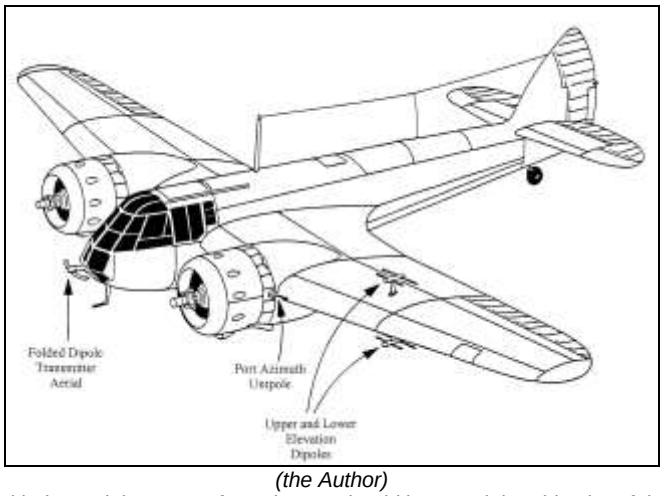
A SHORT HISTORY OF AIR INTERCEPT RADAR AND THE BRITISH NIGHT-FIGHTER, PART ONE 1936 – 1945, by Ian White.

Following the pioneering work undertaken by Robert (later Sir Robert) Watson-Watt, Arnold Wilkins and A.P.Rowe at Daventry and later at the Bawdsey Manor experimental station in Suffolk, in the design of the early warning (EW) radar system code-named Chain Home (CH), the Air Staff's Member for Research & Development, Air Marshal Sir Hugh Dowding, in conjunction with the government scientist, Professor Henry (later Sir Henry) Tizard, turned their attention towards the design and development of an airborne radar set.

1.5 METRE AI RADAR

During August 1936 Watson-Watt, by then the Superintendent of the Air Ministry Research Establishment (AMRE) at Bawdsey, formed an Airborne Group under the leadership of Dr Edward 'Taffy' Bowen to manage the development of air intercept (AI) radar. The first trials of a complete airborne radar system (transmitter, receiver and display) installed in a Heyford bomber and operating on 6.7 metres (45 MHz), were conducted by Bowen in March 1937. By August of that year, the wavelength, and hence the size of the aerial system, had been reduced to 1.25 metres and installed in Avro Anson, K6260, for flight trials at Martlesham Heath. This set, which demonstrated ranges of 2 - 3 miles (3.2 - 4.8 km) in the 'sea search', or air-to-surface vessel (ASV), mode and a mile (1.6 km) in AI, formed the basis for all the wartime airborne radars. With the wavelength increased to 1.5 metres (200 MHz) to improve the sensitivity, the first hand built examples of AI Mk.I were installed in six Blenheim IVf fighters of a special flight of No.25 Squadron at Northolt in August 1939, whilst similar examples of ASV Mk.I were fitted to a very small number of Coastal Command aircraft.

The first operational AI, AI Mk.III, (Mk.II was a failure) were installed in the Blenheim Ifs of Nos.23, 25, 29, 219, 600 & 604 Squadrons in May 1940. The first AI success of the War occurred on the night of July 22/23rd 1940, when a Blenheim If of the Fighter Interception Unit (FIU), piloted by F/O Glyn 'Jumbo' Ashfield, with Sgt Reginald Leyland operating the radar and P/O Morris observing, intercepted and shot down, what is believed to have been a Dornier Do 17Z off Bognor Regis, Sussex. The Blenheim/AI Mk.III combination's principal disadvantage lay in the modest performance of the aircraft and the poor minimum range of the radar. In an attempt to overcome the former, Fighter Command's C-in-C, Air Chief Marshal Sir Hugh Dowding, directed that future night-fighters were to be based on the Bristol Beaufighter, which had both the performance and the armament required of a night-fighter. To match this AMRE called upon the assistance of the EMI Company, and particularly the services of its chief designer, Alan Blumlein, to produce the first practical, series production AI radar, AI Mk.IV. It should be noted that the turning of the aerial system from the horizontal to the vertical plane (polarisation) and the incorporation of a central modular to control the system, brought about a significant improvement in performance of the minimum range over that of AI Mk.III.



(the Author)

Bristol Blenheim If fitted with the aerial system of AI Mk.III. It should be noted that this aircraft has had the gunner's turret removed to save some 800-lbs of weight and improve its performance (slightly).

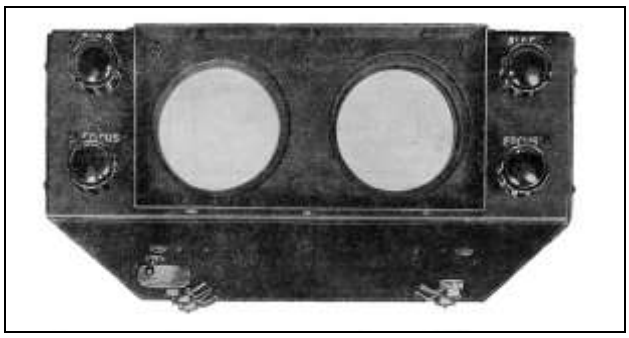
It was with the Beaufighter/AI.IV combination that Fighter Command began the Winter Blitz of 1940/41, albeit in limited numbers. The Beaufighter entered service in September 1940 and scored its first victory on the night of November 15/16th, when an aircraft of No.604 Squadron destroyed a Junkers Ju 88A-5 near Chichester, Sussex. Overall, Fighter Command's performance in the autumn and the early winter of 1940 was poor, due in part to the limited number of Beaufighters, a lack of trained aircrews, poor radar serviceability and the defence's inability to track enemy aircraft once they had passed through the CH screen.

This last problem had been foreseen by the staff at AMRE, who undertook interception trials earlier in the year, which, in turn, led to the development of a ground control of interception (GCI) radar, based on elements of the 1.5 metre Chain Home Low (CHL) radar, that was designed to fill the low level gaps in the CH chain, and the Army's gun-laying (GL) radar. With its rotating aerial and plan position indicator (PPI) display, the first mobile GCI (AMES Type 8) was installed at Durrington in November 1940 and successfully tested under operational conditions the following month. By April 1941, six Type 8s were in operational service. An improved version, AMES Type 7, that was capable of handling multiple interceptions, was deployed at permanent GCI stations from the summer of 1942.

(British Aerospace)

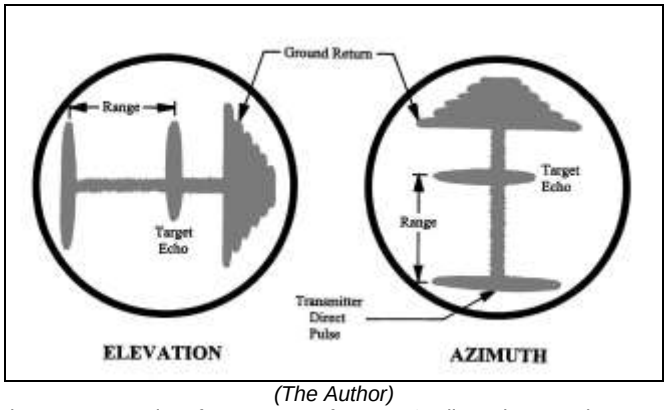
Bristol Beaufighter If fitted with the aerial system of AI Mk.IV. The arrowhead folded dipole transmitter element is mounted on the nose, with the port and starboard azimuth (directional) dipoles on the wing outboard sections and the elevation (up/down) unipole elements above and below the starboard wing tip. This Beaufighter type was flown by both 600 & 604 Squadrons from September 1940 to April 1943.

With the help of the GCI chain and improvements in the delivery of Beaufighters and radar sets, combined with the availability of better trained night-fighter crews from the Operational Training Unit (OTU) organisation and radar mechanics from the Radio Schools, saw the number of enemy aircraft destroyed begin to rise steadily during the late winter and spring of 1941 - three in January, four in February, twenty-two in March, forty-eight in March and ninety-six in May. It should be noted, however, that these numbers represented the combined figures for radar-equipped fighters and cats-eye's day-fighters (Hurricanes and Defiants) operating in the night role. At this juncture (spring 1941) in the development of Britain's night defences, Fighter Command's squadrons were equipped predominantly with Beaufighters (AI Mk.IV), supported by a few Blenheim If/IVf (AI Mk.III) squadrons and one flying the night-fighter version of the Douglas Boston bomber, the Havoc (AI Mk.IV).



(Crown Copyright)

The Radar Operator's (R/O) Display Unit for AI Mk.IV, with the elevation (up/down) CRT on the left and the azimuth (left/right) CRT on the right. Range was shown on both tubes.



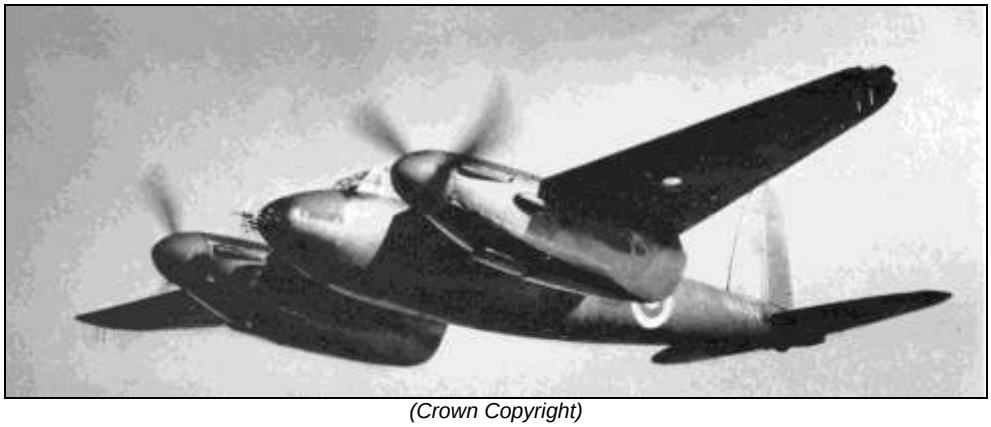
(The Author)
The display shows a target aircraft at a range of approx 3 miles, above and to port of the fighter.

Variations in the quality of radar operators (R/O) and with it the need for the pilot to control the latter parts of an interception, led to the development of AI Mk.V and the introduction of the pilot's indicator (a small cathode ray tube [CRT] that might be regarded as the precursor of the modern head-up display - HUD) in the cockpit. Installed from April 1942 onwards in the superb de Havilland Mosquito, AI.V claimed its first victim on the night of 24/25th June, when a Mosquito NF.II from No.151 Squadron destroyed a Dornier Do 217E-4 over the North Sea. The final metric AI radar, AI Mk.VI, a fully automatic system for single-seat fighters, was developed and test flown in 1942. However, with the removal of single-seat night-fighters from Fighter Command's inventory in 1942 and the imminent introduction of centimetric radar technology, AI.VI production was cancelled and the sets were converted to *Monica* tail-warning radars for Bomber Command.

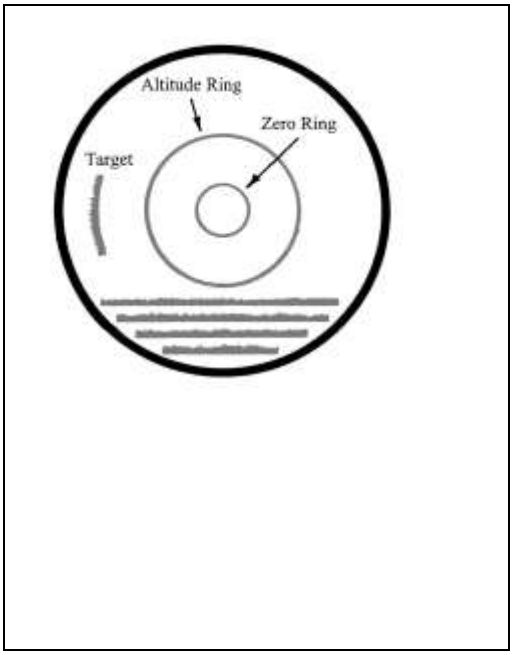
(Crown Copyright via IWM)
Beaufighter IIf powered by two R-R Merlin 20-series engines and fitted with AI Mk.IV radar. A number of these aircraft were employed operationally by 600 Squadron from April 1941 to April 1942.

CENTIMETRIC RADAR

The promise of shorter 'centimetric' wavelengths and narrower beams devoid of ground returns, became a reality in February 1940, when J.T.Randle and H.A.H.Boot ran the first resonant cavity magnetron valve at Birmingham University. This device, which some have rightly described as one of the most significant technological developments of World War Two, demonstrated a test-bench pulsed output of 10 kW on a wavelength of 9.8 cms (3,060 MHz). With the support of the GEC Company, the magnetron was gradually developed to the point where a small number were made available to the scientists at AMRE in May 1940, which by then had moved to Worth Matravers, near Swanage. In great secrecy, a team, initially under the leadership of Dr Herbert Skinner, was formed to design an AI radar around the magnetron valve, whilst Dr Bernard Lovell examined the feasibility of building a parabolic dish aerial and installing it in a radio transparent (perspex) radome fitted to a Blenheim IV.



(Crown Copyright)
The de Havilland Mosquito NF.II prototype, W4052, showing the aerial system of AI Mks.IV & V (they were identical) and the all-black sooty night finish favoured by Fighter Command in the early part of the war.



(The Author)

The R/O's Indicating Unit display for AIS and AI Mks.VII & VIIIA comprised a single screen. The spiral scanning system employed on these radars produced an arc to indicate a target and the ground returns were shown as horizontal lines, which also, conveniently, provided an artificial horizon. The diagram above shows the target aircraft at a range of 10,000 ft and 20 degrees to port and at the same level as the fighter. Although more complicated to interpret than the AI Mk.IV displays, the R/O's took to the spiral display quite quickly and with little trouble. These displays would have been familiar to 600 & 604 Squadrons' operators.

Designated AIS, where the 'S' stood for 'sentimetric', the new radar employed an eccentric spiral scanning system built by Nash & Thompson Ltd, and range displays where the target return was shown as an arc. Blenheim N3522 was fitted with the prototype AIS system and test flown from the Telecommunications Flying Units' (TFU) airfield at Christchurch on March 10th, 1941, where it detected an aircraft at a range of 7,000 feet (2,135 metres) when flying at a height of 5,000 feet (1,525 metres) - a task impossible for AI Mk.IV. Further developed and installed in a Beaufighter for trials with FIU, the set demonstrated ranges up to 10 miles (16 km), before being committed to limited production (100 sets) in December 1941 as AI Mk.VII. During February 1942, Beaufighters of Nos.29, 68, 141 & 604 Squadrons, were converted to AI.VII, with the radar enclosed in a 'thimble' radome developed by the Bristol Aeroplane Company (see opposite).
During September 1942, Mosquito NF.II, DD715, was converted to the thimble-nose standard to take AI Mk.VIIIA, the series production version of AI.VII, and serve as the prototype Mosquito NF.XII. Deliveries of AI.VIIIA from December 1942, enabled No.219 Squadron's Beaufighters to be converted during January 1943 and record the first AI.VIII kill, a Do 217, on the night of February 3/4th. During May 1943, No.151 Squadron converted to the Mosquito NF.XII, followed by Nos.85 & 488 Squadrons.

BRITISH RADAR v AMERICAN RADAR

Devoid of the urgent needs of war, radar research in the US had not advanced as far as that in Europe. However, in exchange for military equipment, ships and bases, Britain provided America with details of its scientific developments through the auspices of the Tizard Mission to Washington in

September 1940. One of its 'gifts' was the magnetron. With the assistance of Dr Bowen, the Massachusetts Institute of Technology (MIT) established its Radiation Laboratory for applied research in the field of centimetric radar technology. Beginning with an experimental design, the SCR 520, built in October 1941, the Western Electric Company developed their SCR 720B AI set, which was made available for testing in Britain in December 1942, alongside the Telecommunications Research Establishment's AI Mk.IX (AMRE was renamed 'TRE' in November 1940). This radar was a development of AIS with the added ability to track a target automatically, known as 'lock-follow', and provide firing information directly into the aircraft's gyro-gunsight. When the prototype AI.IX was lost on December 23rd, along with its principal designer, Dr Downing, and with SCR 720 performing well in the face of *Window* (chaff) jamming, the Air Ministry took the pragmatic decision to order the American set as AI Mk.X for installation in the Mosquito and defer the development of AI Mk.IX until after the war.

(Crown Copyright via the Douglas Fisher Archive)
Beaufighter Mk.If carrying the experimental centimetric AIS in a thimble radome, hence the 'P' on the rear fuselage.

The first AI.X sets were delivered to the UK during December 1943 for installation in Mosquito NF.XVIIs (see below). By the end of January 1944 Nos.25 & 85 Squadrons had completed their conversion and were committed to operations the following month, with No.25 claiming the first Mosquito/AI.X kills on the night of February 20/21st. With a range performance that varied between 5.5 & 6 miles (8.8 - 9.6 km), AI.X was to see service to the War's end and beyond.

THE FURTHER DEVELOPMENT OF THE MOSQUITO

By late 1943/early 1944 the Air Ministry had two principle centimetric AI radars in operation; the British AI Mk.VIIIA and the American AI Mk.X. Because the US equipment was too bulky to fit into the nose of a Beaufighter and production of that fighter was drawing to a close, night-fighter development was concentrated on the Mosquito. In September 1943 de Havilland's introduced a productionised version of the NF.XII, the NF.XIII (Merlin 20-series). This was identical in outline to the Mk.XII and employed AI.VIIIA in a thimble or universal 'Bullnose' and had the stronger wings of the Mk.VI fighter-bomber, whilst the NF.XVII (Merlin 20-series) was the equivalent to the Mk.XIII when fitted with AI Mk.X. Delays in the delivery of AI Mk.X sets from America in 1944, bred the final Merlin 20-series night-fighter, the Mk.XIX, whose bullnose radom was capable of accepting AI Mk.VIIIA or AI Mk.X.

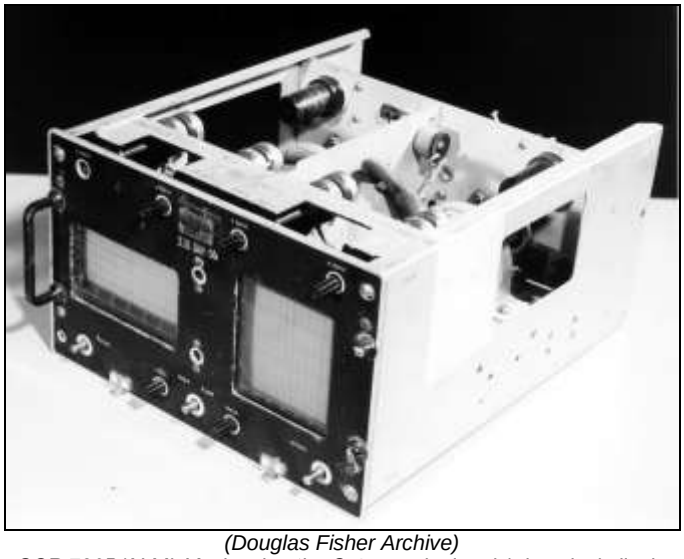
(Crown Copyright via IWM)

Mosquito NF.XII showing the thimble radome that accommodated the AI Mk.VIIIA radar and armament reduced to four 20mm cannon. These aircraft and the very similar NF.XIII were flown by 604 Squadron from February 1944 to April 1945.

The principle reason for the delays in AI Mk.X production was the priority (not unreasonably) ordered by the US Army Air Forces (USAAF) to the Northrop P-61 Black Widow night-fighter to equip its fighter squadrons in the UK, Mediterranean and Pacific Theatres. Unfortunately, the production of this fighter was delayed and in order that USAAF crews might acquire the necessary expertise and confidence prior to the invasion of Europe, set for sometime in late 1943/early 1944, the RAF allocated a number of Beaufighters and Mosquitoes to equip the 414th, 415th, 416th & 417th Night Fighter Squadrons (NFS) in North Africa and Italy. With the majority of the P-61 deliveries being allocated to NFS units in Pacific only the 422nd & 425th NFS in the UK and the 414th NFS in the Mediterranean were converted to the Northrop fighter. The remainder soldiered on perfectly adequately to the war's end with their British fighters.

(Crown Copyright via IWM)

The final development of the Beaufighter, the Mk.VIf, married the Mk.I airframe and AI Mk.VIIIB to the 1,670-hp Bristol Hercules IV or XVI engine. These aircraft equipped 600 Squadron from March 1942 to February 1945, making it in the process, one of the last RAF fighter units to operate Beaufighters. The one shown is in USAAF markings, who used the type as interim equipment in Europe and the Mediterranean between 1943 & 1945 pending the introduction of the Northrop P-61 Black Widow.



(Douglas Fisher Archive)
The R/O's Indicating Unit for SCR 720B/AI Mk.X, showing the C-Scope (Azimuth/Elevation) display on the left and the B-Scope (Range/Azimuth) on the right.

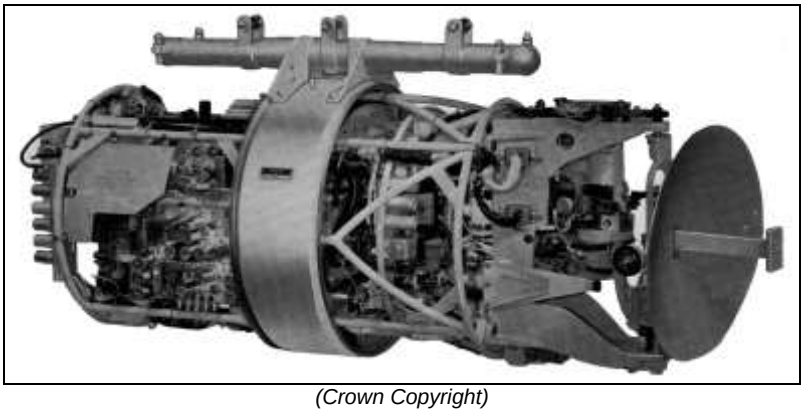
(Crown Copyright via IWM)
Mosquito NF.XIX (Merlin 20-series) as flown by 600 Squadron in Italy from December 1944 to August 1945. These aircraft were capable of mounting AI Mk.VIIIA or AI Mk.X.

(Crown Copyright via IWM)
Mosquito NF.30 showing the bullnose radome for AI Mk.X and 1,690-hp two-stage Merlin 76-engines.

The second stage in the Mosquito night-fighter's development began in September 1944, with the delivery of the first batch of NF.30s that were fitted with the two-stage Merlin 70 or 110-series of engines to improve the aircraft's range and high altitude performance - 407 mph at 28,000 ft, a range of 1,705 miles with underwing auxiliary fuel tanks and an operational ceiling of 33,000 ft. The Mk.30 represented the peak of British night-fighter development during the Second World War and many survived to see service in the post-war Fighter Command alongside the final version of this unique fighter, the NF.36. This variant boasted higher powered Merlin 113/114 engines (also later fitted to the

NF.30) and an improved version of AI Mk.X radar and was destined to be the last twin piston-engined night-fighter to serve in the RAF, when the last machines were retired in 1953 in favour of jet equipment.
The final AI to see operational service during the war was introduced into UK air defence in the autumn of 1944, to counter low-flying enemy aircraft armed with airborne versions of the V-1 *Doodlebug* (Fieseler Fi 103) flying bomb. During the summer of 1944 with their fixed sites in Northern France and Holland in danger of being overrun by the Allied Armies, the *Luftwaffe* adapted a number of Heinkel He 111H-16 and H-20 bombers to carry and launch V-1s against targets along the East Coast of England. These aircraft flew at a very low level (below 1,000 feet) from a base at Venlo, Holland, and in a relatively short period to August 1944 launched 410 missiles at London, Southampton and Gloucester. The low-level approach of the Heinkels was difficult to detect on AI Mk.VIIIA or AI Mk.X, however, the Royal Navy's fleet fighter, the Fairey Firefly, was equipped with an American radar, the AN/APS-4 otherwise known as ASH (air-to-surface homing) by the Navy or AI Mk.XV by the RAF.

(Fleet Air Arm Museum)
Fairey Firefly NF.I, PP617, naval night-fighter fitted with the ASH 'bomb' of AN/APS-4 on a simple crutch below the nose. The APS-4 operated on a wavelength of 6 cms with a horizontally polarised sweep which rendered it effective down to a few hundred feet above the sea. With a range of 5/6 miles, APS-4 was eminently suited to nautical low-level interception.



(Crown Copyright)
The ASH 'Bomb' of AN/APS-4 with the cover removed and showing its attachment to the crutch.

The first operations with the Fireflies of the Naval Fighter Interception Unit (NFIU) detached to RAF Coltishall, Norfolk, began on the night of 25th/26th October 1944, when Lt Kneale and his observer Lt Harrison flew the Navy's first patrol alongside the Mosquitoes of No.68 Squadron. Radio failure forced the pair's return to base, but two nights later another patrol was flown with no results as the *Luftwaffe* failed to put in an appearance. Naval patrols continued with no positive results, but a number of interceptions were made before the *Luftwaffe* withdrew the Heinkels in January 1945. It is worth noting that a number of these interceptions were made under the control of a specialist Wellington fitted with a very early form of airborne early warning (AEW) radar.
Throughout the period 1939 to 1945, the RAF operated seven AI radars (AI Mks.I, III, IV, V, VII, VIII, & X) in twelve marks of night-fighter (Blenheim If & IVf, Beaufighter If, IIf & VIf and Mosquito NF.II, XII, XIII, XVII, XIX, 30 & 36) in Great Britain, Europe, North Africa, the Middle & Far East and Italy, and in the process leaving this country at the end of that war with the best night air defence system in the world - bar none!

COMPARATIVE PERFORMANCE OF THE PRINCIPLE NIGHT-FIGHTERS 1939 - 1945

	Blenheim If	Beaufighter If	Mosquito NF.II	Mosquito NF.30
Powerplant	2 x 840-hp Bristol Mercury VIII	2 x 1,400-hp Bristol Hercules III/X/XI	2 x 1,460-hp R-R Merlin 20-series	2 x 1,690-hp R-R Merlin 113/114
Loaded Weight	12,500-lbs	21,000-lbs	18,547-lbs	21,600-lbs
Max Speed	260 mph at 15,000 ft	330 mph at 15,000 ft	370 mph at 13,000 ft	407 mph at 28,000 ft
Range	920 miles	1,500 miles	1,705 miles	1,705 miles
Service Ceiling	25,500 ft	29,000 ft	33,000 ft	39,000 ft
Armament	4 x 0.303-inch machine-guns	4 x 20mm cannon & 6 x 0.303-inch machine-guns	4 x 20mm cannon & 4 x 0.303-inch machine-guns	4 x 20mm cannon
Radar	AI Mk.III	AI Mks.IV & VIII	AI Mk.V	AI Mk.X

RAF AI NIGHT-FIGHTER SQUADRONS, 1939 - 1945

No.23 Blenheim If and Mosquito NF.30.
No.25 Blenheim If, Beaufighter If and Mosquito NF.II, XVII & 30.
No.29 Blenheim If, Beaufighter If/VIf and Mosquito NF.XII, XIII & NF.30
No.68 Blenheim If, Beaufighter If & VIf and Mosquito NF.XVII, XIX & 30.
No.85 Havoc I/II and Mosquito NF.II, XV, XII, XIII, XVII & 30.
No.89 Beaufighter If & VIf and Mosquito NF.XIX.
No.96 Beaufighter IIf & VIf and Mosquito NF.XIII.
No.125 Beaufighter IIf & VIf and Mosquito NF.XVII & 30.
No.141 Beaufighter If & VIf and Mosquito NF.II & 30.
No.151 Mosquito NF.II, XII, XIII & 30.
No.153 Beaufighter If & VIf.
No.157 Mosquito NF.II, XIX & 30.
No.219 Blenheim If, Beaufighter If & VIf and Mosquito NF.XVII & 30.
No.239 Beaufighter If and Mosquito NF.II & 30.
No.225 Beaufighter IIf & VIf and Mosquito NF.XIX & 30.
No.256 Beaufighter If & VIf and Mosquito NF.II, XIII & XIX.
No.264 Mosquito NF.II, XIII & 30.
No.307 Beaufighter IIf & VIf and Mosquito NF.II, XII & 30.
No.406 Blenheim If & IVf, Beaufighter IIf and Mosquito NF.XII & 30.
No.409 Beaufighter IIf & VIf and Mosquito NF.XIII.
No.410 Beaufighter IIf and Mosquito NF.II, XIII & 30.
No.456 Beaufighter IIf & VIf and Mosquito NF.II, XVII & 30.
No.488 Beaufighter If & VIf and Mosquito NF.XII, XIII & 30.
No.600 Blenheim If, Beaufighter IIf & VIf and Mosquito NF.XIX.
No.604 Blenheim If, Beaufighter If & VIf and Mosquito NF.XII & XIII.

Note: No.307 Squadron was a Free Polish unit, Nos.406, 409 & 410 were Canadian, No.456 was Australian and No.488 New Zealanders.

COMPARATIVE PERFORMANCE OF THE PRINCIPLE AI RADARS
1939 - 1945

	AI Mk.I	AI Mk.IV	AI Mk.VIIIA	AI Mk.X
Wavelength	1½ metres	1½ metres	9.1 cm	9.1 cm
Frequency	Approx 193 MHz	Approx 193 MHz	3.3 GHz (S-band)	3.3 GHz (S-band)
Peak Power	10 kW	10 kW	Approx 25 kW	70 kW
Max Range	2 - 3 miles	2 - 3 miles	5½ miles	6 miles
Min Range	Possibly 900 ft	400 ft	400 - 500 ft	300 ft
Aerial System	Horizontal Yagi	Vertical Yagi	Spiral scanning parabolic dish	Helical scanning parabolic dish
Weight	Not known	118-lbs	212-lbs	500-lbs
Aircraft	Blenheim If	Beaufighter If & VIf, Havoc & Mosquito NF.II	Beaufighter If & VIf & Mosquito NF.XII, XIII & XIX	Mosquito NF.XVII, XIX, & 30