity to launch them.

Revised Defensive System

In mid-July the gun and fighter defences underwent a major reorganisation aimed at increasing their effectiveness. Those changes are described in detail on Plate C, and the accompanying commentary. The revised deployment greatly increased the efficiency of the AA guns, without lessening that of the fighter defences.

At the end of July the RAF prepared to send its first jet fighter unit, the newly reformed No 616 Squadron equipped with Gloster Meteor Is, into action against the V.1s. Below 4,000 feet, the band of sky inhabited by the flying bombs, the jet fighter's top speed of 385 mph was about 25 mph faster than its piston-engined counterparts.

Great things were expected of the jet fighters, but during their first week of operations they had no success against the flying bombs. Although their pilots saw V.1s on several occasions, during each attempted to engage something always went wrong. A common cause of failure was the fighter's armament of four Hispano 20 cannon. During firing the used ammunition links did not fall away cleanly,



The American manufactured SCR-584 microwave gun-control radar, designated the Radar, AA, No 3 Mark 5 in British Army service. Its use, together with the radar proximity fused AA shell, greatly improved the effectiveness of AA guns against the V.1 missiles.

leading to a build-up in the link jettison chute that eventually caused the weapon to jam. The squadron's engineers devised a modification to overcome the problem, but it took a few days to incorporate this into all aircraft.

On 4 August, Flying Officer `Dixie' Dean manoeuvred himself into position behind a flying bomb and opened fire. His guns jammed after firing a few rounds. Nonplussed by the failure, the pilot caught up with the V.1 and edged the Meteor's port wing into a position beneath that of the flying bomb. He then banked sharply to the right, so that his wing struck that of the V.2 and knocked it upwards. The flying bomb went spinning out of control and crashed. At the price of a damaged wing-tip, the Meteor had claimed its first victim. That seemed to remove the jet fighter's apparent jinx, and later that day Flying Officer J. Roger shot down a flying bomb using his cannon. During August the jet fighters accounted for a total of thirteen flying bombs.

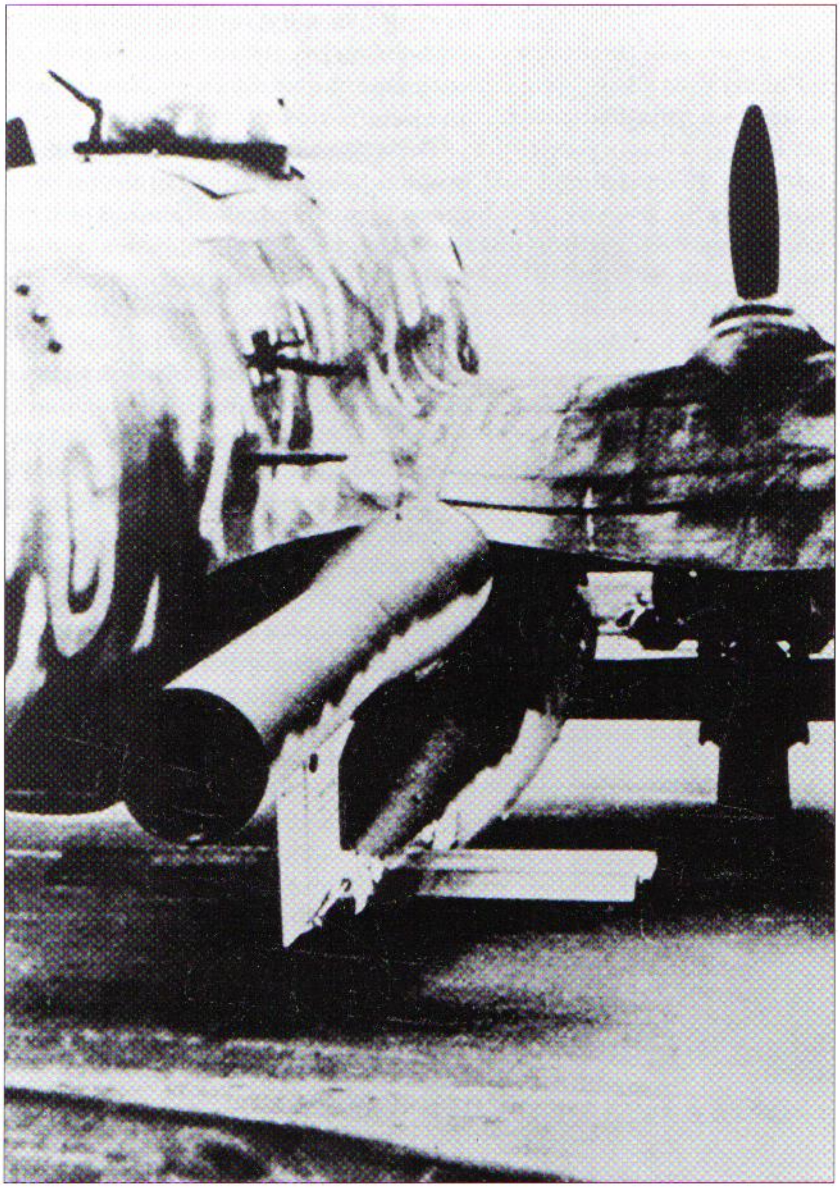
Three important technical developments from the USA now assisted the AA gunners to do even better. The first of these was the SCR-584 microwave gunlaying radar, a state-of-the-art system with the ability to lock-on to targets. The second was the new No 10 Predictor system, designed to make full use of the accurate flow of information from the new radar. The third development was the proximity fuse, miniaturised radar small enough to fit into the nose of an AA shell, which detonated the round as it passed close to an aircraft. Using these devices in conjunction with 3.7in. guns, experienced gunners were able to shoot down flying bombs for an average expenditure of only 156 shells – an unprecedentedly low figure. Writing on his Command's efforts against the flying bombs, General Pile commented: 'More was learnt about the potentialities of anti-aircraft work in 80 days than had been learned in the previous 30 years.'

In the third week in August 1944, the German Army in Normandy began a headlong retreat out of France. Allied troops advanced rapidly through the Pas de Calais and overran all the V.1 launching sites. On the morning of 1 September the last of 8,617 flying bombs was dispatched from a launcher in northern France. The initial phase of V.1 bombardment was over.

Air-Launched Flying Bombs

Although the great majority of the flying bombs launched against England came from ground launchers in the Pas de Calais area, a small percentage had come from another source. Since 9 July 1944, Heinkel 111 bombers of Kampfgeschwader 3, specially modified to launch V.1s, had joined in the bombardment.

The Heinkels ran in over the sea at night or in bad weather, staying below 300ft to remain beneath the cover of the British coastal radars. As a Heinkel neared its V.1 launch point, it turned on to its attack heading and began a slow climb to 1,700ft. It then levelled out and accelerated to 200mph, the minimum flying speed for the flying bomb. Then the flying bomb's pulsejet engine was started, lighting up the sky and making the bomber crew feel very vulnerable. Once the V.1 was released, the bomber entered a steep descending turn aiming to put as much distance as possible between itself and the highly visible missile it had unleashed.

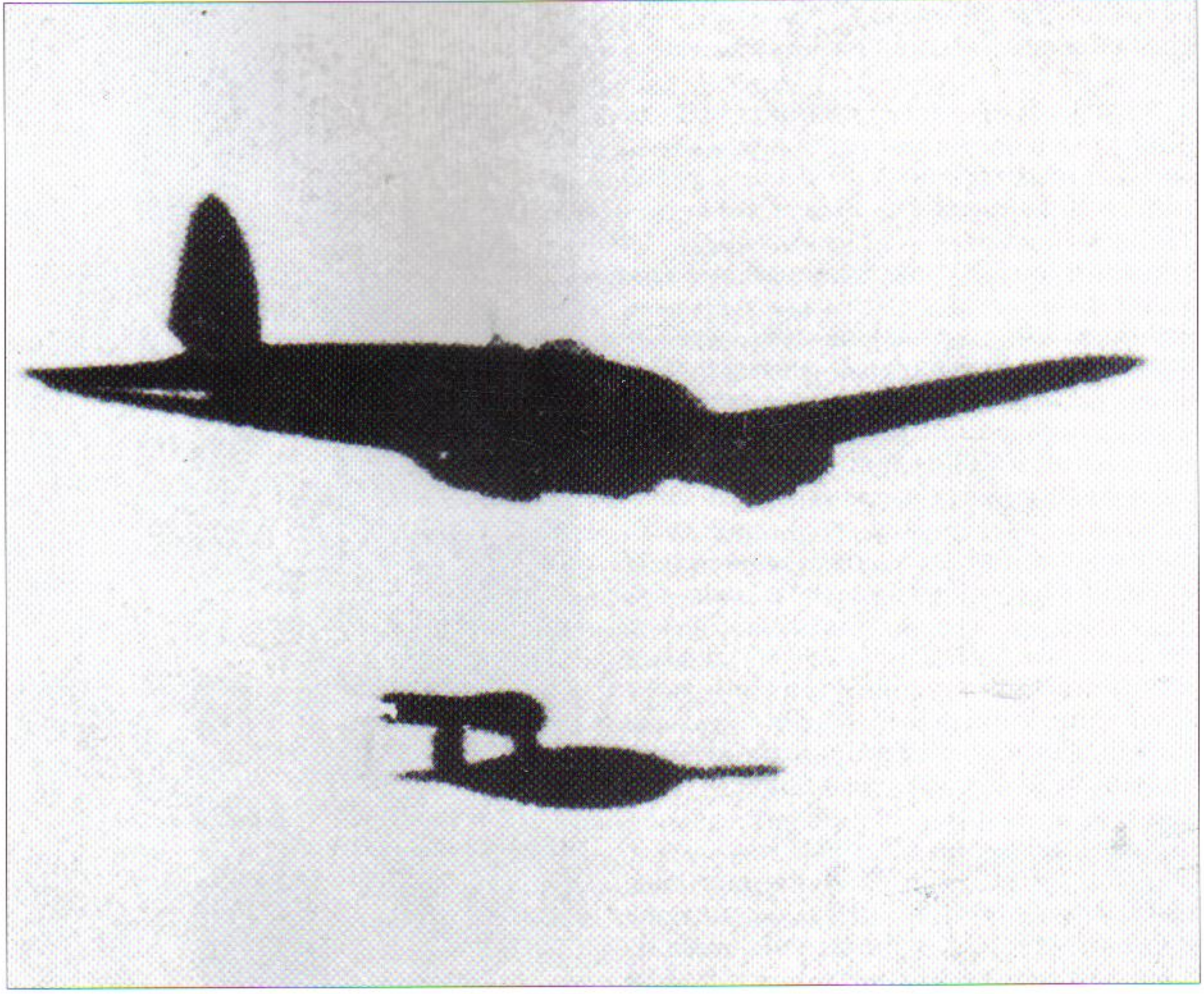


A modified Heinkel 111 carrying a V.1 flying bomb under the starboard wing root. The carriage of the large and heavy missile externally imposed a severe performance penalty on the obsolescent bomber.

Following release, between a third and a half of the air-launched flying bombs failed to function correctly and crashed or wandered off course. Even when they functioned properly, the air-launched missiles were far less accurate than those from ground launchers.

Once the RAF learned of the new form of attack, it reacted forcibly. Each night when operations were considered likely, Mosquito intruders flew standing patrols over the Heinkels' bases. Also, Mosquito night-fighters mounted standing patrols in the areas over the North Sea from which the Heinkels launched their missiles. To meet the changed axis of the threat, many gun batteries moved from the south-east coast of England to the east coast north of the Thames estuary.

An attack on the night of 16 September 194 provides an excellent example of an air-launched missile attack. The weather over the North Sea was perfect for such an operation: a thick overcast with the cloud



He 111 launching a V.1 in flight.

base between 700ft and 1,200ft, and light drizzle. Fifteen Heinkels launched missiles at London from points over the North Sea, nine of which got under way satisfactorily. Night-fighters and warships' guns destroyed three missiles before they reached the coast of England. Fighters shot down two more over land. Two of the remaining missiles fell in open countryside in Essex. Only two V.1s reached the Greater London area, of which one fell on Woolwich and the other on Barking. No V.1 launching aircraft were lost.

Enter the V.2

London's citizens enjoyed only a brief respite following the end of the main V.1 bombardment, before the second of the new German weapons hit them. On the afternoon of 8 September, without warning, a V.2 ballistic missile exploded on Chiswick to the west of London. The weapon killed three people and injured 17.

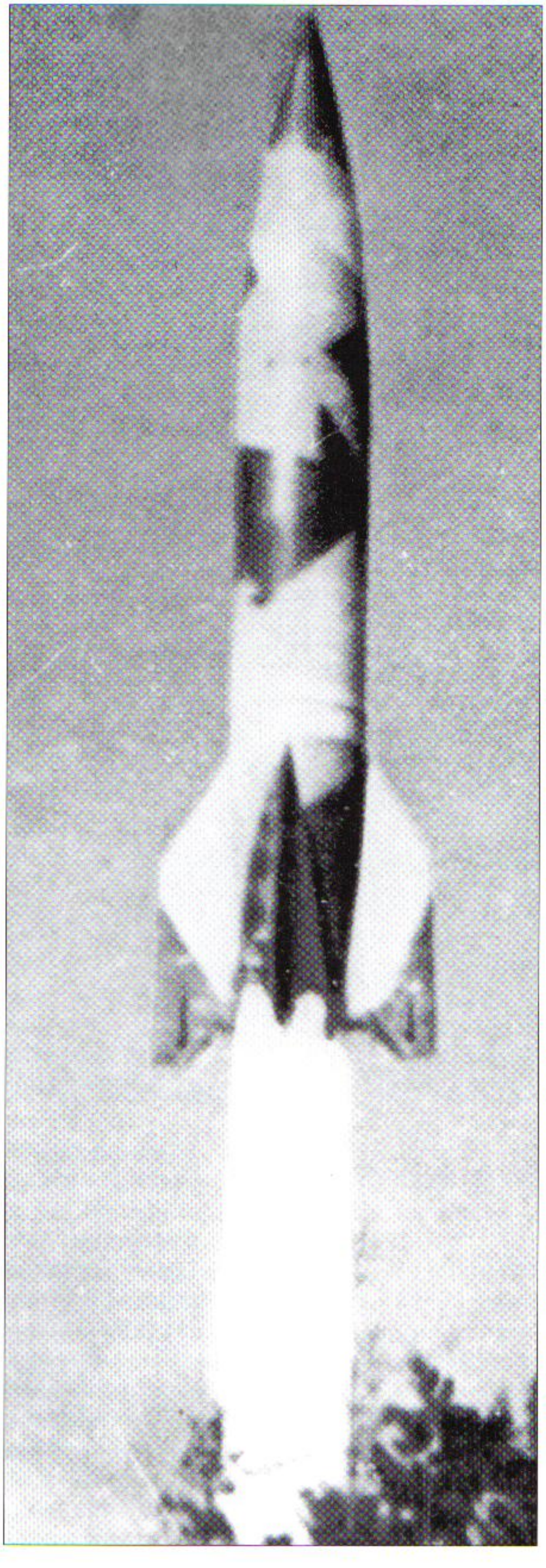
The V.2 had been fired from The Hague in Holland, about 195 miles away. During the next 5½ months, 1,053 rockets fell on England (an average of about five per day). Of that total 516 (an average of less than three per day) hit London. Just over 2,700 Londoners were killed in the attacks. As an act of terrorism the V.2 bombardment was successful, but the damage was spread over such a large area that it failed to achieve any decisive result.

No defence was attempted against V.2s in flight, though one such scheme was considered. Ground radars regularly tracked the incoming missiles, and their trajectories were well known. The idea was to use the 5.25in. super-heavy AA gun, a new weapon deployed in small numbers, to fire shells that would burst at a designated point ahead of an approaching missile. The aim was to create a curtain of shell splinters in front of the V.2 to inflict damage to the warhead or cause it to detonate prematurely. Scientists calculated that firing 400 of the big 80-pound shells into that part of the sky would give a one-in-30 chance of neutralising the warhead. Or, to put it another way, it would need an average of 12,000 shells to be fired for each V.2 countered. If just one per cent of those shells failed to explode in the air but instead detonated when they fell back to the ground – a conservative figure – the returning shells were likely to cause more damage than a V.2 left to reach its target. The scheme was not tested in action.

In the event, the only effective countermeasure against the V.2 campaign was the disruptive air attacks on the Dutch rail system, which slowed the delivery of missiles to the launching sites. That, and difficulties with mass producing the large and complex missile, kept the scale of the V.2 bombardment within bearable limits.

Box 12: The V.2 Ballistic Rocket

At launch the V.2 weighed 28,229 pounds, of which about 19,000 pounds was fuel and 2,200 pounds was warhead. The bi-fuel rocket, running on liquid oxygen and a 3:1 alcohol/water mixture, developed a thrust of 68,500 pounds for 55 seconds. After launch the weapon climbed vertically for four seconds, then it inclined to an angle of about 35 degrees from the vertical pointing in the direction of the target. The missile accelerated to around 3,500mph, then the fuel supply was cut off. The missile's inertia carried it to an altitude of between 50 and 60 miles, and from there it followed a ballistic trajectory until it impacted at a speed of about 2,400mph. The time of flight, for a full-range shot of about 200 miles, was just under five minutes.



V.2 rocket pictured immediately after launch. At lift-off the missile weighed just over 12½ tons, of which about 8½ tons was fuel and 1 ton was warhead.

Later Air-Launched V.1s

The bombardment of Britain with air-launched V.1s continued through the autumn and winter of 1944, but failed to achieve any degree of intensity. In the autumn of 1944, the V.1 launching force was expanded to a full Geschwader, KG 53, established at 90 aircraft. Shortages of aviation fuel prevented the unit achieving its full potential, however.

The vast majority of the air-launched missiles were aimed at London. The only major exception was during the early morning darkness of 24 December 1944, when there was a large-scale operation against Manchester. Some 50 Heinkels launched missiles at the city. Thirty V.1s crossed the coast between Skegness and Bridlington, 11 of which landed within 15 miles of the centre of Manchester. Only one landed within the city limits, however. The attack killed 37 people and seriously injured 67. One Heinkel was shot down by a night-fighter.

In mid-January 1945 the air-launched V.1 flights ceased, a victim of the severe fuel shortage now afflicting the entire Luftwaffe. From first to last, 77 Heinkels were lost during in the course of the operations. Mosquito night-fighters accounted for 16 of those losses. Most the others were destroyed in accidents when flying at low altitude, at night and in bad weather, to avoid RAF fighters.

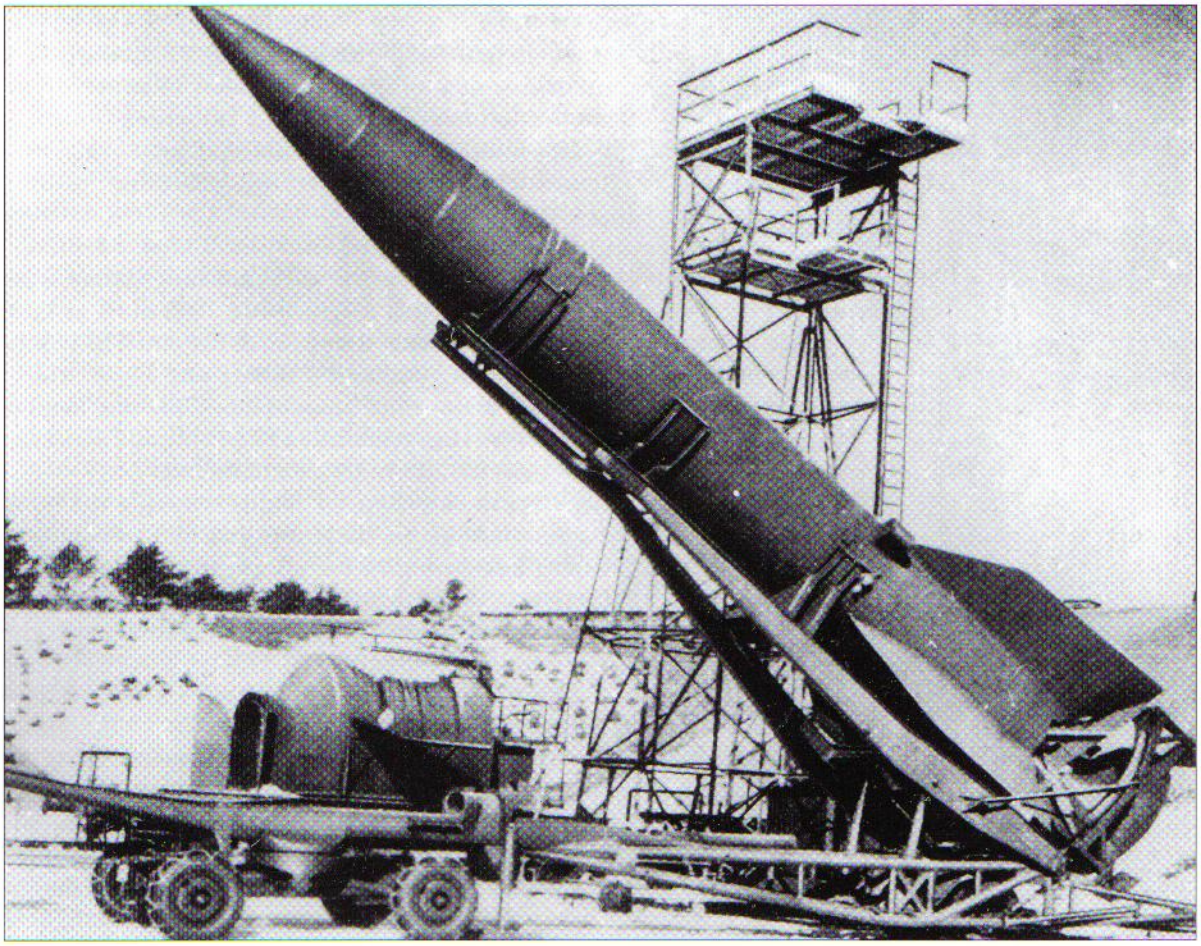
The V.1 Attack Resumed

On 3 March 1945 the V.1 bombardment of London resumed, using an extended-range version of the V.1 with a larger fuel tank, a smaller warhead and a modified engine. The improved missile had a maximum range of 200 miles, sufficient to reach the capital from ground launching sites in Holland. This phase of the attack lasted less than a month, and saw the firing of 275 missiles. By the end, the British fighter and gun defences had reached their peak of efficiency. Only 13 of the extended-range flying bombs – less than one-in-five of those launched – reached the London area.

The Robot Attack Summed Up

In total, just over 10,000 V.1s were launched against England. About 85 per cent of those came from ground launchers, the rest were air launched. Of that total, 7,488 missiles crossed the coast of England or were otherwise observed by the defences, and 3,957 were brought down short of their targets. Of the 3,531 which eluded the defences, 2,419 reached London, about 30 reached Southampton and Portsmouth, and one hit Manchester. Thus only about a quarter of the ground-launched bombs reached their intended target areas. For air-launched missiles the figure was about one-tenth. The flying bombs launched against England caused 6,184 deaths – an average of three for every five bombs fired. A further 17,981 people were injured.

The original plan had been to co-ordinate V.1 and V.2 attacks with large-scale raids by manned bombers during Operation *Steinbock*. Had this been the case, the defences might have been seriously over-extended and the attacks could have caused far more damage and casualties than actually occurred. In the event, however, Londoners faced the more severe threats individually and that did much to blunt their force.



V.2 ballistic missile being hoisted into the vertical position, prior to fuelling.

IN RETROSPECT

With the prospect of war against Germany looming ever larger during the late 1930s, there was widespread alarm in Great Britain regarding the nation's vulnerability to air attack. If war came, it was feared that the Luftwaffe would immediately deliver devastating attacks on London and other cities. Yet when war did come, in September 1939, the homeland remained virtually untouched for nearly ten months. That allowed invaluable time for the fighter and AA gun defences to modernise their equipment and prepare for battle.

The main phase of the Battle of Britain opened in August 1940, and Royal Air Force Fighter Command inflicted heavy losses on the raiding forces. Central to that success was the carefully prepared and rigorously exercised system of fighter control from the ground, which Air Chief Marshal Sir Hugh Dowding had created. Using radar to provide early warning of attacks, it allowed Group commanders to maintain an unprecedented degree of control over the course of each air battle. That ability proved decisive, and at the end of September 1940 the Luftwaffe abandoned its large-scale daylight bombing attacks.

Fighter Command had demonstrated that it could administer a bloody nose to attackers coming in by day. Yet at night, during the latter half of 1940, it was a different story. Then the defences were ineffectual, and Luftwaffe bombers operated at will over Britain. City after city suffered heavy damage. For want of anything more lethal, an important aspect of the defences was the jamming of the German radio beams. Even if the enemy bombers could not be knocked down, at least many of them might be prevented from delivering accurate attacks.

Desperate times call for desperate measures, and this period was one of vigorous experimentation and much trial and error. By the end of it, at the beginning of 1941, the nation had established the requirements for an effective night air defence system. The essential items were the powerfully armed and radar-equipped Beaufighter aircraft, and the precision Ground Controlled Interception (GCI) radar to guide it into position to engage enemy bombers. At the same time, new types of ground radar came into service in quantity to direct the AA guns and searchlights. In parallel with that influx of new equipment, there was an energetic effort to teach those who operated and maintained the various systems to get the most out of them.

During the early months of 1941, Britain's fighter and gun defences became noticeably stronger with each month that passed. In the latter part of May the Luftwaffe attacks became less frequent, and in the following month the reason became clear: Adolf Hitler launched his onslaught on the Soviet Union. The bulk of the Luftwaffe bomber force had by then transferred to the Eastern Front to support it.

The next two-and-a-half years saw only spasmodic air attacks on Great Britain. Throughout that time the defences improved steadily, and often made raiding forces pay dearly for their incursions. That phase of the bombardment culminated in January 1944 with Operation Steinbock, the final series of manned bomber attacks on London and other cities. Again the defenders proved able to meet the threat, and inflicted heavy losses until the attacks came to an end in May 1944.

Meanwhile, two revolutionary German weapon systems had entered mass production: the V.1 flying bomb and the V.2 ballistic rocket. The attack with the former, mainly against London, began in June 1944. The main phase of the V.1 bombardment lasted until the beginning of September 1944, with an average firing rate of just over 100 missiles per day. Thereafter it continued at a much lower rate, until it petered out in March 1945. The V.2 attack, also aimed mainly on London, began at the end of the first week in September 1944. It achieved an average firing rate of only five missiles per day, and it too petered out in March 1945.

Nazi leaders had hoped to run a combined bombardment against London in 1944, with simultaneous attacks by manned bombers, flying bombs and ballistic missiles. Had that happened it might have seriously over-extended the defences, but fortunately for the capital's citizens it did not occur.

With the end of the V.1 and V.2 attacks, the aerial bombardment of Great Britain ended also. This had taken many different forms, few of which had been foreseen before the war. Except for the V.2 ballistic rocket, against which no defence was possible, each form of attack was successfully countered within a few months. As a result the aerial bombardment failed in its aim, that of inflicting decisive levels of destruction and casualties on the nation.

THE PLATES

A1: RAF Flight Lieutenant Fighter Pilot

RAF flight lieutenant fighter pilot wearing 1940 pattern battledress, officially known as Suits, Aircrew. The outfit looked slept in, because it had been. During periods at standby in dispersal huts close to their aircraft, pilots often dozed off. He wore a bright yellow Life Jacket Mk 1, known universally as the 'Mae West', inflated by a small carbon dioxide cylinder or by an oral inflation tube. On the lower left side was a fluorescine sea marker, which could be released into the sea to make the wearer more visible. He wore a Type B leather flying helmet with Mark IV flying goggles. The D Variant 2 oxygen mask, 'on the dangle', contains the radio microphone. The fleece-lined 1936-pattern flying boots provided a useful place in which to stow flying maps. The long radio lead, coming from the back of the flying helmet, terminated in a bell connector.

A2: Member of the Royal Observer Corps

Member of the Royal Observer Corps, at an observation post. The government-supplied items of apparel were limited to the black Royal Observer Corps beret and silver badge, and the black and white striped armband. The latter afforded the wearer special constable status and could save him from being shot as a spy, should the enemy capture him. He purchased the rest of his clothing. For warmth, he wore a high-buttoned waterproof riding coat and brown leather gloves. The high-magnification binoculars slung from his neck were his own property.

A3: WAAF Operations Room Plotter

WAAF (Women's Auxiliary Air Force) Operations Room Plotter at Fighter Command Headquarters, Stanmore Park, during the Battle of Britain. For comfort when working in the large room, she wore a blue knitted woollen cardigan. On her head she wore earphones to receive the aircraft plots, and a microphone on her chest with which to confirm the plots. She wielded a long varnished wooden pole, like a croupier's rake, to move the markers around on the large situation-map table.

B: FIGHTER COMMAND'S RIPOSTE TO THE ATTACK ON LONDON ON THE AFTERNOON OF 15 SEPTEMBER 1940.

The map shows the route flown by the German bombers during their attack on dock areas on the eastern side of London on that day. The bombers crossed the coast at Dungeness, then headed north-west to a point on the Thames just west of Gravesend. From there, the unmistakable line of the river led the raiders to their targets. Fighter Command's response. At **(1)**, shortly after the raiders crossed the coast, three forward-deployed squadrons of Spitfires engaged the raiders. About five minutes later, at **(2)**, two Hurricane squadrons joined the fight. Two further Hurricane squadrons engaged at **(3)** and two more at **(4)**. The intention of these moves was to maintain pressure on the raiding force, from the time it crossed the coast.

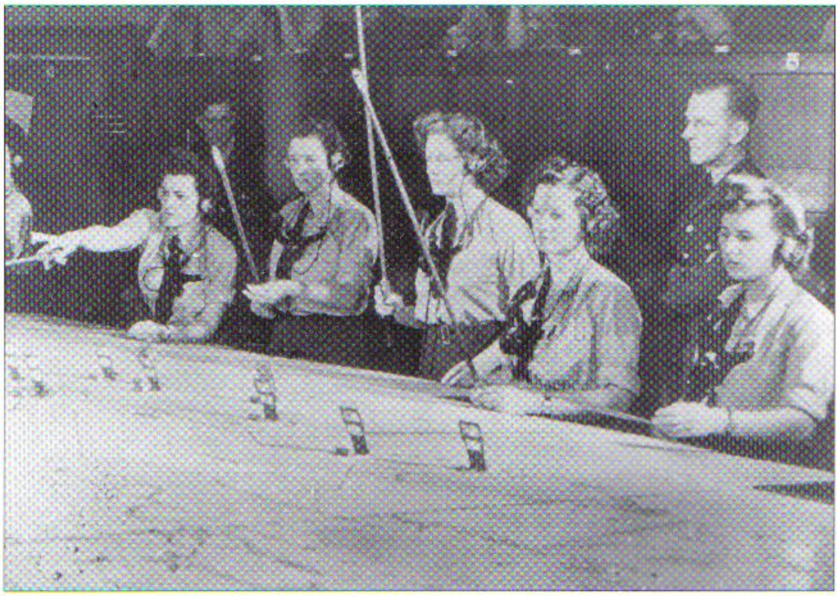
At point **(5)**, immediately in front of the capital, Air Vice Marshal Park threw his main force at the enemy: 19 fighter squadrons with 185 Spitfires and Hurricanes.

Twenty-eight squadrons of fighters scrambled to meet this attack, and all made contact with the enemy force and went into action. In what is now called 'Battle Management', Fighter Command's well-practised system of ground control made it possible to direct the fighters into action with precision, to achieve maximum effect.

Inset

The Luftwaffe attack formation comprised five bomber Gruppen, drawn from Bomber Geschwader 2, 3, 26 and 53. With 52 Heinkel 111s and 62 Dornier 17s, this constituted a powerful attack phalanx to strike at dock areas on the eastern side of London. Each bomber Gruppe had an assigned close escort of one Gruppe with about 30 Messerschmitt 109 fighters. Providing open cover for the force were an additional five Gruppen of fighters, while five more Gruppen of Messerschmitts flew in the free-hunting role to clear the skies ahead and on the flanks of the raiding force.

OPPOSITE **A Gruppe of Dornier 17s in attack formation.**



WAAFs at the No 11 Group operations room at Uxbridge, moving unit symbols into place to update the air picture on the situation-map table.

C: DISPOSITION AND RE-DISPOSITION OF DEFENCES TO COUNTER THE V.1 FLYING BOMB ATTACK ON LONDON, 1944.

The upper map shows the initial dispositions of the defences to counter the V.1 flying bombs. Fighters flew standing patrols along three lines: one some 20 miles off the coast, one along the coast and one about 15 miles inland. Behind the fighter patrol lines came the gun zone, with 192 heavy guns and a similar number of light AA weapons deployed across a strip of ground 20 miles deep. Behind the gun zone, close to London itself, was the balloon zone with 480 LZ barrage balloons.

The lower map shows the revised dispositions of the defences after 20 July. Attempts to operate AA guns and fighters simultaneously against individual V.1s had led to instances of fighters coming under fire. It also led to missed opportunities for the gunners, when they erroneously thought the approaching machine was a fighter. The answer was to give each system a clearly defined area where it alone could engage incoming targets without restriction.

Under the new scheme the AA guns, 412 heavy weapons and 572 light guns, were redeployed along the 65-mile-long strip of coast between St Margaret's Bay and Cuckmere Haven. Fighters were prohibited from entering the zone, a ban reinforced by the knowledge that the gunners were free to loose off at anything flying towards them.

The fighter engagement zone was split into two. The outer zone was over the English Channel and ended 5 miles short of the coast, where the gun zone began. The inner fighter engagement zone extended from the rear of the gun zone, to the start of the balloon zone. By mid-August 1944, there were 15 squadrons of day fighters and six of night fighters operating against the V.1s.

The 'backstop' balloon zone remained in place, behind the inner fighter zone. By now there had been a fourfold increase in the number of balloons deployed, bringing the total to more than 2,000.

The new deployment greatly increased the efficiency of the AA guns, without lessening the effectiveness of the fighters. During the first week of the new deployment the defenders destroyed about half the flying bombs observed coming in, compared with 43 per cent during the previous week. Thereafter, the proportion of missiles destroyed continued to rise.

D: PRINCIPLES OF SITING LIGHT ANTI-AIRCRAFT GUNS

As in the case of heavy anti-aircraft guns, light AA weapons like the 40mm Bofors were positioned to bring raiding aircraft under accurate fire during their bombing run to disrupt their attack. Low-flying raiders, for the most part fighter-bombers, typically released their bombs in a shallow dive from 600ft flying at speeds around 300mph. That gave the bombs a forward throw of about half a mile. Provided ground features did not obscure the plane, the Bofors gun had a maximum effective range of just over 1 mile. These weapons were usually fired over open sights, so they were at their most effective against aircraft flying directly towards or directly away from them. Only rarely were there sufficient defensive weapons to provide protection against low altitude attacks from every possible direction. In this case there were six Bofors guns and three barrage balloons, to protect the target factory **(1)**. The crew of the 40mm Bofor gun **(inset)** comprised six men: No 1, NCO gun commander, No 2 Layer for bearing, No 3 layer for elevation, No 4 breach loader, and two 'ammunition numbers' to pass the four-round clips of ammunition to the breach loader.

In considering how best to deploy these defensive systems, it is necessary to consider the raiders' likely tactics. To achieve surprise, the raiders needed to spend as short a time as possible over hostile territory. Also, to navigate accurately at low altitude, they required a succession of fixing points including some with vertical extent. At a point about 2 miles from the target they used a distinctive object to mark their Initial Point, where they commenced a short climb before entering the bombing run. To assist in concealing their approach, the raiders might plan their route to attack from out of the sun.

Those requirements usually meant there was only a limited number of good low-altitude approach routes. For the target depicted the most direct route, from due south, was unsuitable due to the lack of suitable fixing points. Moreover, the wooded hillock **(2)** would shield the target from the raiders until late in their attack.

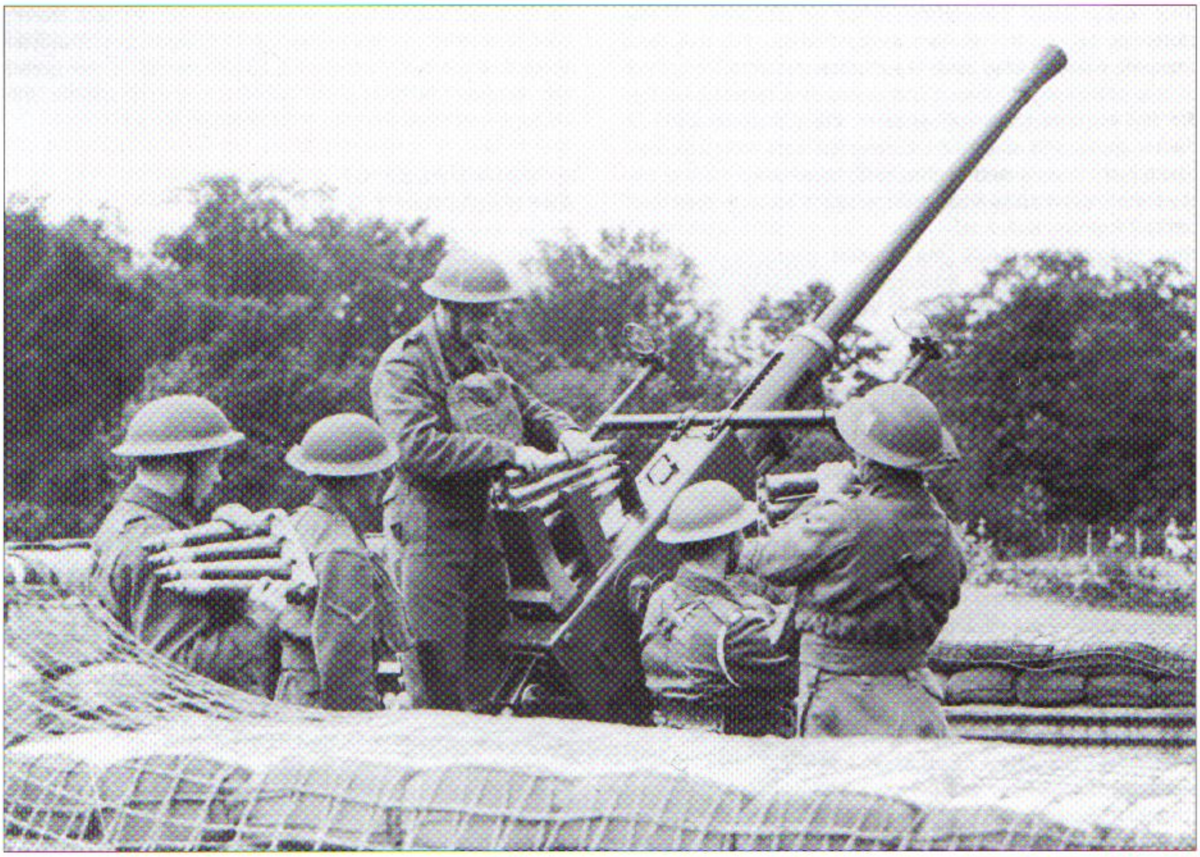
There were, however, two suitable routes that low-altitude raiders could follow. For Attack Route A, the raiders could run in from the south-east, with the sun on their backs in the early morning. They would aim to cross the coast near the ancient hill fort **(3)** keeping just east of the river **(4)**. They would then follow the line of the river until they reached the distinctive concrete bowstring bridge at **(5)**, 2 miles from the target and the Initial Point for the attack. The raiders then moved into line astern, turned on to their attack heading and commenced a swift climb to 1,000ft. The extra altitude allowed the pilots to pick out their aiming points, then deliver their bombs in a shallow dive. The planes released their bombs from about 600ft to avoid the blast and splinters when the weapons detonated, then descended to very low altitude to make their escape.

For Attack Route B, the raiders would run in from the south-west, with the sun on their backs in the late afternoon. They would cross the coast just to the east of the lighthouse **(6)**, keeping the wooded ridge **(7)** to their left. At the end of the ridge the raiders would pick up the rail line **(8)** and follow it to the fertiliser plant **(9)**, the Initial Point for the attack from that direction.

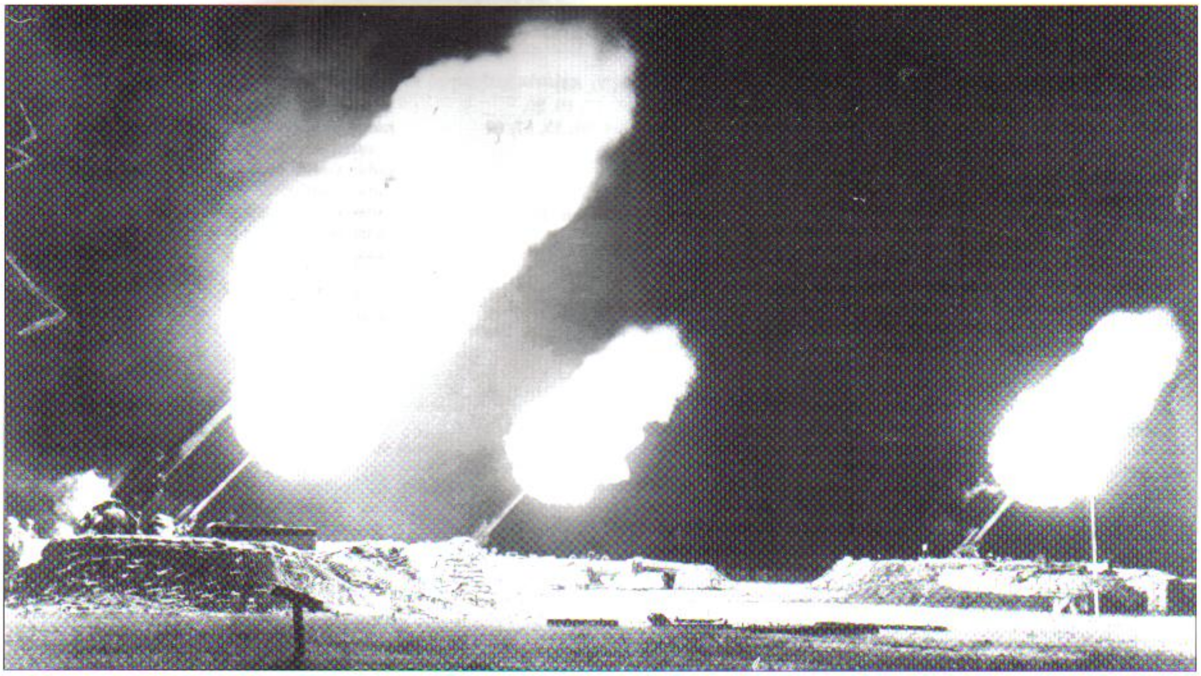
To cover both likely attack routes on the factory, the six Bofors guns were positioned in two 3-gun units, each unit about 600 yards in front of the target at **(10)** and **(11)**. Each unit's guns were laid out in a triangle of sides approximately 200 yards, with the apex towards the target. Each gun crew selected one raider and engaged it from the climb to the bomb release point. Once that point was passed, they switched their attention to the following aircraft. The second trio of guns engaged the raiders as they came away from the target.

Although those gun defences were tailored to meet attacks routed as described, they would also provide useful protection against attacks from other directions.

OPPOSITE **A spectacular shot of a half-battery of four 3.7in. guns, sited in Hyde Park, firing a salvo at night.**



The main defence against low-flying aircraft, and dive-bombers, was the 40mm Bofors gun. Usually aimed over open sights, this weapon fired 2-pound high-explosive impact-fused shells at a maximum rate of 120 per minute. A single hit from one of these rounds was normally sufficient to bring down an aircraft.



The most likely times for attack were when the sun was low on the horizon, an hour or so after dawn and a similar time before dusk. To meet those threats, gun crews were routinely stood to during those periods.

Three balloons were flown from sites immediately beside the potential target. If there was cloud below 5,000ft, the balloons were usually invisible to attacking aircraft.

E: HEAVY ANTI-AIRCRAFT GUN AND CREW

Two men from the crew of a 3.7in. Heavy Anti-Aircraft gun. The full crew comprised 11: No 1 NCO gun commander, No 2 layer for bearing, No 3 layer for elevation, No 4 shell fuse setter, No 5 breach loader and six 'ammunition numbers'.

Plate F depicts the Sergeant gun commander (No 1) and the breach loader (No 5).

Both men wore standard pattern khaki overalls, topped with service-issue brown sleeveless leather jerkins. That combination gave maximum freedom of movement during the hard manual work of feeding shells into the gun during firing. Each man wore a Mark I* steel helmet, with the strap behind the neck. The latter was important because if the wearer was close to the gun's muzzle when it fired, the blast could whip away the helmet; if the strap was under the chin, it could cause serious or even lethal injuries to the wearer. The breach loader held a 3.7in. high-explosive round, identified by the yellow shell and the green band and circle. The complete round weighed 56 pounds, and the loader wore a thick leather glove on his right hand for protection when he pushed the round into the breech.

F: HEIGHT-FINDER AND CREW

A lance bombardier, height-finder commander of the ATS (Auxiliary Territorial Service). The expansion of the AA gun defences during the war, coupled with the drain of able-bodied men to serve in fighting units overseas, brought ATS women into gun batteries to perform active roles. Although it was considered inappropriate for women to operate guns, they operated other items of equipment at gun sites. This girl wore standard army pattern overalls, with a service greatcoat for added warmth. Like her male counterparts (Plate B/1 above) she wore a Mark I* steel helmet with the strap behind her neck. The thick khaki scarf, probably knitted by herself, was an unofficial addition to help keep out the cold.

G: OPERATION OF THE LZ BARRAGE BALLOON

The LZ (Low Zone) barrage balloon, 62ft long and 25ft in diameter, held 19,000 cubic feet of hydrogen gas and had a normal maximum flying altitude of 5,000ft. To protect a vulnerable point from attack by low-flying aircraft or dive-bombers, the balloons were distributed randomly across the area of the potential target.

When an aircraft hit the balloon cable, a cutting link at each end severed the cable. The aircraft thus carried away the main portion of the cable, about a mile long. Attached to each end of the cable was an 8ft diameter canvas drogue parachute. When fully open, the parachutes generated a combined drag of about six times the bomber's engine thrust. That stopped the plane almost in its tracks, causing it to stall and fall out of the sky.

As the cable was pulled away from the balloon, a wire connected to the balloon tore off a large ripping patch. That allowed the hydrogen to escape, and the balloon descended slowly to the ground.

The purpose of the balloons was to protect targets by preventing accurate attacks by low-flying aircraft or dive-bombers. In this, they were brilliantly successful. Although they brought down few German aircraft – less than 30 during the entire war – there is no recorded instance of low-flying aircraft or dive-bombers making a deliberate attack on a target protected by balloons.

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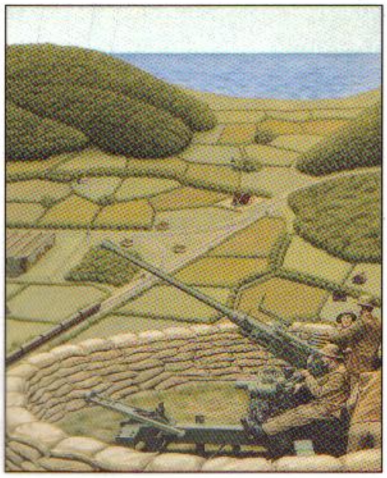

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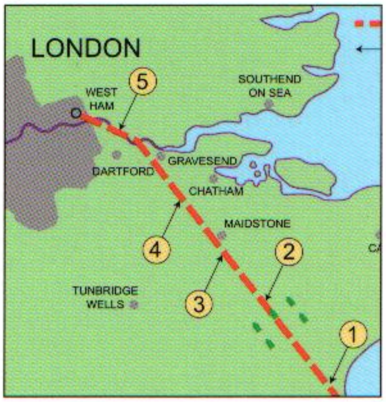

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