The **English Electric Lightning** is a supersonic fighter aircraft of the Cold War era. It was designed, developed, and manufactured by English Electric, which was subsequently absorbed by the newly formed British Aircraft Corporation. It was then marketed as the **BAC Lightning**. The Lightning was the only all-British Mach 2 fighter aircraft. The Lightning was used by the Royal Air Force (RAF) and the Royal Saudi Air Force (RSAF). Although it was the RAF's primary interceptor for more than two decades, it was never required to attack another aircraft.

The Lightning is powered by two Rolls-Royce Avon turbojet engines in a unique staggered stacked installation in the fuselage. The Lightning was initially designed and developed as an interceptor to defend the V bomber airfields from attack by anticipated future nuclear-armed supersonic Soviet bombers such as what emerged as the Tupolev Tu-22, but it was subsequently also required to intercept other bomber aircraft such as the Tupolev Tu-16 and the Tupolev Tu-95. The Lightning has exceptional rate of climb, ceiling, and speed; pilots have described flying it as "being saddled to a skyrocket". This performance and the initially limited fuel supply made the Lightning a "fuel-critical" aircraft, meaning that its missions are dictated to a high degree by its limited range. Later developments provided greater range and speed along with aerial reconnaissance and ground-attack capability.

Following retirement in the late 1980s, many of the remaining aircraft became museum exhibits and, until 2009, three Lightnings were kept flying at "Thunder City" in Cape Town, South Africa. In September 2008, the Institution of Mechanical Engineers conferred on the Lightning its "Engineering Heritage Award" at a ceremony at BAE Systems' site at Warton Aerodrome.

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### Lightning

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<th>Role</th>
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<tr>
<td>National origin</td>
<td>United Kingdom</td>
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<tr>
<td>Manufacturer</td>
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<td>First flight</td>
<td>4 August 1954 (P.1A)</td>
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<td>4 April 1957[1]</td>
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<tr>
<td>Introduction</td>
<td>December 1959</td>
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<tr>
<td>Retired</td>
<td>1988 (RAF)</td>
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<td>Primary users</td>
<td>Royal Air Force</td>
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<td>Kuwait Air Force</td>
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<td>Royal Saudi Air Force</td>
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<tr>
<td>Number built</td>
<td>337 (including prototypes)[1]</td>
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The specification for the aircraft followed the cancellation of the Air Ministry's 1942 E.24/43 supersonic research aircraft specification which had resulted in the Miles M.52 programme. W.E.W. "Teddy" Petter, formerly chief designer at Westland Aircraft, was a keen early proponent of Britain's need to develop a supersonic fighter aircraft. In 1947, Petter approached the Ministry of Supply (MoS) with his proposal, and in response, Specification ER.103 was issued for a single research aircraft, which was to be capable of flight at Mach 1.5 (1,593 km/h) and 50,000 feet (15,000 m).

Petter initiated a design proposal with F. W. "Freddie" Page leading the design and Ray Creasey responsible for the aerodynamics. By July 1948 their proposal incorporated the stacked engine configuration and a high-mounted tailplane but was designed for Mach 1.5. As a consequence, it had a conventional 40° swept wing. This proposal was submitted in the November and in January 1949 the project was designated P.1 by English Electric. On 29 March 1949 MoS granted approval for English Electric to start the detailed design, develop wind tunnel models, and build a full-size mockup. The design that had developed during 1948 evolved further during 1949. To achieve Mach 2 the wing sweep was increased to 60° with the ailerons moved to the wingtips. In late 1949 low-speed wind tunnel tests showed that a vortex was generated by the wing which caused a large downwash on the tailplane; this issue was solved by lowering its height below the wing. Following the resignation of Petter, Page took over as design team leader for the P.1.
In 1949, the Ministry of Supply had issued Specification F23/49, which expanded upon the scope of ER103 to include fighter-level manoeuvring. On 1 April 1950, English Electric received a contract for two flying airframes, as well as one static airframe, designated P.1.[13]

The Royal Aircraft Establishment was sceptical of Petter's swept wing concepts. To test the design of both the wing, the tailplane and to assess handling, Short Brothers were issued a contract to produce the short SB5 in mid-1950. This was a low-speed research aircraft and was designed so that different wing sweep angles could be assumed by the single aircraft. An assortment of tailplanes and wings were supplied and could be installed in order for their flight performance to be evaluated. However, following the first flight of the SB.5 on 2 December 1952, the trials demonstrated the choice of a tailplane and a 60 degree wingsweep and proved the design principles to be effective.[15]

From 1953 onwards, the first three prototype aircraft were hand-built at Samlesbury. These aircraft had been assigned the aircraft serials WG760, WG763, and WG765 (the static airframe). The prototypes were powered by unheated Armstrong Siddeley Sapphire turbojets, as the selected Rolls-Royce Avon engines which would power subsequent production aircraft had fallen behind schedule due to their own development problems.[16] Due to the limited internal space of the fuselage the fuel capacity was relatively small, giving the prototypes an extremely limited endurance, and the narrow tyres housed in the thin wings would rapidly wear out.[17] Outwardly, the prototypes looked very much like the production series, but they were distinguished by the rounded-triangular intakes, short fins and lack of operational equipment.[1] On 9 June 1952, it had been decided that there would be a second phase of prototypes built to develop the aircraft towards achieving Mach 2.0 (2,450 km/h); these were designated P.1B while the initial three prototypes were retroactively reclassified as P.1A.[18]

P.1B was a significant improvement on P.1A. While it was similar in aerodynamics, structure and control systems, it incorporated extensive alterations to the forward fuselage, reheated Rolls Royce Avon R24R engines, a conical centre body inlet cone, variable nozzle reheat and provision for weapons systems integrated with the ADC and AI.23 radar.[19][20] Three P1B prototypes were built, assigned serials XA847, XA853 and XA855[21]

In May 1954, WG760 and its support equipment were moved to RAF Boscombe Down for pre-flight ground taxi trials; on the morning of 4 August 1954, WG760, piloted by Roland Beamont, flew for the first time from Boscombe Down.[22] One week later, WG760 officially achieved supersonic flight for the first time, having exceeded the speed of sound during its third flight.[20] During its first flight, WG760 had unknowingly exceeded Mach 1 (1,225 km/h), but due to position error the Mach meter only showed a maximum of Mach 0.95 (1,164 km/h). The occurrence was noticed during flight data analysis a few days later.[23] While WG760 had proven the P.1 design to be viable, it was limited to Mach 1.51 (1,850 km/h) due to directional stability limits. In May 1956, the P.1 received the "Lightning" name, which was said to have been partially selected to reflect the aircraft's supersonic capability.[24]

On 4 April 1957 Beamont made the first flight of the P.1B (XA847) exceeding Mach 1 during this flight.[25][26] On the 25th November he reached Mach 2,[27] the first time in a British aircraft. During the early flight trials of the P.1B speeds in excess of 1,000 mph were achieved daily; during this period the Fairey FD2 delta held the world speed record (1,132 mph achieved on 10 March 1956 and held till December 1957). While the P.1B was potentially faster than the FD2, it lacked the fuel capacity to provide one run in each direction at maximum speed to claim the record in accordance with international rules.[28]

Production

The first operational Lightning, designated Lightning F.1, was designed as an interceptor to defend the V Force airfields in conjunction with the V Force airfield's own "last ditch" Bristol Bloodhound missile defences from enemy nuclear-armed bomber attack long enough for the also nuclear-armed V Force bombers to take-off and get clear of their airfields, airfields which, along with the dispersal airfields, would be the highest priority targets in the UK for enemy nuclear weapons. To best perform this intercept mission, emphasis was placed on rate-of-climb, acceleration, and speed, rather than range – originally a radius of operation of 150 miles from the V bomber airfields was specified – and combat endurance. It was equipped with two 30 mm ADEN cannon in front of the cockpit windscreen and an interchangeable fuselage weapons pack containing either an additional two ADEN cannon, 48 two-
inch (51 mm) unguided air-to-air rockets, or two de Havilland Firestreak air-to-air missiles\[^{29}\] a heavy loadout optimised for damaging large aircraft, missile guidance and ranging, as well as search and track functions, mainly were provided via the Ferranti A.I.23 onboard radar.\[^{30}\]

The next two Lightning variants, the Lightning F.1A and F.2, were steady but relatively minor refinements of the design; the next variant, the Lightning F.3, was a major departure. The F.3 had higher thrust Rolls-Royce Avon 301R engines, a larger squared-off fin and strengthened inlet cone allowing a service clearance to Mach 2.0 (2,450 km/h) (the F.1, F.1A and F.2 were limited to Mach 1.7 (2,083 km/h)).\[^{32}\] The A.I.23B radar and Red Top missile offered a forward hemisphere attack capability and deletion of the nose cannon. The new engines and fin made the F.3 the highest performance Lightning yet, but with an even higher fuel consumption and resulting shorter range. The next variant, the Lightning F.6, was already in development, but there was a need for an interim solution to partially address the F.3’s shortcomings, the F.3A.

The F.3A introduced two improvements: a new, non-jettisonable, 610-imperial-gallon (2,800 L) ventral fuel tank\[^{32}\] and a new, kinked, conically cambered wing leading edge, incorporating a slightly larger leading edge fuel tank, raising the total usable internal fuel to 716 imperial gallons (3,260 L). The conically cambered wing noticeably improved manoeuvrability especially at higher altitudes, and the ventral tank nearly doubled available fuel. The increased fuel was very welcome, but the lack of cannon armament was felt to be a deficiency. It was thought that cannons were desirable to fire warning shots in the intercept mission.\[^{33}\]

The Lightning F.6 was the ultimate Lightning version to see British service. Originally, it was nearly identical to the F.3A with the exception that it could carry two 260-imperial-gallon (1,200 L) ferry tanks on pylons over the wings. These tanks were jettisonable in an emergency, and gave the F.6 a substantially improved deployment capability. There remained one glaring shortcoming: the lack of cannon. This was finally rectified in the form of a modified ventral tank with two ADEN cannons mounted in the front. The addition of the cannons and their ammunition decreased the tank’s fuel capacity from 610 to 535 imperial gallons (2,770 to 2,430 L), but the cannon made the F.6 a “real fighter” again\[^{32}\]

The final British Lightning was the Lightning F.2A. This was an F.2 upgraded with the cambered wing, the squared fin, and the 610 imperial gallons (2,800 L) ventral tank. The F.2A retained the A.I.23 and Firestreak missile, the nose cannon, and the earlier Avon 211R engines.\[^{34}\] Although the F.2A lacked the thrust of the later Lightnings, it had the longest tactical range of all Lightning variants, and was used for low-altitude interception over West Germany.

### Export and further developments

The Lightning F.53, otherwise known as the Export Lightning, developed as a private venture by BAC; while the Lightning had originated as an interception aircraft, this version was to have a multirole capability for quickly interchanging between interception, reconnaissance, and ground-attack duties.\[^{35}\] The F.53 was based on the F.6 airframe and avionics, including the large ventral fuel tank, cambered wing and overwing pylons for drop tanks of the F.6, but incorporated an additional pair of hardpoints under the outer wing. These hardpoints could be fitted with pylons for air-to-ground weaponry including two 1,000 lb (450 kg) bombs or four SNEB rocket pods each carrying 18 68 mm rockets. A gun pack carrying two ADEN cannons and 120 rounds each could replace the forward part of the ventral fuel tank.\[^{36}\][nb 1] Alternative, interchangeable packs in the forward fuselage carried two Firestreak missiles, two Red Top missiles, twin retractable launchers for 44× 2-inch (50 mm) rockets, or a reconnaissance pod fitted with five 70 mm Type 360 Vinten cameras.\[^{38}\]

BAC also proposed clearing the overwing hardpoints for carriage of weapons as well as drop tanks, with additional Matra JL-100 combined rocket and fuel pods (each containing 18 SNEB 68 mm (2.7 in) rockets and 50 imperial gallons (227 L) of fuel) or 1,000 pounds (450 kg) bombs being possible options. This could give a maximum ground attack weapons load for a developed export Lightning of six 1,000 pounds (450 kg) bombs or 44 × 2 in (51 mm) rockets and 144 × 68 mm rockets.\[^{39}\][40] The Lightning T.55 was the export two-seat variant; unlike the RAF two-seaters, the T.55 was equipped for combat duties. The T.55 had a very similar
fuselage to the T.5, while also using the wing and large ventral tank of the F.6.\[41\] The Export Lightning had all of the capability of the RAF's own Lightnings such as exceptional climb rate and agile maneuvering. Unfortunately, the Export Lightning also retained the difficulty of maintenance, and serviceability rates suffered. The F.53 was generally well regarded by its pilots, and its adaptation to multiple roles showed the skill of its designers.\[42\]

In 1963, BAC Warton was working on the preliminary design of a two-seat Lightning development with a variable-geometry wing, based on the Lightning T.5. In addition to the variable-sweep wing which was to sweepback between 25 degrees and 60 degrees, the proposed design featured an extended ventral pack for greater fuel capacity, an enlarged dorsal fin fairing, an arrestor hook, and a revised inward-retracting undercarriage. The aircraft was designed to be compatible with the Royal Navy's existing aircraft carriers carrier-based aircraft, the VG Lightning concept was revised into a land-based interceptor intended for the RAF the following year.\[43\] Various alternative engines to the Avon were suggested, such as the newer Rolls-Royce Spey engine; it is also likely that the VG Lightning would have adopted a solid nose (by moving the air inlet to the sides or to upper fuselage) to install a larger, more capable radar.\[44\]

Design

Overview

The Lightning had several distinctive design features, the principal of these being the twin engine arrangement, notched delta wing, and low-mounted tailplane. The vertically stacked and longitudinally staggered engines were the solution devised by Petter to meet the conflicting requirements of minimizing frontal area, providing undisturbed engine airflow across a wide speed range, and packaging two engines to provide sufficient thrust to meet performance goals. The unusual over/under configuration allowed for the thrust of two engines, with the drag equivalent to only 1.5 engines mounted side-by-side, a reduction in drag of 25% over more conventional twin engine installations.\[45\] The engines were fed by a single nose inlet (with inlet cone), with the flow split vertically aft of the cockpit, and the nozzles tightly stacked, effectively tucking one engine behind the cockpit. The result was a low frontal area, an efficient inlet, and excellent single-engine handling with no problems of asymmetrical thrust. However, because the engines were close together, an uncontained failure of one engine was likely to damage the other engine. If desired, an engine could be shut down in flight and the remaining engine run at a more efficient power setting which increased range or endurance;\[46\]\[47\] although this was rarely done operationally because there would be no hydraulic power if the remaining engine failed.\[48\]

Production aircraft were powered by various models of the Rolls-Royce Avon engine. This power-plant was initially rated as capable of generating 11,250 lbf (50.0 kN) of dry thrust, but when employing the four-stage afterburner this increased to a maximum thrust of 14,430 lbf (64.2 kN). Later models of the Avon would feature, in addition to increased thrust, a full-variable reheat arrangement.\[49\] A special heat-reflecting paint containing gold was used to protect the aircraft's structure from the hot engine casing which could reach temperatures of 600 °C. Under optimum conditions, a well-equipped maintenance facility would take four hours to perform an engine change so specialised ground test rigs were developed to speed up maintenance and remove the need to perform a full ground run of the engine after some maintenance tasks.\[50\] The stacked engine configuration complicated maintenance work, and the leakage of fluid from the upper engine was a recurring fire hazard.\[51\] The fire risk was reduced, but not eliminated, following remedial work during development.\[52\] For removal the lower No.1 engine was removed from below the aircraft, after removal of the ventral tank and lower fuselage access panels, by lowering the engine down, while the upper No.2 engine was lifted out from above via removable sections in the fuselage top.

The fuselage was tightly packed, leaving no room for fuel tankage or main landing gear. While the notched delta wing lacked the volume of a standard delta wing, each wing contained a fairly conventional three-section main fuel tank and leading-edge tank, holding 312 imp gal (1,420 L);\[nb 2\] the wing flaps also each contained a 33 imp gal (150 L) fuel tank and an additional 5 imp gal (23 L) was contained in a fuel recuperator, bringing the aircraft's total internal fuel capacity to 700 imp gal (3,200 L). The main
landing gear was sandwiched outboard of the main tanks and aft of the leading edge tanks, with the flap fuel tanks behind. The long main gear legs retracted towards the wingtip, necessitating an exceptionally thin main tyre inflated to the high pressure of 330–350 psi (23–24 bar; 2,300–2,400 kPa). On landing the No. 1 engine was usually shut down when taxiing to save brake wear, as keeping both engines running at idle power was still sufficient to propel the Lightning to 80 mph if brakes were not used. Dunlop Maxaret anti-skid brakes were fitted.

The Lightning featured a conformal ventral store to house either a fuel tank or a rocket engine. The rocket engine, a Napier Double Scorpion motor, also contained a reserve of 200 imp gal (910 L) of high-test peroxide (HTP) to drive the rocket's turbopump and act as an oxidizer; fuel would have been drawn from the aircraft internal tankage. The rocket engine was intended at an early stage in the Lightning's development to boost performance should non-afterburning (reheated) engines be fitted; the subsequent basic performance with reheated Avons was deemed sufficient and the rocket engine option was cancelled in 1958. The ventral store was routinely used as an extra fuel tank, holding 247 imp gal (1,120 L) of usable fuel. On later variants of the Lightning, a ventral weapons pack could be installed to equip the aircraft alternatively with different armaments, including missiles, rockets, and cannons.

**Avionics and systems**

Early versions of the Lightning were equipped with the Ferranti-developed AI.23 monopulse radar, which was contained right at the front of the fuselage within an inlet cone at the centre of the engine intake. Radar information was displayed on an early head-up display and managed by onboard computers. The AI.23, an immediate predecessor of the AI.24 Foxhunter, supported several operational modes, which included autonomous search, automatic target tracking, and ranging for all weapons; the pilot attack sight provided gyroscopically-derived lead angle and backup stadiametric ranging for gun firing. The radar and gunsight were collectively designated the AIRPASS: Airborne Interception Radar and Pilot Attack Sight System. The radar would be successively upgraded with the introduction of more capable Lightning variants, such as to provide guidance for the Red Top missile.

The cockpit of the Lightning was designed to meet the RAF's OR946 specification for tactical air navigation technology, and thus featured an integrated flight instrument display arrangement, an Elliott Bros (London) Ltd auto-pilot, a master reference gyroscopic reader, an auto-attack system, and an instrument landing system. Despite initial scepticism of the aircraft's centralised detection and warning system, the system proved its merits during the development program and was subsequently redeveloped for greater reliability. Communications included UHF and VHF radios and a datalink. Unlike the previous generation of aircraft which used gaseous oxygen for lifesupport, the Lightning would employ liquid oxygen-based apparatus for the pilot; cockpit pressurisation and conditioning would be maintained through tappings from the engine compressors.

Electricity was provided via a bleed air-driven turbine housed in the rear fuselage, which in turn drove an AC alternator and DC generator; the approach was considered unusual at the time due to most aircraft using driveshaft-driven generators/alternators for electrical energy. A 28V DC battery provided emergency backup power. Aviation author Kev Darling stated of the Lightning: “Never before had a fighter been so dependent upon electronics.” Each engine was equipped with a pair of hydraulic pumps, one of which would provide pressure for the flight-control systems and the other, pressure for the undercarriage, flaps, and airbrakes; switchable hydraulic circuits were used for redundancy in the event of a leak or other failure. A combination of Dunlop Maxaret anti-skid brakes on the main wheels and an Irvin Air Chute braking parachute slowed the aircraft during landing; a tailhook was also fitted. Accumulators on the wheel brakes performed as backups to the hydraulics, providing minimal braking. Above a certain airspeed a stopped engine would 'windmill', i.e., continue to be rotated by the air flowing through it in a similar manner to a ram air turbine, sufficiently to still generate adequate hydraulic power for the powered controls during flight.
Towards the end of its service, the Lightning was increasingly outclassed by newer fighters, mainly due to the avionics and armaments being obsolete. The radar had a limited range and no track while scanning capability, and it could detect targets only in a fairly narrow (40 degree) arc. While an automatic collision course attack system was developed and successfully demonstrated by English Electric, it was not adopted due to cost concerns.[68][69] Plans were mooted to supplement or replace the obsolete Red Top and Firestreak missiles with modern AIM-9L Sidewinder missiles to help rectify some of the obsolescence, but these ambitions were never realised due to lack of funding.[68][70] An alternative to the modernization of existing aircraft would have been the development of more advanced variants; a proposed Variable-sweep wing Lightning would have likely involved the adoption of a new powerplant and radar and was believed by BAC to significantly increase performance, but ultimately was not pursued.[44]

Climb

"Lightning, was designed...as an interceptor fighter. As such, it has probably the fastest rate-of-climb of any combat aircraft" – Flight International, 21 March 1968[71]

The Lightning possessed a remarkable climb rate. It was famous for its ability to rapidly rotate from takeoff to climb almost vertically from the runway, though this did not yield the best time-to-altitude. The Lightning’s trademark tail-stand manoeuvre exchanged airspeed for altitude; it could slow to near-stall speeds before commencing level flight. The Lightning’s optimum climb profile required the use of afterburners during takeoff. Immediately after takeoff, the nose would be lowered for rapid acceleration to 430 knots (800 km/h) IAS before initiating a climb, stabilising at 450 knots (830 km/h). This would yield a constant climb rate of approximately 20,000 ft/min (100 m/s).[53][nb 3] Around 13,000 ft (4,000 m) the Lightning would reach Mach 0.87 (1,009 km/h) and maintain this speed until reaching the tropopause, 36,000 ft (11,000 m) on a standard day.[nb 4] If climbing further, pilots would accelerate to supersonic speed at the tropopause before resuming the climb.[32][53] A Lightning flying at optimum climb profile would reach 36,000 ft (11,000 m) in under three minutes.[53]

The official ceiling of the Lightning was kept secret; low security RAF documents would often state in excess of 60,000 ft (18,000 m). In September 1962, Fighter Command organised interception trials on Lockheed U-2As at heights of around 60,000–65,000 ft (18,000–20,000 m), which were temporarily based at RAF Upper Heyford to monitor Soviet nuclear tests.[72][73][74] Climb techniques and flight profiles were developed to put the Lightning into a suitable attack position. To avoid risking the U-2, the Lightning was not permitted any closer than 5,000 ft (1,500 m) and could not fly in front of the U-2. For the intercepts, four Lightning F1As conducted eighteen solo sorties. The sorties proved that, under GCI, successful intercepts could be made at up to 65,000 ft (20,000 m). Due to sensitivity, details of these flights were deliberately avoided in the pilot log books.[75]

In 1984, during a NATO exercise, Flt Lt Mike Hale intercepted a U-2 at a height which they had previously considered safe (thought to be 66,000 feet (20,000 m)). Records show that Hale also climbed to 88,000 ft (27,000 m) in his Lightning F.3 XR749. This was not sustained level flight but a ballistic climb, in which the pilot takes the aircraft to top speed and then puts the aircraft into a climb, exchanging speed for altitude. Hale also participated in time-to-height and acceleration trials against Lockheed F-104 Starfighters from Aalborg. He reports that the Lightnings won all races easily with the exception of the low-level supersonic acceleration, which was a “dead heat”.[76] Lightning pilot and Chief Examiner Brian Carroll reported taking a Lightning F.53 up to 87,300 feet (26,600 m) over Saudi Arabia at which level "Earth curvature was visible and the sky was quite dark", noting that control-wise “[it was] on a knife edge”.[77]
Brian Carroll compared the Lightning and the F-15C Eagle, having flown both aircraft, stating that: "Acceleration in both was impressive, you have all seen the Lightning leap away once brakes are released, the Eagle was almost as good, and climb speed was rapidly achieved. Takeoff roll is between 2,000 and 3,000 ft [610 and 910 m], depending upon military or maximum afterburner-powered takeoff. The Lightning was quicker of the ground, reaching 50 ft [15 m] height in a horizontal distance of 1,630 ft [500 m]".

Chief test pilot for the Lightning Roland Beamont, who also flew most of the "Century Series" US aircraft, stated his opinion that nothing at that time had the inherent stability, control and docile handling characteristics of the Lightning throughout the full flight envelope. The turn performance and buffet boundaries of the Lightning were well in advance of anything known to him.

### Speed

Early Lightning models, the F.1, F.1A, and F.2, had a rated top speed of Mach 1.7 (1,815 km/h) at 36,000 feet (11,000 m) in an ICAO standard atmosphere, and 650 knots (1,200 km/h) IAS at lower altitudes. Later models, the F.2A, F.3, F.3A, F.6, and F.53, had a rated top speed of Mach 2.0 (2,136 km/h) at 36,000 feet (11,000 m), and speeds up to 700 knots (1,300 km/h) indicated air speed for "operational necessity only". A Lightning fitted with Avon 200-series engines, a ventral tank and two Firestreak missiles typically ran out of excess thrust at Mach 1.9 (2,328 km/h) on a Standard Day, while a Lightning powered by the Avon 300-series engines, a ventral tank and two Red Top missiles ran out of excess thrust at Mach 2.0. Directional stability decreased as speed increased, there were potentially hazardous consequences in the form of vertical fin failure if yaw was not correctly counteracted by rudder use. Imposed Mach limits during missile launches protected stability; later Lightning variants had a larger vertical fin, giving a greater stability margin at high speed.

Supersonic speeds also threatened inlet stability; the inlet's central shock cone served as a compression surface, diverting air into the annular inlet. As the Lightning accelerated through Mach 1, the shock cone generated an oblique shock positioned forward of the intake lip; known as a subcritical inlet condition, this was stable but produced inefficient spillage drag. Around the Design Mach speed, the oblique shock was positioned just in front of the inlet lip and efficiently compressed the air without spillage. When travelling beyond the Design Mach, the oblique shock would become supercritical, and supersonic airflow would enter the inlet duct, which could only handle subsonic air. In this condition, the engine generated drastically less thrust and may result in surges or compressor stalls; these could cause flameouts or damage.

Thermal and structural limits were also present. Air is heated considerably when compressed by the passage of an aircraft at supersonic speeds. The airframe absorbs heat from the surrounding air, the inlet shock cone at the front of the aircraft becoming the hottest part. The shock cone was composed of fibreglass, necessary because the shock cone also served as a radar radome; a metal shock cone would interfere with the AI 23’s radar emissions. The shock cone would be eventually weakened due to the fatigue caused by the thermal cycles involved in regularly performing high-speed flights. At 36,000 feet (11,000 m) and Mach 1.7 (1,815 km/h), the heating conditions on the shock cone would be similar to those at sea level and 650 knots (1,200 km/h) indicated airspeed but if the speed was increased to Mach 2.0 (2,136 km/h) at 36,000 feet (11,000 m), the shock cone would be exposed to higher temperature than those at Mach 1.7. The shock cone was strengthened on the later Lightning F.2A, F.3, F.6, and F.53 models, thus allowing routine operations at up to Mach 2.0.

The small-fin variants could exceed Mach 1.7 but the stability limits and shock cone thermal/strength limits made such speeds risky. The large-fin variants, especially those equipped with Avon 300-series engines could safely reach Mach 2, and given the right atmospheric conditions, might even achieve a few more tenths of a Mach. All Lightning variants had the excess thrust to slightly exceed 700 knots (1,300 km/h) indicated airspeed under certain conditions, and the service limit of 650 knots (1,200 km/h) was occasionally ignored. With the strengthened shock cone, the Lightning could safely approach its thrust limit, but fuel consumption at very high airspeeds was excessive and became a major limiting factor.

### Other flying

The Lightning was fully aerobatic and was capable of rates of roll far in excess of that which could be normally tolerated by a pilot.
The first aircraft to enter service with the RAF, three pre-production P.1Bs, arrived at RAF Coltishall in Norfolk on 23 December 1959, joining the Air Fighting Development Squadron (AFDS) of the Central Fighter Establishment, where they were used to clear the Lightning for entry into service. The production Lightning F.1 entered service with the AFDS in May 1960, allowing the unit to take part in the air defence exercise “Yeoman” later that month. The Lightning F.1 entered frontline squadron service with 74 Squadron under the command of Squadron Leader John "Johnny" Howe at Coltishall from 11 July 1960. The aircraft's radar and missiles proved to be effective and pilots reported that the Lightning was easy to fly. However, in the first few months of operation the aircraft's serviceability was extremely poor. This was due to the complexity of the aircraft systems and shortages of spares and ground support equipment. Even when the Lightning was not grounded by technical faults, the RAF initially struggled to get more than 20 flying hours per aircraft per month compared with the 40 flying hours that English Electric believed could be achieved with proper support. In spite of these concerns, within six months of the Lightning entering service, 74 Squadron was able to achieve 100 flying hours per aircraft.

In addition to its training and operational roles, 74 Squadron was appointed as the official Fighter Command aerobatic team for 1961, flying at air shows throughout the United Kingdom and Europe. Deliveries of the slightly improved Lightning F.1A, with improved avionics and provision for an air-to-air refuelling probe, allowed two more squadrons, 56 and 111 Squadron, both based at RAF Wattisham to convert to the Lightning in 1960–1961. The Lightning F.1 would only be ordered in limited numbers and serve for a short time, regardless it was viewed as a significant step forwards in Britain's air defence capabilities. Following their replacement from frontline duties by the introduction of successively improved variants of the Lightning, the remaining F.1 aircraft were employed by the Lightning Conversion Squadron.

An improved variant, the F.2 first flew on 11 July 1961 and entered service with 19 Squadron at the end of 1962 and 92 Squadron in early 1963. Conversion of these two squadrons was aided by the use of the two seat T.4 trainer, which entered service with the Lightning Conversion Squadron (later renamed 226 Operational Conversion Unit) in June 1962. While the OCU was the major user of the two seater, small numbers were also allocated to the front-line fighter squadrons. More F.2s were produced than there were available squadron slots so later production aircraft were stored for years before being used operationally; some Lightning F.2s were converted to F.2a's. They had some of the improvements added to the F.3.

The F.3, with more powerful engines and the new Red-Top missile (but no cannon) was expected to be the definitive Lightning, and at one time it was planned to equip ten squadrons, with the remaining two squadrons retaining the F.2. On 16 June 1962, the F.3 flew for the first time. It had a short operational life and was withdrawn from service early due to defence cutbacks and the introduction of the F.6, some of which were converted F.3s.

The Lightning F.6 was a more capable and longer-range version of the F.3; it initially had no cannon, but installable gun packs were made available later. A few F.3s were upgraded to F.6s. Author Kev Darling suggests that decreasing British overseas defence commitments had led to those aircraft instead being prematurely withdrawn. The introduction of the F.3 and F.6 allowed the RAF to progressively reequip squadrons operating aircraft such as the Gloster Javelin and retire these types during the mid-1960s.
A Lightning was tasked with shooting down a pilot-less Harrier over West Germany in 1972. The pilot had abandoned the Harrier which continued flying towards the East German border. It was shot down to avoid a diplomatic incident. During British Airways trials in April 1985, Concorde was offered as a target to NATO fighters including F-15 Eagles, F-16 Fighting Falcons, F-14 Tomcats, Mirages, and F-104 Starfighters – but only Lightning XR749, flown by Mike Hale and described by him as “a very hot ship, even for a Lightning”, managed to overtake Concorde on a stern conversion intercept.

During the 1960s, as strategic awareness increased and a multitude of alternative fighter designs were developed by Warsaw Pact and NATO members, the Lightning’s range and firepower shortcomings became increasingly apparent. The transfer of McDonnell Douglas F-4 Phantom IIs from Royal Navy service enabled these much longer-ranged aircraft to be added to the RAF’s interceptor force alongside those withdrawn from Germany as they were replaced by SEPECAT Jaguars in the ground attack role. The Lightning’s direct replacement was the Tornado F3s, an interceptor variant of the Panavia Tornado. The Tornado featured several advantages over the Lightning, including a far larger weapons load and considerably more advanced avionics. Lightnings were slowly phased out of service between 1974 and 1988. In their final years the airframes required considerable maintenance to keep them airworthy due to the sheer number of accumulated flight hours.

**Fighter Command/Strike Command**

The main Lightning role was the air defence of the United Kingdom and was operated at first as part of Fighter Command and then from 1968 with No. 11 Group of Strike Command. At the formation of Strike Command nine Lightning squadrons were operational in the United Kingdom.

**Far East Air Force**

In 1967 No. 74 Squadron was moved to RAF Tengah, Singapore to take over the air defence role from the Gloster Javelin equipped 60 Squadron. The squadron was disbanded in 1971 following the withdrawal of British forces from Singapore.

**Near East Air Force**

The Royal Air Force had detached Lightnings to RAF Akrotiri, Cyprus to support the Near East Air Force and in 1967 No. 56 Squadron RAF moved from RAF Wattisham with the Lightning F.3 to provide a permanent air defence force, it converted to the F.6 in 1971 and returned to the United Kingdom in 1975.

**Royal Air Force Germany**

In the early 1960s No. 19 Squadron and No. 92 Squadron with Lightning F.2s, moved from RAF Leconfield to RAF Gütersloh in West Germany as part of Royal Air Force Germany and operated in the low-level air defence role until disbanded in 1977 when the role was taken over by the Phantom FGR2.

**Middle East**

On 21 December 1965, Saudi Arabia keen to improve its air defences owing to the Saudi involvement in the North Yemen Civil War and the resultant air incursions into Saudi airspace by Egyptian forces supporting the Yemeni Republicans, placed a series of orders with Britain and the United States to build a new integrated air defence system. BAC received orders for 34 multirole single-seat Lightning F.53s that could still retain very high performance and reasonable endurance, and six two-seat T.55 trainers, together with 25 BAC Strikemaster trainers, while the contract also included new radar systems, American HAWK surface-to-air missiles and training and support services.
In order to provide an urgent counter to the air incursions, with Saudi towns close to the border being bombed by Egyptian aircraft, an additional interim contract, called "Magic Carpet", was placed in March 1966 for the supply of six ex-RAF Lightnings (four F.2s and two T.4 trainers, redesignated F.52 and T.54 respectively\[nb 11\]), six Hawker Hunters, two air defence radars and a number of Thunderbird surface-to-air missiles.\[41\]\[109\] The "Magic Carpet" Lightnings were delivered to Saudi Arabia in July 1966, with an additional F.52 being delivered in May 1967 to replace a Lightning lost in an accident. The Lightnings and Hunters, flown by mercenary pilots, were deployed to Khamis Mushait airfield near the Yemeni border, resulting in the curtailing of operations by the Egyptian Air Force over the Yemeni-Saudi border.\[37\]\[109\]

Although the first F.53s had been handed over to the RSAF in December 1967, they were kept at Warton while trials and development continued and the first Saudi Lightnings to leave Warton were four T.55s delivered in early 1968 to the Royal Air Force 226 Operational Conversion Unit at RAF Coltishall, the four T.55s were used to train Saudi aircrew for the next 18 months.\[111\] The new-build Lightnings were delivered under Operation "Magic Palm" between July 1968 and August 1969. Two Lightnings, a F.53 and a T.55 were destroyed in accidents prior to delivery and were replaced by two additional aircraft, the last of which was delivered in June 1972.\[110\]\[112\]

The multirole F.53s served in the ground-attack and reconnaissance roles as well as an air defence fighter with Lightnings of No 6 Squadron RSAF carrying out ground-attack missions using rockets and bombs during a border dispute with South Yemen between December 1969 and May 1970. One F.53 (53–697) was shot down by Yemeni ground fire on 3 May 1970 during a reconnaissance mission, with the pilot ejecting successfully and being rescued by Saudi forces.\[112\]\[113\] Saudi Arabia received Northrop F-5E fighters from 1971, which resulted in the Lightnings relinquishing the ground-attack mission, concentrating on air defence, and to a lesser extent, reconnaissance.\[114\]

Up to 1982, the Lightnings were mainly operated by 2 and 6 Squadron RSAF (although a few were also used by 13 Squadron RSAF), but when 6 Squadron re-equipped with the F-15 Eagle then all the remaining aircraft were operated by 2 Squadron at Tabuk.\[115\]\[116\] In 1985 as part of the agreement to sell the Panavia Tornado to the RSAF, the 22 flyable Lightnings were traded in to British Aerospace and returned to Warton in January 1986.\[115\] While BAe offered the ex-Saudi Lightnings to Austria and Nigeria, no sales were made, and the aircraft were eventually disposed of to museums.\[112\]\[117\]

Kuwait also ordered 14 Lightnings in December 1966, comprising 12 F.53Ks and two T.55Ks. The first Kuwait aircraft, a T.55K first flew on 24 May 1968 and deliveries to Kuwait started in December 1968.\[118\] The Kuwaitis somewhat overestimated their ability to maintain such a complex aircraft, not adopting the extensive support from BAC and Airwork Services that the Saudis used to keep their Lightnings operational, so serviceability was poor.\[119\] The Kuwaiti Lightnings did not have a long service career; after unsuccessfully trying to sell them to Egypt in 1973, Kuwait replaced its last Lightnings with Dassault Mirage F1s in 1977.\[120\] The remaining aircraft were stored at Kuwait International Airport, many were subsequently destroyed during the Invasion of Kuwait by Iraq in August 1990.\[121\]

### Variants

**English Electric P.1A**

Single-seat supersonic research aircraft, two prototypes built and one static test airframe.

**English Electric P.1B**
Single-seat operational prototypes to meet Specification F23/49, three prototypes built, further 20 development aircraft ordered in February 1954. Type was officially named 'Lightning' in October 1958.

**Lightning F.1**
Development batch aircraft, single-seat fighters delivered from 1959, a total of 19 built (and one static test airframe). Nose-mounted twin 30 mm ADEN cannon, two Firestreak missiles, VHF Radio and Ferranti AI-23 "AIRPASS" radar.

**Lightning F.1A**

**Lightning F.2**
Single-seat fighter (an improved variant of the F.1), delivered in 1962. A total of 44 built with 31 later modified to F.2A standard, five later modified to F.52 for export to Saudi Arabia.

**Lightning F.2A**
Single-seat fighter (F.2s upgraded to near F.6 standard); featuring Avon 211R engines, retained ADEN cannon and Firestreak (replaceable Firestreak pack swappable with ADEN Cannon Pack for a total of four ADEN Cannon), arrestor hook and enlarged Ventral Tank for two hours flight endurance. A total of 31 converted from F.2.

**Lightning F.3**
Single-seat fighter with upgraded AI-23B radar, Avon 301R engines, new Red Top missiles, enlarged and clipped tailfin due to aerodynamics of carriage of Red Top, and deletion of ADEN cannon. A total of 70 built (at least nine were converted to F.6 standard).

**Lightning F.3A**
Single-seat fighter with extended range of 800 miles due to large ventral tank and new cambered wings. A total of 16 built, known also as an F.3 Interim version or F.6 Interim Version, 15 later modified to F.6 standard.

**Lightning T.4**
Two-seat side-by-side training version, based on the F.1A; two prototypes and 20 production built, two aircraft later converted to T.5 prototypes, two aircraft later converted to T.54.

**Lightning T.5**
Two-seat side-by-side training version, based on the F.3; 22 production aircraft built. One former RAF aircraft later converted to T.55 for Saudi Arabia.

**Lightning F.6**
Single-seat fighter (an improved longer-range variant of the F.3). It featured new wings with better efficiency and subsonic performance, overwing fuel tanks and a larger ventral fuel tank, reintroduction of 30 mm cannon (initially no cannon but later in the forward part of the
ventral pack rather than in the nose), use of Red Top missiles. A total of 39 built (also nine converted from F.3 and 15 from F.3A).

**Lightning F.7**
Proposed single-seat interceptor featuring variable geometry wings, extended fuselage, relocated undercarriage, underwing hardpoints, cheek-mounted intakes, new radar and use of the Sparrow/Skyflash AAMs. Never built.[122]

**Lightning F.52**
Slightly modified ex-RAF F.2 single-seat fighters for export to Saudi Arabia (five converted).

**Lightning F.53**
Export version of the F.6 with pylons for bombs or unguided rocket pods, 44 × 2 in (50 mm), total of 46 built and one converted from F.6 (12 F.53Ks for the Kuwaiti Air Force, 34 F.53s for the Royal Saudi Arabian Air Force, one aircraft crashed before delivery).

**Lightning T.54**
Ex-RAF T.4 two-seat trainers supplied to Saudi Arabia (two converted).

**Lightning T.55**
Two-seat side-by-side training aircraft (export version of the T.5), eight built (six T.55s for the Royal Saudi Arabian Air Force, two T.55Ks for the Kuwaiti Air Force and one converted from T.5 that crashed before delivery).

**Sea Lightning FAW.1**
Proposed two-seat Royal Navy Fleet Air Arm carrier capable variant with variable-geometry wing; not built.[44]

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**Operators**

### Military operators

**Kuwait**
- Kuwait Air Force operated both the F.53K (12) single-seat fighter and the T.55K (2) training version from 1968 to 1977.

**Saudi Arabia**
  - 2 Squadron operated the F.53 and T.55
  - 6 Squadron operated the F.52 and F.53
  - 13 Squadron operated the F.52, F.53 and T.55
  - RSAF Lightning Conversion Unit

**United Kingdom**
  - RAF Aerial display teams
    - *The Tigers* of No 74 Squadron. Lead RAF aerial display team from 1962 and first display team with Mach 2 aircraft.
    - *The Firebirds* of No 56 Squadron from 1963 in red and silver
  - RAF Squadrons
    - 5 Squadron formed at RAF Binbrook on 8 October 1965, operating the Lightning F.6 and T.5. A few F.1s, F.1As and F.3s were used as targets (and later for air display use) from 1971. The Squadron remained
operational at Binbrook with the Lightning F6 until 1987, disbanding on 31 December.[123]

- 11 Squadron formed at RAF Leuchars in April 1967 with the Lightning F6. It moved to RAF Binbrook in March 1972, receiving a few F3s for target duties. It remained operational until 1988, disbanding on 30 April 1988.[123]
- 19 Squadron operated the F2 and the F2A (1962–1976)
- 23 Squadron operated the F3 and the F6 (1964–1975)
- 29 Squadron operated the F3 (1967–1974)
- 56 Squadron operated the F1, F1A, F3 and the F6 (1960–1976)
- 65 Squadron operated as No. 226 OCU with the F1, F1A and the F3 (1971–1974)
- 74 Squadron operated the F1, F3 and the F6 (1960–1971)
- 92 Squadron operated the F2 and the F2A (1963–1977)
- 111 Squadron operated the F1A, F3 and the F6 (1961–1974)
- 145 Squadron operated as No. 226 OCU with the F1, F1A and the F3 (1963–1971)
- Air Fighting Development Squadron
- Lightning Conversion Squadron (1960–1963)
- RAF Flights
  - Lightning Training Flight (1975–1987)
- RAF Stations
  - RAF Akrotiri
  - RAF Binbrook
  - RAF Coltishall
  - RAF Geilenkirchen
  - RAF Gütersloh
  - RAF Leconfield
  - RAF Middleton St. George
  - RAF Leuchars
  - RAF Tengah
  - RAF Wattisham

### Civil operators

#### South Africa

- Thunder City, a private company based at Cape Town International Airport, South Africa operated one Lightning T5 and two single-seat F.6s. The T5 XS452, (civil registration ZU-BBD) flew again on 14 January 2014 after restoration and is currently the only airworthy example.[124]

A Lightning T.5, XS451 (civil registration ZU-BEX) belonging to Thunder City crashed after developing mechanical problems during its display at the biennial South African Air Force Overberg Airshow held at AFB Overberg near Bredasdorp on 14 November 2009.[125] The Silver Falcons, the South African Air Force’s official aerobatic team, flew an missing man formation after it was announced that the pilot had died in the crash.[126]

#### United Kingdom

- British Aerospace operated four ex-RAF F6s as radar targets to aid development of the Panavia Tornado ADV’s AI.24 Foxhunter radar from 1988 to 1992.[127][128]
**United States**

- The Anglo-American Lightning Organisation, a group based at Stennis Airport, Kiln, Mississippi, is returning EE Lightning T5, XS422 to airworthy status. As of November 2013 the aircraft was capable of running its engines. The aircraft was formerly with the Empire Test Pilots' School (ETPS) at Boscombe Down in Wiltshire, UK.\(^{[129]}\)

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**Survivors**

**Cyprus**

**On display**

- **XS929 Lightning F.6** at RAF Akrotiri, Cyprus.\(^{[130]}\)

**France**

**On display**

- **XM178 Lightning F.1A** at Savigny-les-Beaune.\(^{[131]}\)

**Germany**

**On display**

- **XN730 Lightning F.2A** at the Luftwaffe Museum, Gatow, Germany.
- **XN782 Lightning F.2A** at the Flugausstellung Hermeskeil, Germany.\(^{[132]}\)

**Kuwait**

**On display**

- **53–418 Lightning F.53** at the Kuwait Science and Natural History Museum, Kuwait City.
- **Lightning F.53** at the Abdullah Al-Mubarak Air Base
- **Three Lightnings on stands** at Al Jaber Air Base

**Netherlands**

**On display**

- **XN784 Lightning F.2A** at Baarlo.

**Saudi Arabia**

**On display**

- **XN770 Lightning F.52** at the Royal Saudi Air Force Museum, Riyadh, Saudi Arabia.
- **XN989 Lightning T.54** at the main entrance to King Abdul-Aziz Air Base, Dhahran, Saudi Arabia.

The following are on display but with no public access:

- **Survivors**
  - Preserved Lightning XN776 at East Fortune
  - Lightning P.1A at the Museum of Science and Industry in Manchester
  - Preserved Lightning XS903 at RAF Akrotiri, Cyprus
  - Lightning XS903 F.6 at the Yorkshire Air Museum
  - Survivors
    - Preserved Lightning XN776 at East Fortune
    - Lightning P.1A at the Museum of Science and Industry in Manchester
    - Preserved Lightning XS903 at RAF Akrotiri, Cyprus
    - Lightning XS903 F.6 at the Yorkshire Air Museum

- XG313 Lightning F.1 at the VIP terminal on King Abdulaziz Air Base, Dhahran, Saudi Arabia.
- XN767 Lightning F.52 pylon mounted at the Aeromedical centre on King Abdulaziz Air Base, Dhahran, Saudi Arabia.
- Unidentified Lightning at entrance to Taif Heart Mall in downtown Taif, Saudi Arabia.

**South Africa**

**Airworthy**

- ZU-BBD (former XS452) Lightning T.5 based at Cape Town.

**Stored or under restoration**

- ZU-BEW (former XR773) Lightning F.6 stored in Cape Town.
- ZU-BEY (former XP693) Lightning F.6 stored in Cape Town.

**United Kingdom**

**On display**

- WG760, the first prototype P.1A at the RAF Museum Cosford, England.[133]
- WG763, the second prototype P.1A at the Museum of Science and Industry, Manchester, England.[134]
- XG329 P1B/Lightning F.1 pre-production aircraft at the Norfolk & Suffolk Aviation Museum, Flixton, England.[135]
- XG337 P1B/Lightning F.1 pre-production aircraft at the RAF Museum Cosford.[136]
- XM135 Lightning F.1A at the Imperial War Museum Duxford, England.[137]
- XM192 Lightning F.1A at Tattershall Thorpe, Lincolnshire, England.[138]
- XN776 Lightning F.2A at the National Museum of Flight, East Fortune, Scotland.[139]
- XP706 Lightning F.3 at AeroVenture, Doncaster, England.[140]
- XR713 Lightning F.3 with LPG, Bruntingthorpe Aerodrome, Leicestershire, England.
- XR728 Lightning F.6 with LPG, Bruntingthorpe Aerodrome, Leicestershire, England (taxi-able).[141]
- XR749 Lightning F.3 outside Score Group's Integrated Valve and Gas Turbine Plant, Peterhead, Scotland.[142]
- XR753 Lightning F.3 at RAF Coningsby, Lincolnshire.[143]
- XR770 Lightning F.6 RAF Manston History Museum, Manston, Kent
- XR771 Lightning F.6 at the Midland Air Museum, Coventry, England.[144]
- XS417 Lightning T.5 at the Newark Air Museum, Newark, England.[145]
- XS420 Lightning T.5 on loan to the Farnborough Air Sciences Trust, Farnborough, England.[146]
- XS456 Lightning T.5 at the Skegness Water Leisure Park, Lincolnshire.[147]
- XS458 Lightning T.5 at Cranfield Airport, Bedfordshire, England (taxi-able).[148]
- XS459 Lightning T.5 at the Fenland and West Norfolk Aviation Museum, Wisbech, England.[149]
- XS897 Lightning F.6 (painted as F.3 XP765) at RAF Coningsby, Lincolnshire.[143]
- XS903 Lightning F.6 at the Yorkshire Air Museum, Elvington, England.[150]
XS904 Lightning F.6 with LPG, Bruntingthorpe Aerodrome, Leicestershire, England (taxi-able)

XS925 Lightning F.6 stand mounted at Castle Motos on the A38 near Liskeard, Cornwall, England

XS928 Lightning F.6 at Warton Aerodrome, Lancashire

XS936 Lightning F.6 at the Royal Air Force Museum London, England

ZF578 Lightning F.53 as XR753 at the Tangmere Military Aviation Museum, Tangmere, England

ZF579 Lightning F.53 at the Gatwick Aviation Museum, Charlwood, near Gatwick Airport, England

ZF580 Lightning F.53 outside BAE Systems, Samlesbury, England

ZF581 Lightning F.53 at the Bentwaters Cold War Museum, Suffolk, England

ZF583 Lightning F.53 at the Solway Aviation Museum, Carlisle Airport, Cumbria, England

ZF584 Lightning F.53 at the Dumfries and Galloway Aviation Museum, Dumfries, Scotland

ZF588 Lightning F.53 on static display at East Midlands Aeropark

ZF592 Lightning F.53 as 53–686 at the City of Norwich Aviation Museum, Norwich, England

ZF594 Lightning F.53 painted as XS733 at the North East Aircraft Museum, Sunderland, England

ZF598 Lightning T.55 as 55–713 at the Midland Air Museum, Coventry, England

XL629 Lightning T.4 inside the main gate at MoD Boscombe Down, Wiltshire, England

Stored or under restoration

XA847 P.1B stored dismantled in Suffolk, England

XM172 Lightning F.1A in a private collection at Spark Bridge, Cumbria

XM173 Lightning F.1A at the Dyson Research Centre, Malmesbury, Wiltshire

XP745 Lightning F.3 stored in Greenford, London

XR724 Lightning F.6 in a private collection at the former RAF Binbrook, Lincolnshire

XS416 Lightning T.5 in a private collection at New York, Lincolnshire

XR725 Lightning F.6 in a private collection at Binbrook, Lincolnshire

United States

On display

ZF593 Lightning F.53 painted in 5 Squadron camouflage colours, on display at Pima Air & Space Museum, Tucson, Arizona

Stored or under restoration

N422XS Lightning T.5 painted as XS422 of the Royal Air Force, under restoration to fly at Stennis Airport, Mississippi.

Specifications (Lightning F.6)

Data from Pilots Notes and Operating Data Manual for Lightning F.6 (unless otherwise noted)

General characteristics

- **Crew:** one
- **Length:** 55 ft 3 in (16.8 m)
- **Wingspan:** 34 ft 10 in (10.6 m)
- **Height:** 19 ft 7 in (5.97 m)
- **Wing area:** 474.5 ft² (44.08 m²)
- **Empty weight**: 31,068 lb[^53][nb 12] (14,092 kg)
- **Max. takeoff weight**: 45,750 lb[^32][nb 13] (20,752 kg)
- **Powerplant**: 2 × Rolls-Royce Avon 301R afterburning turbojets
  - **Dry thrust**: 12,530 lb[^31] (55.74 kN) each
  - **Thrust with afterburner**: 16,000 lb[^31] (71.17 kN) each

### Performance
- **Maximum speed**: Mach 2.0 (1,300 mph, 2,100 km/h) at 36,000 ft. 700 KIAS at lower altitude[^53][nb 14]
- **Range**: 850 mi[^53][nb 15] (1,370 km) Supersonic intercept radius: 155 mi[^53][nb 16] (250 km)
- **Ferry range**: 920 mi (800 NM[^53] 1,660 km) 1,270 mi (1,100 NM[^53] 2,040 km) with ferry tanks
- **Service ceiling**: 54,000 ft[^53] (16,000 m) zoom ceiling >70,000 ft[^53][169]
- **Rate of climb**: 20,000 ft/min[^53][nb 17] (100 m/s)
- **Wing loading**: 76 lb/ft[^4][nb 18] (370 kg/m²)
- **Thrust/weight**: 0.78

### Armament
- **Guns**: 2 × 30 mm (1.18 in) ADEN cannon
- **Hardpoints**: 2 × under-fuselage for mounting air-to-air missiles, 2 × overwing pylon stations for 260 gal ferry tanks and provisions to carry combinations of:
  - **Missiles**: 2 De Havilland Firestreak or 2 × Hawker Siddeley Red Top

### Notable appearances
- British journalist and TV presenter Jeremy Clarkson borrowed a Lightning (serial XM172) which was temporarily placed in his garden and documented on Clarkson's TV show Speed[^170]
- Professor Brian Cox used a South African Lightning (KS451) in an episode of the BBC TV programme Wonders of the Solar System. The Lightning climbed to a very high altitude, allowing the Professor to show the curvature of the Earth and the relative dimensions of the atmosphere[^71]. This aircraft crashed a month later at the Overberg Airshow after developing mechanical problems[^125]

### See also
- List of accidents and incidents involving the English Electric Lightning

### Related development
- Short SB.5

### Aircraft of comparable role, configuration and era
- Convair F-102 Delta Dagger
- Convair F-106 Delta Dart
- Dassault Mirage III
- Lockheed F-104 Starfighter
- Mikoyan-Gurevich MiG-21
- Sukhoi Su-15

### Related lists

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[^53]: Supplementary note
[^12]: Supplementary note
[^13]: Supplementary note
[^32]: Supplementary note
[^31]: Supplementary note
[^4]: Supplementary note
[^15]: Supplementary note
[^16]: Supplementary note
[^17]: Supplementary note
[^18]: Supplementary note
[^125]: Supplementary note
[^170]: Supplementary note
[^71]: Supplementary note
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References

Notes

1. The ventral cannon installation was designed for the export aircraft but was later adopted by the RAF for the F.6 and F.2A.[37]

2. All fuel tank volumes are listed in Imperial gallons.

3. The Lightning would increase forward velocity during the climb, the angle of the climb lessening from about 27 deg to 19 deg at 13,000 ft (4,000 m).

4. The true airspeed associated with a given indicated airspeed increases with altitude. Below the tropopause, the true airspeed associated with a given Mach number decreases with altitude. The Lightning Air Data System automatically corrected for errors in position and speed; following correction, 450 KIAS was equal to Mach 0.87 (1,009 km/h) at 13,000 ft (4,000 m).[53]

5. Along with directional stability, rudder effectiveness decreased at higher Mach numbers; timely and larger deflections of the rudder were required to counter any yaw especially under increased g-loading.[30][32] Two Lightning prototypes, XL628 and XM966, were lost to vertical fin failure during roll testing at high Mach numbers.[82]

6. Firestreak firing limits were Mach 1.3 with the small fin, Mach 1.7 with the large fin. Red Top limit was Mach 1.8.[30][32]

7. On a standard day the temperature of the air at the tip of the shock cone (stagnation temperature) was 156 °F (69 °C) at Mach 1.7 (1,815 km/h) and 36,000 feet (11,000 m). At sea level and 650 knots (1,200 km/h) indicated airspeed, this temperature was 151 °F (66 °C).

8. At Mach 2.0, the stagnation temperature would be 242 °F (117 °C).

9. Roland Beamont took the Lightning P.1B XA847, a prototype of the F.1, to Mach 2.0. Prior testing had determined that the aircraft would have the excess thrust to achieve this speed, given the right atmospheric conditions of a high tropopause and lower-than-standard temperature. The test flight was to check for inlet stability and monitor temperatures at higher Mach. The aircraft was equipped with a temperature probe to monitor the stagnation temperature, up to a never-exceed temperature of 115 °C. On 28 November 1958, the weather availed a high tropopause and a substandard −67 °C at 40,000 feet (12,000 m). This was sufficient to allow Beamont to achieve Mach 2.0 (2,125 km/h) in a British aircraft for the first time, reached only 7 minutes after takeoff but the record dash left the Lightning critically short of fuel.[85] The Machmeter fitted to service Lightning F.1s and F.1Bs had a scale that stopped at Mach 1.8 — with a redline at 1.[30]

10. At 30,000 feet (9,100 m), a Lightning F.6 would require approximately 1 minute and 1,250 pounds (570 kg) of fuel to accelerate from 650 to 675 knots (1,204 to 1,250 km/h) indicated airspeed.[53]

11. A single F.1 was supplied as a ground instructional airframe.[110]

12. The value for "empty weight" is really the Zero Fuel weight, which includes equipped pilot, Red Top missiles, cannon and ammunition. The Basic weight, without these items, is 27,759 lb.[53]

13. The maximum permissible weight for takeoff and all forms of flying is 45,750 lb. At weights above 45,000 lb, the mainwheel tyres have to be changed after one use.[32]

14. An F.6 equipped with Red Top missiles can reach Mach 2.0 on an ICAO Std. day at 36,000 ft. A clean F.6 can reach Mach 2.1 at 37,000 ft.[53]

15. This is based on a maximum-range subsonic intercept radius of 370 NM (425 mi, 625 km). An F.6 equipped with Red Top missiles can climb to 36,000 ft and cruise at Mach 0.87 to a loiter or intercept area 370 NM distant. It then has 15 minutes on station to complete the intercept or identification task before returning to base. The afterburners are not used during this profile, and the total mission time is 112 min.[53]

16. An F.6 equipped with Red Top missiles can climb to 36,000 ft, accelerate to Mach 1.8, and intercept a target at 135 NM only 10.7 min after brake release. A 2g level turn allows a rear-quarter re-attack 1.6 min later. Following a best-range cruise and descent, the Lightning enters the landing pattern with 800 lb of fuel remaining with a total mission time of 35 min.[53]
17. This is the initial climb rate associated with the Lightning's best time-to-climb profile of 450 KIAS to Mach 0.87. Using this profile, a Lightning F6 with Red Top missiles can climb from Sea Level to 36,000 ft in 2.1 min following initial acceleration to 450 KIAS, or 2.8 min from brake release. A clean F6 can perform the same climb in 2.0 min following initial acceleration or 2.7 min from brake release.[53]

18. Wing loading is calculated from the above weight and wing area data. The listed value represents an F6 with Red Top missiles and 1/2 fuel. The wing loading can range between 86–67 lb/ft² over the duration of a mission, depending on fuel load.

a. The SB5 was allocated serial number WG768 on 27 July 1950

Citations

1. Winchester 2006, p. 82.
2. Note: at the time, the V bombers carried Britain's nuclear deterrent and thus were the likely first-strike targets of any Soviet air attack on the UK. In addition to the Lightning, last line-of-defence for the airfields was to be what became the Bristol Bloodhound guided missile.
3. Note: the original specification only called for a 150-mile radius of action from the V bomber bases the aircraft was defending. Roland Beamont later called for the Lightning's fuel capacity to be greatly increased, which it was.
5. Halpenny 1984,
23. "Progress with the P1" [Flight 26 April 1957 p543]
25. Flight & 26 April 1957
42. McLelland 2009,
60. Darling 2008, p. 25.
63. Darling 2008, pp. 27, 35.
64. Darling 2000, pp. 20, 25, 35.
72. *Public Record Office*, London. TNA AIR 20/11370
74. Public Record Office, London. TNA AIR 20/1370
89. Lake 1997, p. 43.
90. Lake 1997, pp. 43–44.
98. Lake Air International. February 2006, p. 64.
100. Darling 2008, p. 95.
101. Darling 2008, pp. 95, 105, 121.
110. Lake 1997, p. 100.
111. Ransom and Fairclough 1987, p. 258.
113. Lake 1997, pp. 58, 100.


### Further reading


### External links

- Anglo American Lightning Organisation, returning to flight XS422, the former ETPS Lightning at Stennis Airport, Kiln Mississippi
- The Lightning Association
- Thunder City
- Five-minute RAF Recruiting film "Streaked Lightning" from 1962 at the National Archives Public
