



Rocket-Powered Aircrafts

Gisele Fowlkes

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Email: info@wtbooks.com

Table of Contents

Introduction

Chapter 1 - Bell X-1

Chapter 2 - Bereznyak-Isayev BI-1

Chapter 3 - Boeing X-37

Chapter 4 - DFS 346

Chapter 5 - Douglas Skyrocket

Chapter 6 - Saunders-Roe SR.53 and Heinkel He 176

Chapter 7 - SpaceShipOne

Chapter 8 - North American X-15

Chapter 9 - Messerschmitt Me 163

Chapter 10 - Mitsubishi J8M

Chapter 11 - Northrop HL-10

Chapter 12 - Buran (spacecraft)

Introduction



A **rocket-powered aircraft** or **rocket plane** is an aircraft that uses a rocket for propulsion, sometimes in addition to airbreathing jet engines. Rocket planes can achieve much higher speeds than similarly-sized jet aircraft, but typically for at most a few minutes of powered operation, followed by a glide. Unhindered by the need for oxygen from the atmosphere they are suitable for very high altitude flight. They are also capable of delivering much higher acceleration and shorter takeoffs.

Rockets have been used simply to assist the main propulsion in the form of Jet Assisted Take Off (JATO) also known as "Rocket Assisted Take Off" (RATO). Not all rocket planes are of the conventional takeoff like "normal" aircraft. Some types have been air-launched from another plane, while other types have taken off vertically - nose in the air and tail to the ground ("tail-sitters"). It is also possible, that rocket planes launch vertically without changing their orientation.

Because of the heavy propellant use and the various practical difficulties of operating rockets, the majority of rocket planes have been built for experimental use, as interceptor fighters and space aircraft.

History

The first rocket-powered aircraft was the Lippisch Ente, flown in 1928. The Russian Bereznyak-Isayev BI-1 flew in 1942.

The Heinkel He 176 was the world's first aircraft to be propelled solely by a liquid-fuelled rocket, making its first powered flight on 20 June 1939 with Erich Warsitz at the controls.

The antipodal bomber was planned by the Germans late in WWII, however later calculations showed that it would not have worked, and would have been destroyed during reentry.

The only rocket planes ever to be mass-produced were the Messerschmitt Me 163 in 1944, one of several German World War II attempts at rocket-powered aircraft. The Bachem Ba 349 was a WWII vertical takeoff manned rocket interceptor aircraft.

The Japanese also produced 850 Ohka, rocket powered suicide attack planes in WWII.

In 1946 the Soviet Mikoyan-Gurevich I-270 was built partly using technology developed by Sergei Korolev in 1943 and 1932.

In 1946 the rocket plane Bell X-1 was the first aircraft to break the speed of sound in level flight. The development of X-1 was the driving force behind the development of the Space Program.

In the 1950s the British developed mixed power designs to cover the performance gap that existed in then-current turbojet designs. The rocket was the main engine for delivering the speed and height required for high speed interception of high level bombers and the turbojet gave increased fuel economy in other parts of flight, most notably to make sure the aircraft was able to make a powered landing rather than risking an unpredictable gliding return. The Saunders-Roe SR.53 was a successful design and was due to be developed into production when economics forced curtailment of most British aircraft programmes in the late 1950s. The advancement of the turbojet engine output, the advent of missiles, and advances in radar had made a return to mixed power unnecessary.

The North American X-15 was used for several years and eventually reached Mach 6.7.

In the early 60s American research into the X-20 Dyna-Soar spaceplane was cancelled due to lack of purpose; later the studies contributed to the Space Shuttle. Another similar program was ISINGLASS which was to be a rocket plane launched from a B-52 carrier, which was intended to achieve Mach 22, but this was never funded.

Work on the Space Shuttle began in 1972 and Space Shuttle Columbia first launched in 1981.

The Lunar Landing Research Vehicle was a mixed powered vehicle- a jet engine cancelled 5/6 of the force due to gravity, and the rocket power was able to simulate the Apollo lunar lander.

The development of SpaceShipOne, first flown in 2003, and XCOR Aerospace's EZ-Rocket, suggests that rocket planes may become more common.

Planned rocket powered aircraft

- Reaction Engines Skylon
- Spaceship Two
- Lynx rocketplane
- ARES (martian rocketplane)

Chapter- 1

Bell X-1

X-1



X-1 #46-062, nicknamed "Glamorous Glennis"

Role	rocket plane, Experimental Aircraft
Manufacturer	Bell Aircraft
First flight	19 January 1946
Status	Retired United States Air Force
Primary users	National Advisory Committee for Aeronautics

The **Bell X-1**, originally designated **XS-1**, was a joint NACA-U.S. Army/US Air Force supersonic research project built by Bell Aircraft. It was the first aircraft to exceed the speed of sound in controlled, level flight, and was the first of the so-called X-planes, an American series of experimental aircraft designated for testing of new technologies and usually kept highly secret.

Design and development



Chuck Yeager in front of the X-1, which he named *Glamorous Glennis* after his wife.



XLR-11 rocket engine

On 16 March 1945, the United States Army Air Forces' Flight Test Division and the National Advisory Committee for Aeronautics (NACA) (now NASA) contracted Bell Aircraft to build three XS-1 (for "Experimental, Supersonic", later X-1) aircraft to obtain flight data on conditions in the transonic speed range.

The X-1 was in principle a "bullet with wings", its shape closely resembled the Browning .50-caliber (12.7 mm) machine gun bullet that was known to be stable in supersonic flight. The pattern shape was followed to the point of seating the pilot behind a sloped, framed window inside a confined cockpit in the nose, with no ejection seat. After the aircraft ran into compressibility problems in 1947, it was modified to feature a variable-incidence tailplane. An all-moving tail was developed by the British for the Miles M.52,

and first saw actual transonic flight on the Bell X-1 that allowed it to pass through the sound barrier safely.

The rocket propulsion system was a four-chamber engine built by Reaction Motors, Inc., one of the first companies to build liquid-propellant rocket engines in America. It burned ethyl alcohol diluted with water and liquid oxygen. The thrust could be changed in 1,500 lbf (6,700 N) increments by firing one or more of the chambers. The fuel and oxygen tanks for the first two X-1 engines were pressurized with nitrogen and the rest with steam-driven turbopumps. The all-important fuel turbopumps, necessary to raise the chamber pressure and thrust, while lightening the engine, were built by Robert Goddard who was under Navy contract to provide jet-assisted takeoff rockets.

Operational history

Bell Aircraft Chief Test Pilot, Jack Woolams became the first to fly the XS-1, in a glide flight over Pinecastle Army Airfield, in Florida, on 25 January 1946. Woolams would complete nine additional glide flights over Pinecastle before March 1946, when the #1 aircraft was returned to Bell for modifications in anticipation of the powered flight tests, planned for Muroc Army Air Field (now Edwards Air Force Base) in California. Following Woolams' death on 30 August 1946, Chalmers "Slick" Goodlin was the primary Bell Aircraft test pilot of X-1-1 (serial 46-062). He made 26 successful flights in both of the X-1 aircraft from September 1946 until June 1947.

The Army Air Force was unhappy with the cautious pace of flight envelope expansion and Bell Aircraft's flight test contract for aircraft #46-062 was terminated and was taken over by the Army Air Force Flight Test Division on 24 June after months of negotiation. Goodlin had demanded a US\$150,000 bonus for breaking the sound barrier. Flight tests of the X-1-2 (serial 46-063) would be conducted by NACA to provide design data for later production high-performance aircraft.

On 14 October 1947, just under a month after the United States Air Force had been created as a separate service, the tests culminated in the first manned supersonic flight, piloted by Air Force Captain Charles "Chuck" Yeager in aircraft #46-062, which he had christened *Glamorous Glennis* after his wife. The rocket-powered aircraft was launched from the bomb bay of a specially modified B-29 and glided to a landing on a runway. XS-1 flight number 50 is the first one where the X-1 recorded supersonic flight, at Mach 1.06 (361 m/s, 1,299 km/h, 807.2 mph) peak speed.

As a result of the X-1's initial supersonic flight, the National Aeronautics Association voted its 1948 Collier Trophy to be shared by the three main participants in the program. Honored at the White House by President Harry S. Truman were Larry Bell for Bell Aircraft, Captain Yeager for piloting the flights, and John Stack for the NACA contributions.

On 5 January 1949, Yeager used Aircraft #46-062 to carry out the only conventional (runway) take off performed during the X-1 program, reaching 23,000 ft (7,000 m) in 90 seconds.

Legacy

The research techniques used in the X-1 program became the pattern for all subsequent X-craft projects. The NACA X-1 procedures and personnel also helped lay the foundation of America's space program in the 1960s. The X-1 project defined and solidified the post-war cooperative union between U.S. military needs, industrial capabilities, and research facilities. The flight data collected by the NACA in the X-1 tests then provided a basis for American aviation supremacy in the latter half of the 20th century.

Disposition



X-1 at the Smithsonian

Aircraft #46-062 is currently on display in the Milestones of Flight gallery of the National Air and Space Museum in Washington, DC, alongside the Spirit of St. Louis and SpaceShipOne. Aircraft #46-063, now the X-1E, is on display in front of the NASA Dryden Flight Research Center headquarters building.

Variants

Later variants of the X-1 were built to test different aspects of supersonic flight; one of these, the X-1A, with Yeager at the controls, inadvertently demonstrated a very dangerous characteristic of fast (Mach 2 plus) supersonic flight: inertia coupling. Only Yeager's skills as an aviator prevented him from dying that day; later Mel Apt would die testing the Bell X-2 under similar circumstances.

X-1A



X-1A.

Ordered by the Air Force on 2 April 1948, the **X-1A** (serial 48-1384) was intended to investigate aerodynamic phenomena at speeds above Mach 2 (681 m/s, 2,451 km/h) and altitudes greater than 90,000 ft (27 km), specifically focusing on dynamic stability and air loads. Longer and heavier than the original X-1, with a bubble canopy for better vision, the X-1A was powered by the same Reaction Motors XLR-11 rocket engine. The aircraft first flew, unpowered, on 14 February 1953 at Edwards AFB, with the first powered flight on 21 February. Both flights were piloted by Bell test pilot Jean "Skip" Ziegler.

After NACA started its high-speed testing with the Douglas Skyrocket, culminating in Scott Crossfield achieving Mach 2.005 on 20 November 1953, the Air Force started a series of tests with the X-1A, which the test pilot of the series, Chuck Yeager, named "Operation NACA Weep". These culminated on 12 December 1953, when Yeager achieved an altitude of 74,700 feet (22,770 m) and a new air speed record of Mach 2.44 (equal to 1620 mph, 724.5 m/s, 2608 km/h at that altitude). Unlike Crossfield in the Skyrocket, Yeager achieved that in level flight. Shortly after, the aircraft spun out of control, due to the then not yet understood phenomenon of inertia coupling. The X-1A dropped from maximum altitude to 25,000 feet (7,620 m), exposing the pilot to accelerations of up to 8g, during which Yeager broke the canopy with his helmet before regaining control.

The aircraft was transferred to NACA in September 1954. Following modifications, including the installation of an ejection seat, the aircraft was lost on 8 August 1955 while being prepared for launch from the RB-50 mothership, becoming the first of many early X-planes that would be lost to explosions.

X-1B

The **X-1B** (serial 48-1385) was equipped with aerodynamic heating instrumentation for thermal research (over 300 thermal probes were installed on its surface). It was similar to the X-1A except for having a slightly different wing. The X-1B was used for high speed research by the US Air Force starting from October 1954 prior to being turned over to the NACA in January 1955. NACA continued to fly the aircraft until January 1958 when cracks in the fuel tanks forced its grounding. The X-1B completed a total of 27 flights. A notable achievement was the installation of a system of small reaction rockets used for directional control, making the X-1B the first aircraft to fly with this sophisticated control system, later used in the X-15. The X-1B is now at the National Museum of the United States Air Force, Wright-Patterson Air Force Base at Dayton, Ohio, where it is displayed in the Museum's Research & Development Hangar.

X-1C

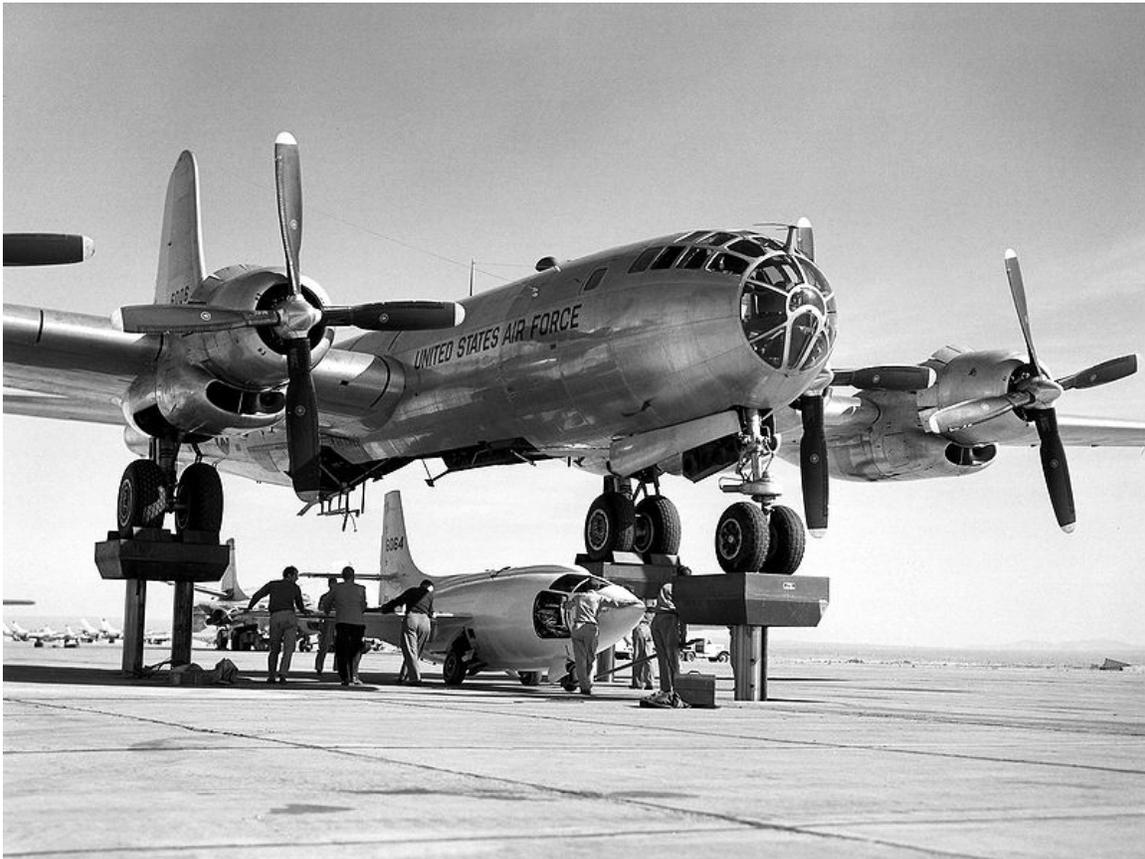
The **X-1C** (serial 48-1387) was intended to test armaments and munitions in the high transonic and supersonic flight regimes. It was canceled while still in the mock-up stage, as the birth of transonic and supersonic-capable aircraft like the North American F-86 Sabre and the North American F-100 Super Sabre eliminated the need for a dedicated experimental test platform.

X-1D

The **X-1D** (serial 48-1386) was the first of the second generation of supersonic rocket planes. Flown from an EB-50A (s/n #46-006), it was to be used for heat transfer research. The X-1D was equipped with a new low-pressure fuel system and a slightly increased fuel capacity. There were also some minor changes to the avionics set.

On 24 July 1951, with Bell test pilot Jean "Skip" Ziegler at the controls, the X-1D was launched over Rogers Dry Lake, on what was to become the only successful flight of its career. The unpowered glide was completed after a nine-minute descent, but upon landing, the nose gear failed and the aircraft slid ungracefully to a stop. Repairs took several weeks to complete and a second flight was scheduled for mid-August. On 22 August 1951, the X-1D was lost in a fuel explosion during preparations for the first powered flight. The aircraft was destroyed upon impact after it was jettisoned from its EB-50A mothership.

X-1E



Bell X-1-3, aircraft #46-064, being mated to the B-50 mothership for a captive flight test on 9 November 1951. While being de-fueled after this flight it exploded, destroying itself and the B-50, and seriously burning Joe Cannon. X-1-3 had only completed a single glide flight on 20 July.

The **X-1E** was the result of a reconstruction of the X-1-2 (serial 46-063), in order to pursue the goals originally set out for the X-1D and X-1-3 (serial 46-064), both lost in explosions in 1951. The cause of the mysterious explosions was finally traced to the use of Ulmer leather gaskets impregnated with tricresyl phosphate (TCP), a leather treatment, which was used in the liquid oxygen plumbing. TCP becomes unstable and explosive in

the presence of pure oxygen and mechanical shock. This mistake cost two lives, caused injuries and lost several aircraft.



The X-1E, christened '*Little Joe*', with pilot Joe Walker.

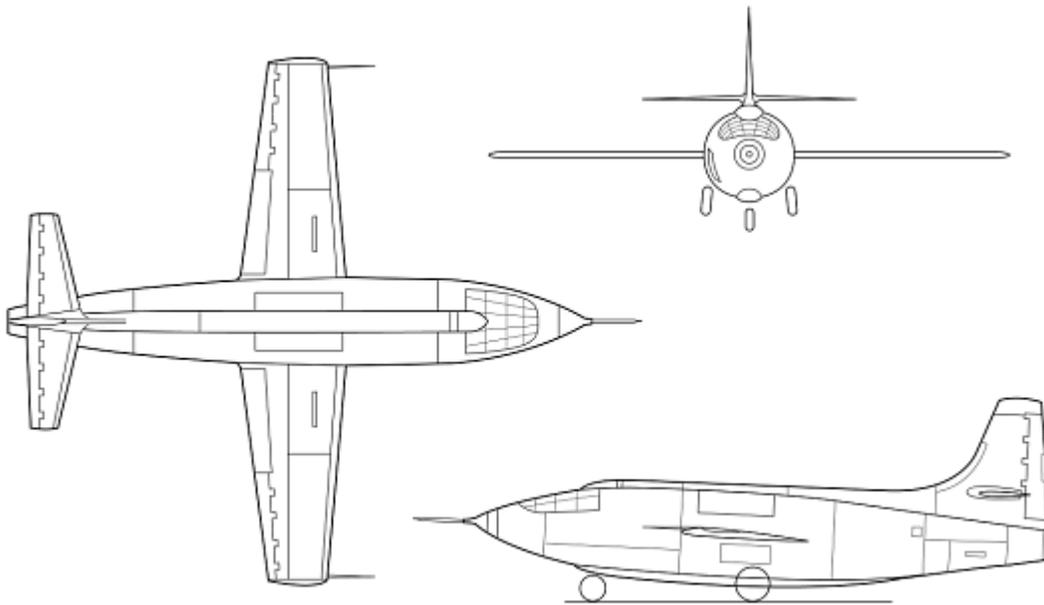
The changes included:

- A turbopump fuel feed system, which eliminated the high-pressure nitrogen fuel system used in '062 and '063. (Concerns about metal fatigue in the nitrogen fuel system resulted in the grounding of the X-1-2 after its 54th flight in its original configuration.)
- A re-profiled super-thin wing ($3\frac{3}{8}$ inches at the root), based on the X-3 Stiletto wing profile, enabling the X-1E to reach Mach 2.
- A 'knife-edge' windscreen replaced the original greenhouse glazing, an upward-opening canopy replaced the fuselage-side hatch and allowed the inclusion of an ejection seat.

- The addition of 200 pressure ports for aerodynamic data, and 343 strain gauges to measure structural loads and aerodynamic heating along the wing and fuselage.

The X-1E first flew on 15 December 1955, a glide flight under the controls of USAF test pilot Joe Walker. Walker left the X-1E program in 1958, after 21 flights, attaining a maximum speed of Mach 2.21 (752 m/s, 2,704 km/h). NACA research pilot John B. McKay took his place in September 1958, completing five flights in pursuit of Mach 3 (1,021 m/s, 3,675 km/h). before the X-1E was permanently grounded following its 26th flight, in November 1958, due to the discovery of structural cracks in the fuel tank wall.

Specification (Bell X-1)



Orthographic diagram

General characteristics

- **Crew:** 1
- **Length:** 30 ft 11 in (9.4 m)
- **Wingspan:** 28 ft (8.5 m)
- **Height:** 10 ft (3.3 m)
- **Wing area:** 130 ft² (12 m²)
- **Empty weight:** 7,000 lb (3,175 kg)
- **Loaded weight:** 12,225 lb (5,545 kg)
- **Max takeoff weight:** 12,250 lb (5,557 kg)
- **Powerplant:** 1× Reaction Motors XLR-11-RM3 liquid fuel rocket, 6,000 lbf (1,500 lbf per chamber) (26.7 kN)

Performance

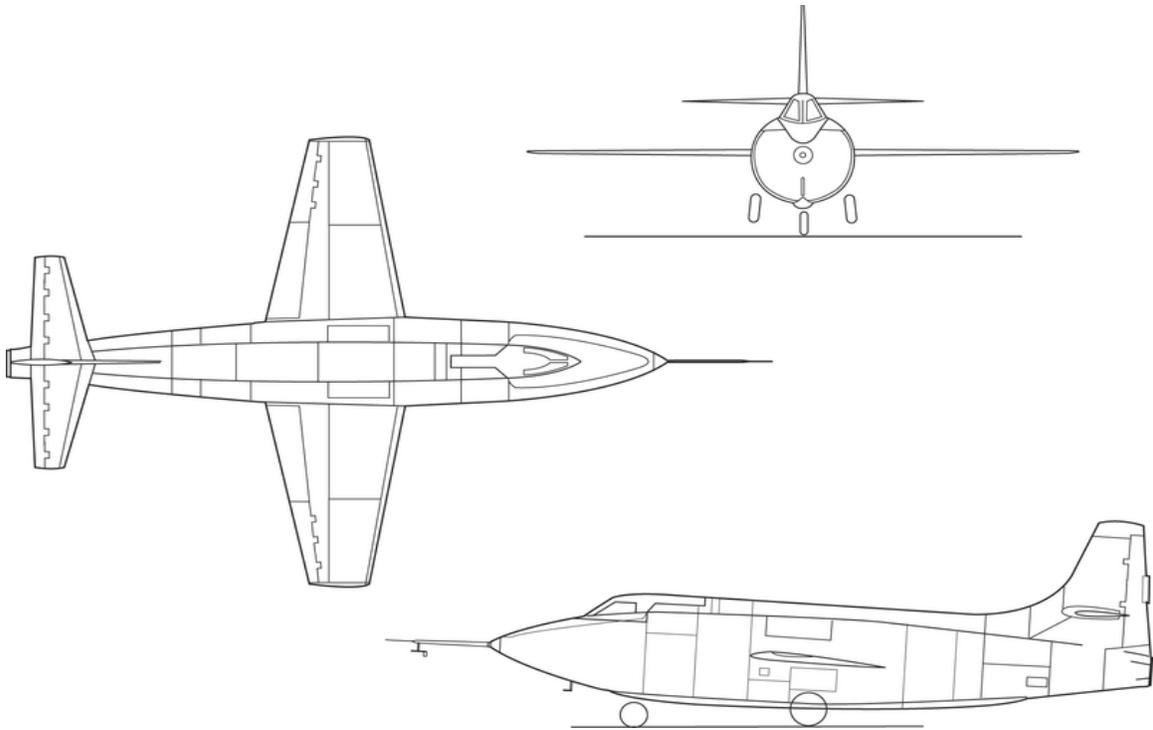
- **Maximum speed:** 957 mph (Mach 1.26) (1,541 km/h)
- **Range:** 5 minutes (powered endurance)
- **Service ceiling:** 71,900 ft (21,900 m)
- **Wing loading:** 94 lb/ft² (463 kg/m²)
- **Thrust/weight:** 0.49







Specification (Bell X-1E)



X-1E line drawing

General characteristics

- **Crew:** 1
- **Length:** 31 ft (9.4488 m)
- **Wingspan:** 22 ft 10 in (6.9596 m)
- **Height:** 10 ft 10 in (3.3 m)
- **Wing area:** 115 ft² (10.684 m²)
- **Empty weight:** 6,850 lb (3,107.107 kg)
- **Loaded weight:** 14,750 lb (6,690.487 kg)
- **Powerplant:** 1× Reaction Motors RMI LR-8-RM-5 rocket, 6,000 lbf (26.7 kN)

Performance

- **Maximum speed:** 1,450 mph (Mach 2.24) (2,333.548 km/h)
- **Range:** 4 minutes 45 seconds ((powered endurance))
- **Service ceiling:** 90,000+ ft (27,432+ m)

Chapter- 2

Bereznyak-Isayev BI-1

Bereznyak-Isayev-1



The BI-1

Role	Fighter
Manufacturer	OKB-293
Designed by	A.Y.Bereznyak and A.M.Isayev
First flight	15 May 1942
Retired	9 March 1945
Primary user	Soviet Air Force
Number built	9

Soviet research and development of rocket-powered aircraft began with Sergey Korolev's GIRD-6 project in 1932. His interest in stratospheric flight was also shared by Marshal Mikhail Tukhachevsky who supported this early work. After a long series of unmanned tests of vehicles, Korolev's RP-318-1 rocket plane flew on Feb 28, 1940. That Spring, the Zhukovsky Institute in Moscow (TsAGI) hosted a conference for aircraft chief designers on the subject of ramjet and rocket propulsion. On July 12, the Council of People's Commissioners (SNK) called for the development of high-speed stratospheric aircraft.

Early Design

Aircraft designer and head of OKB-293, Viktor Fedorovich Bolkhovitinov attended the TsAGI conference along with two of his top engineers, A. Ya. Bereznyak and A. M.

Isaev. The young Bereznyak had made an impression in 1938 with a high-speed airplane design that some thought could break the world speed record. Bereznyak and Isaev were excited by the idea of designing a rocket-powered aircraft, and their "patron" Bolkhovitinov approved. By the Autumn of 1940, they were able to show fellow engineer Boris Chertok a preliminary design of "Project G". The design, made up mostly from plywood and duralumin had a take-off weight of 1500 kg, and they planned to use the new 1400 kgf rocket engine under development in the Jet Propulsion Research Institute (RNII). Chertok was astounded that the aircraft could almost climb vertically.

Bereznyak, Isaev and Chertok visited RNII in March 1941, but the new rocket engine was not working yet. The engine was designed by Leonid Dushkin, who had made the engine (RD-A-150) for RP-318-1. Powered by tractor kerosene and red fuming nitric acid, it fell short of the hoped for 1400 kgf of thrust. Designated D-1-A-1100, it was expected to reach 1100 kgf. The "A" stood for "Nitric" (versus "Oxygenic"), a distinction of unusual importance and controversy among Soviet rocket scientists. Dushkin's propellant pump was causing considerable problems. It was a turbine pump driven by hot gas and steam from a small combustion chamber fed with rocket propellants mixed with water. This system was perfected a few years later in Dushkin's RD-2M engine.

The D-1-A-1100 was built from carbon steel with diffusion chrome plating. At this point in time, Russian rocket engines were built with typical aviation piston-engine manufacturing technology. Weighing 48 kg, it could be broken down into discrete forged-steel sections -- a conical head with 60 centrifugal injectors, the cylindrical chamber, and the nozzle -- joined with bolts and copper gaskets. It was ignited with a nichrome glow plug, later replaced with silicon-carbide. The engine was cooled regeneratively by both propellants, the chamber walls by a spiral flow of incoming fuel, and the nozzle section by the flow of oxidizer.

War-Time Development

On June 21, Isaev proposed a new design using compressed air instead of a pump to force propellant to the engine. The next day, Operation Barbarossa brought the Soviet Union into World War II, and the rocket-powered interceptor suddenly became important. Bereznyak and Isaev began a new more detailed design, which they finished in three weeks. On July 9, Bolkhovitinov and his project-G team met with Andrey Kostikov the head of RNII. Dushkin was not happy about the idea of bypassing his fuel pump design, but they backed the plan and cosigned a letter that was eventually shown to Stalin. After giving a report at the Kremlin, they were ordered to build the plane and were given only 35 days to do so. The official order was dated August 1, but work began in late July. The engineers were given leave to visit their families, and then literally lived at the factory until the planes were finished.

The new design was called "BI" for *Blizhnii Istrebitel* (close-range fighter), but the letters were also understood by everyone to stand for its inventors: Bereznyak and Isaev. The original plan to include four machine guns was replaced by a design with a pair of 20 mm ShVAK cannons. The new plane was a low-wing monoplane 6.4 meters long, with a

wingspan of 6.5 meters and an estimated take-off mass of 1650 kg (including 710 kg of propellant). Working around the clock, local furniture workers were employed to build the first two prototypes (BI-1 and BI-2). The skin was 2 mm plywood with a bonded covering of fabric. The Ailerons, elevators and rudder were fabric covered, and the flaps were duralumin. In the forward section were 5 compressed air tanks and 2 kerosene tanks. In the aft were 5 compressed air tanks and three nitric acid tanks. Pressurized to 60 atm, the tanks were made from a high-strength chromium-manganese-silicon steel ("Chromansil") that was not especially resistant to corrosion. Thus, the acid tanks had to be replaced periodically. Compressed air was also used to retract and deploy the landing gear and to power the anti-aircraft cannons.

On September 1, 1941, BI-1 was completed and ready for glider tests by pilot Boris N. Kudrin. Dushkin's engine was still not ready. A few weeks later, rival aircraft designer A.S. Yakovlev took it upon himself to tow the prototype to TsAGI for windtunnel testing. This alarmed Bolkhovitinov's team, because their patron had a rocky history with Yakovlev, but Alexander Sergeevich and aircraft designer Ilya Florov studied the test results and gave them sound advice for improvements. Yaw instability was corrected by enlarging the rudder and adding two circular plates to the tail horizontal stabilizer.

Test Flights In The Urals



Bereznyak, Isaev, Bakhchivandzhi, and Bolkhovitinov

In October, both OKB-293 and RNII were evacuated to the Urals, along with most of Moscow's war industry. Bolkhovitinov's team was stationed in Bilimbay, and Dushkin's team in Sverdlovsk, about 60 km away. A test stand was built on the shore of frozen lake Bilimbay, with a dynamometer cradle to hold the BI-1 during engine testing. A new test pilot, Grigory Yakovlevich Bakhchivandzhi, was assigned to the team. Dushkin was increasingly absorbed by other work, including RNII's own rocket plane project, the Kostikov-302. He assigned his engineer Arvid V. Pallo to oversee the installation and testing of the rocket engine.

Nitric acid presented a constant problem, corroding parts and causing skin burns and respiratory irritation. Tanks of sodium carbonate solution were kept around to neutralize acid spills. On February 20 1942, the engine exploded during a full system test. The

nozzle section was blasted into the lake, and the engine head struck the back of the pilot's seat, knocking Bakhchivandzhi against the instrument panel and injuring him slightly. From a broken propellant line, pressurized nitric acid drenched Pallo. Fortunately, quick thinking mechanics dunked him head-first into a tank of soda solution. His face was yellow from the characteristic acid staining, but his glasses saved him from being blinded. To protect the pilot in the future, a 5.5 mm steel plate was added to the back of the seat.

By April 1942, BI-1 was ready for testing at nearby Koltsove airfield. A test commission was formed, with representatives from OKB-293, RNII and the airforce research lab (NII VVS). On May 2, the pilot let the plane lift off one meter under low thrust.

On May 15, at 19:02 (UTC), Bakhchivandzhi made the first real flight of BI-1, reaching an altitude of 840 meters and a maximum speed of 400 km/h. The mass of the plane had been reduced to 1300 kg (only 240 kg of nitric acid and 60 kg of kerosene loaded), and the engine was operated under a thrust of only 500 kgf. The pilot shut the rocket engine off after about one minute, when a light indicated it was overheating. Landing, the aircraft descended too rapidly because of insufficient forward speed, and the landing gear broke on touchdown. The pilot was unhurt and reported that, aside from the rough landing, the plane handled well. The flight lasted only 3 minutes and 9 seconds.

In July, Dushkin recalled Pallo to help work on the "302" rocket-plane project. Bolkovitinov asked Isaev to take over and master the technology of liquid fuel rocket engines. Isaev got permission to visit Valentin Glushko, the leading Soviet expert on rocket engines, who was then working in a special lab for political prisoners. Glushko taught Isaev the complex techniques of chamber-wall heat transfer calculation and engine design, developed by himself and Fridrikh Tsander in the early 1930s. Isaev's propellant feed system was simple, but it produced an uneven fuel pressure that diminished as compressed air was used up. Bolkovitinov and his engineers wrestled with this problem, designing pressure regulators and even a piston fuel pump driven by compressed air, but none of these improvements were realized.

Too damaged by acid to fly safely, BI-1 was retired and the second prototype BI-2 was made ready. Bakhchivandzhi made the second flight on Jan 10, 1943, reaching 1100 meters but with the engine still throttled back for a maximum speed of 400 km/h. The first flight had been with landing gear kept down, and some vibration has been observed. This time, the flight was made with landing gear stowed, and no vibration was observed at the cautious speed.

The third flight was made on Jan 12 (some sources say Feb 10) by a temporary test pilot, Konstantin Gruzdev, while Bakhchivandzhi was consulting on Kostikov's "302" project. This time the engine was opened up to full thrust of 1100 kgf and a speed of 675 km/h was achieved and a maximum altitude of 2190 meters. During the winter, the landing gear was switched from wheels to skis. On Gruzdev's flight, one ski broke off during take-off, but he was able to land safely. Bakhchivandzhi returned to make flights in the

third test plane BI-3 on March 11, 14 and 21. He reached a maximum altitude of 4000 meters with a maximum rate of climb of 83 meters per second.

The March 21 flight was with a full load of ammunition. Most of the BI models did not contain an actual pair of anti-aircraft cannons, and some reports claim that BI-4 was used for the live ammunition tests. The guns were never fired in any flight. The BI-4 model was reportedly used as the template for the mass production of 30 to 50 BI-VS model aircraft by Andrey Moskalev's factory. Moskalev augmented the twin ShVAK guns with a load of ten thermite bombs.

On March 27, during a low-altitude test flight, Backchivandzhi pushed the aircraft's speed. After 78 seconds, the plane went into a 45-degree dive and crashed into the ground, killing the beloved pilot. The accident put a halt to flight tests, and a lengthy investigation began. Eventually, after wind tunnel testing, it was determined that the BI-1 lost control due to the effects of transonic velocity. Estimates of Backchivandzhi's final velocity range from 800 to 990 km/h, but the recording instruments were too damaged by the crash for a reliable measurement. March 27 is considered a black day in Soviet aviation history, also being the date that Yuri Gagarin died in a jet plane crash. In 1973, Backchivadzhi was posthumously awarded Hero of the Soviet Union.

Return To Moscow, Isaev's Engine

In May 1943, OKB-293 returned from its evacuation and set up operation in Khimki, a suburb of Moscow. On May 18, Bolkhovitinov wrote a detailed report "On Rocket Aircraft and Further Prospects". He emphasized the need to study the dangerous regime of "shock stall", and to safely transition through transonic speed and beyond. He proposed the goal of a new rocket plane capable of 2000 km/h.

The next year, Bolkhovitinov had five more aircraft produced, BI-5 through BI-9. In the Spring of 1944, BI-6 was fitted with a pair of Igor A. Merkulov's DM-4 ramjet engines. It did not contain a rocket engine, so it was towed into the air. The pilot, Boris Kudrin, flew the BI-6 three times, but was never able to get both ramjets to start at the same time. The plane was taken to TsAGI for further tests in the T-101 wind tunnel. The DM-4 auxiliary motor was also tested on the YaK-7b fighter.

With the loss of the D-1-A-1100 engine, Isaev began designing a new engine. The RD-1 was completed and tested in October 1944. The general form of the engine was the same as Dushkin's, but with numerous improvements. Isaev fashioned the sections from 12Kh13 stainless chromium steel (13% chromium, 0.12% carbon content). The head had 85 swirling injectors arranged in a honeycomb pattern that promoted improved fuel-oxidizer mixture. It also used a more reliable electric arc starter instead of a glow plug. Isaev also improved the regenerative cooling, increasing the flow rate around the nozzle.

BI-7 was flown twice with the RD-1 engine, on January 24 and March 9 1945. Pallo reports there was an emergency with the landing gear during the January flight. In addition to the new engine, various changes were made to the plane's design: a larger

rudder, smaller false keel, and different wing fillets. During the test flights, the pilot Boris Kudrin, noticed some tailfin flutter. On May 29, the pilot M.K. Baykalov tested the BI-7 in glider mode, without starting the engine, and the flutter was not detected. At this point, the plane was too corroded by nitric acid to fly again, and it was retired. To further investigate the flutter problem, BI-5 was modified in the same fashion as BI-7 (but with no engine) and tested in glider flights; however, the problem was not reproduced.

After BI-6 was sent to TsAGI, BI-9 was put into service as a replacement (marked with a "6" on its tail). Flown by Boris Kudrin and M.A. Baikalov, it was used in glider tests with extra payload weight. The fate of BI-8 is unknown.

Powered Flights

The BI was flown 12 times under power, seven times with Dushkin's D-1-A-1100 engine, three times with the DM-4 ramjets, and twice with Isaev's RD-1 rocket engine.

Date	Model	Pilot	Thrust, kgf	Burn Time, s	Altitude, m	Speed, km/h	Climb, m/s
May 02 1942	BI-1	Bakhchivandzhi	500	13	1	-	-
May 15 1942	BI-1	Backchivandzhi	600	66	840	400	23
Jan 10 1943	BI-2	Backchivandzhi	800	63	1,100	400	-
Jan 12 1943	BI-2	Gruzdev	1100	58	2,190	675	-
Mar 11 1943	BI-3	Backchivandzhi	1,100	80	4,000	600	82
Mar 14 1943	BI-3	Backchivandzhi	1,100	84	3,000	~650	-
Mar 21 1943	BI-3	Backchivandzhi	1,100	30	3,000	550	160
Mar 27 1943	BI-3	Backchivandzhi	1,100	89	2,000	>800	-
Spring 1944	BI-6	Kudrin	-	-	-	-	-
Spring 1944	BI-6	Kudrin	-	-	-	-	-
Spring 1944	BI-6	Kudrin	-	-	-	-	-

Jan 24 1945	BI-7	Kudrin	1,100	72.3	1,250	587	87
Mar 09 1945	BI-7	Baykalov	1,100	73	3,500	550	-

Operators

 Soviet Union

- Soviet Air Force

Specifications

General characteristics

- **Crew:** 1
- **Length:** 6.40 m (21 ft 0 in)
- **Wingspan:** 6.48 m (21 ft 3 in)
- **Height:** 2.06 m (6 ft 9 in)
- **Wing area:** 7 m² (75 sq ft)
- **Empty weight:** 958 kg (2,112 lb)
- **Max takeoff weight:** 1,683 kg (3,710 lb)
- **Powerplant:** 1 × Dushkin D-1A-1100 liquid-fuel rocket motor 1100kg

Performance

- **Maximum speed:** 990 km/h (620 mph; 530 kn) estimated
- **Endurance:** 15 minutes under power

Armament

- **Guns:** two nose-mounted 20 mm Sh VAK cannon

Chapter- 3

Boeing X-37

X-37



X-37B being prepared for launch

Role	Spaceplane
National origin	United States
Manufacturer	Boeing
First flight	7 April 2006 (drop test);

	22 April – 3 December 2010 (first spaceflight)
Status	Development and testing, one spaceflight completed
Primary users	NASA/DARPA (X-37A) USAF (X-37B)
Number built	2
Developed from	Boeing X-40

The **Boeing X-37** (also known as the **Orbital Test Vehicle**) is an American unmanned vertical-takeoff, horizontal-landing (VTHL) spaceplane. The X-37 is operated by the United States Air Force for orbital spaceflight missions intended to demonstrate reusable space technologies. It is a reusable robotic spaceplane that is a 120% scaled derivative of the X-40A.

The X-37 began as a NASA project in 1999, then was transferred to the U.S. Department of Defense in 2004. It had its first flight as a drop test on 7 April 2006, at Edwards Air Force Base. The spaceplane's first orbital mission, USA-212 was launched on 22 April 2010 using an Atlas V rocket. Its return to Earth on 3 December 2010 was the first test of the vehicle's heat shield and hypersonic aerodynamic handling. A second X-37B was launched on 5 March 2011 with the mission designation USA-226.

Development

In 1999 NASA selected Boeing Integrated Defense Systems to design and develop the vehicle, built by the California branch of Boeing's Phantom Works. Over a four-year period NASA contributed \$109 million, the US Air Force \$16 million, and Boeing \$67 million to the project. In late 2002 a new \$301 million contract was awarded to Boeing in the framework of NASA's Space Launch Initiative.

The X-37 was transferred from NASA to the Defense Advanced Research Projects Agency (DARPA) on 13 September 2004. The program has become a classified project, although it is not known whether DARPA will maintain this status for the project. NASA's spaceflight program may be centered around the Crew Exploration Vehicle, while DARPA will promote the X-37 as part of the independent space policy that the US Department of Defense has pursued since the *Challenger* disaster.

The X-37 was originally designed to be carried into orbit in the Space Shuttle cargo bay, but underwent redesign for launch on a Delta IV or comparable rocket after it was determined that a shuttle flight would be uneconomical. The X-37's aerodynamic design was derived from the Space Shuttle, hence the X-37 has a similar lift-to-drag ratio, and a lower cross range at high altitudes and Mach numbers than DARPA's Hypersonic Technology Vehicle.

As part of its Space Support mission goals, X-37 was designed to rendezvous with friendly satellites to refuel them, or to replace failed solar arrays using a robotic arm. Its payload could also support Space Control (Defensive Counter-Space, Offensive Counter-Space), Force Enhancement and Force Application. An early requirement for the spacecraft called for a delta-v of 7,000 mph (3.1 km/s) to change its orbit.

Glide tests

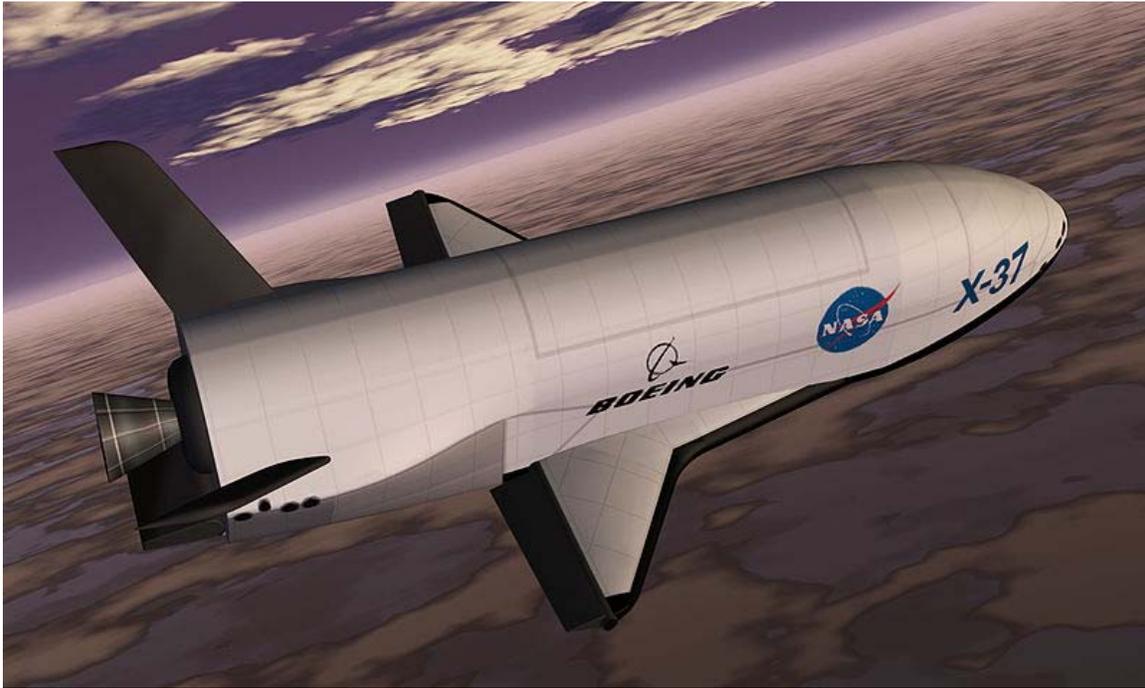
The vehicle that was used as an atmospheric drop test glider had no propulsion system. Instead of an operational vehicle's payload bay doors it had an enclosed and reinforced upper fuselage structure to allow it to be mated with a mothership. In September 2004 DARPA announced that for its initial atmospheric drop tests the X-37 would be launched from the Scaled Composites White Knight, a high-altitude research aircraft.

On 21 June 2005 the X-37 completed a captive-carry flight underneath the White Knight from Mojave Spaceport, Mojave, California. Through the second half of 2005, the X-37 underwent structural upgrades including reinforcement of the nose wheel supports. Further captive-carry flight tests and the first drop test were expected mid-February 2006. The X-37's public debut was scheduled for its first free flight on 10 March 2006, but was canceled due to an Arctic storm. The next attempt at flight on 15 March 2006 was canceled due to high winds.

On 24 March 2006, the X-37 flew, but a data link failure prevented the free flight and the vehicle returned to the ground still attached to its White Knight carrier. On 7 April 2006, the X-37 made its first free glide flight. During landing, the vehicle overran the runway and it sustained minor damage.

Following an extended downtime while the vehicle was repaired, the program moved from Mojave to Air Force Plant 42 (KPMD) in Palmdale, California for the remainder of the flight test program. White Knight continued to be based at Mojave, but would ferry over to Plant 42 when flights were scheduled. Five additional flights were performed, two of which resulted in X-37 releases with successful landings. These free flights occurred on 18 August 2006 and 26 September 2006.

X-37B Orbital Test Vehicle



X-37 spacecraft, artist's rendering from 1999

On 17 November 2006 the U.S. Air Force announced it would develop the X-37B from the NASA X-37A. The Air Force version is designated X-37B Orbital Test Vehicle (OTV). The OTV program builds on industry and government investments by DARPA, NASA and the Air Force. The X-37B effort will be led by the Air Force Rapid Capabilities Office, and includes partnerships with NASA and the Air Force Research Laboratory. Boeing is the prime contractor for the OTV program. The X-37B can remain in orbit for up to 270 days at a time.

The Secretary of the Air Force states the OTV program will focus on "risk reduction, experimentation, and operational concept development for reusable space vehicle technologies, in support of long-term developmental space objectives."

The X-37B was originally scheduled for launch in the payload bay of the Space Shuttle, but following the *Columbia* accident, it was transferred to a Delta II 7920. It was subsequently transferred to a shrouded configuration on the Atlas V following concerns over the unshrouded spacecraft's aerodynamic properties during launch. Following their missions, X-37B spacecraft are to land on a runway at Vandenberg Air Force Base, California, with Edwards Air Force Base as an alternate site.

Manufacturing on the second X-37B, OTV-2 was underway in 2010; it was completed and was first launched in March 2011.

Design

The X-37 Orbital Test Vehicle is a reusable robotic spaceplane. It is a derivative of X-40 and 120% larger. The OTV has a length of over 29 feet (8.8 m) and features two angled tail fins.

The X-37 is expected to operate in a velocity range of up to Mach 25 on reentry. Among the technologies to be demonstrated with the X-37 are improved thermal protection systems, avionics, the autonomous guidance system and an advanced airframe. The vehicle is powered by a Rocketdyne AR2-3 engine. The AR2-3 was the human-rated rocket powerplant for the dual-power NF-104A astronaut training vehicle and was given a new flight certification for use on the X-37 with hydrogen peroxide/JP-8 propellants. The X-37B now uses a hydrazine monopropellant rocket.

The X-37 has a payload bay available for experiments and other space payloads. It features thermal protection systems that are improved from previous generations of spacecraft. The thermal protection system uses improved silica ceramic tiles.

Operational history



OTV-1 sits on the runway at Vandenberg AFB after landing

The first orbital flight of OTV-1, the first X-37B, with a mission name of USA-212, was launched on an Atlas V rocket at Cape Canaveral Air Force Station, Florida on 22 April 2010, at 23:58 GMT. The spacecraft was placed into low Earth orbit for testing.

While the U.S. Air Force revealed few orbital details after the first X-37B was successfully placed in orbit due to the secretive nature of the mission, amateur astronomers claimed to have identified the experimental spacecraft in orbit and shared their findings. A worldwide network of amateur astronomers reported that as of 22 May it was in an inclination of 39.99 degrees, circling the Earth once every 90 minutes in an orbit 401 by 422 kilometers (249 by 262 mi).



Personnel inspect OTV-1, the first X-37B, after its return

The U.S. Air Force announced on 30 November 2010 that the X-37 would return for a landing during the 3–6 December timeframe. As scheduled, OTV-1 de-orbited, reentered Earth's atmosphere, and landed at Vandenberg AFB on 3 December 2010, at 1:16 PST (09:16 UTC). The X-37B had a tire blowout during landing and sustained minor damage to its underside.

A second X-37B mission, designated USA-226, was launched aboard an Atlas V rocket, on 5 March 2011. The mission was classified and described by the US military as to test out new space technologies.

Controversy

In April 2010, the *China Daily* newspaper wrote that the X-37B program raised concerns about an arms race in space. The Xinhua News Agency took a more moderate tone in questioning if the secretive program might lead to weapons in space. Tom Burghardt wrote for Spacedaily.com that the X-37B could be used as a spy satellite or to deliver weapons from space. The Pentagon has denied claims that the X-37B's mission supports the development of space-based weapons.

A group of amateur sky watchers, named Visual Satellite Observers reported the X-37B's track took it over North Korea, Afghanistan and other trouble spots; they said the spacecraft's mission is to support space-based surveillance and reconnaissance technology. According to the sky watchers, the spacecraft passes over the same given spot on Earth every four days, and operates at an altitude of 255 miles (410 km), which would be typical for a military surveillance satellite.

Specifications

X-37B

General characteristics

- **Crew:** None
- **Length:** 29 ft 3 in (8.9 m)
- **Wingspan:** 14 ft 11 in (4.5 m)
- **Height:** 9 ft 6 in (2.9 m)
- **Loaded weight:** 11,000 lb (4,990 kg)
- **Power:** Gallium arsenide solar cells with lithium-ion batteries
- **Payload Bay:** 7 × 4 ft (2.1 × 1.2 m)

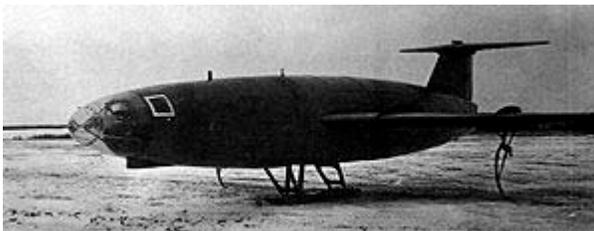
Performance

- **Orbital speed:** 17,500 mph (28,200 km/h)
- **Orbit:** Low Earth orbit
- **Orbital time:** Up to 270 days

Chapter- 4

DFS 346

DFS 346

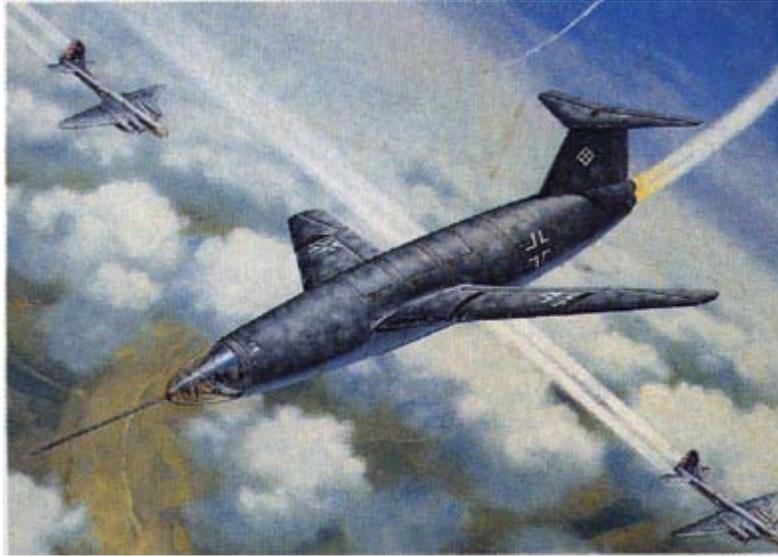


Aircraft 346-P

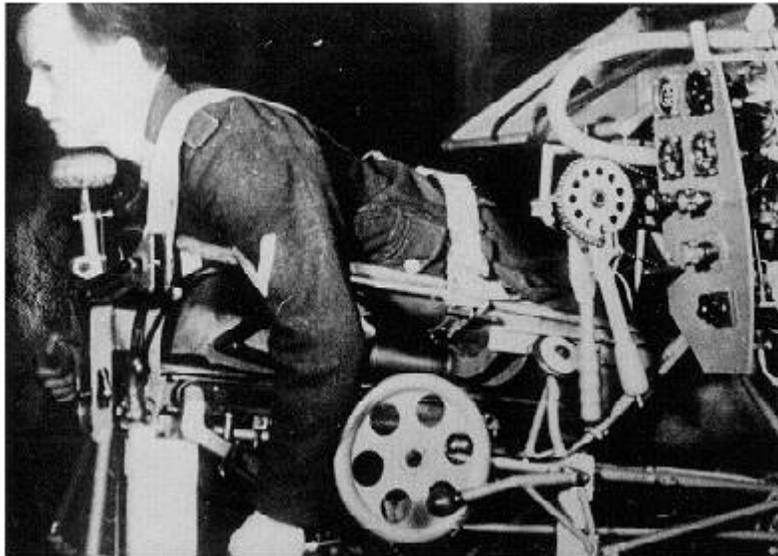
Role	Research aircraft
Manufacturer	Siebel OKB-2
Designed by	Felix Kracht
First flight	346-P in 1948 as glider 346-3 in 13.08 1951 with engine
Retired	14 September 1951
Status	Project cancelled
Primary user	Soviet Air Force
Number built	4
Variants	Bisnovat 5

The **DFS 346** (*Samolyot 346*) was a German rocket-powered, high-speed research aircraft of World War II. It was designed by Felix Kracht at the *Deutsche Forschungsanstalt für Segelflug* (DFS), the "German Institute for Sailplane Flight". The prototype was still unfinished by the end of the war and was taken to the Soviet Union where it was rebuilt, tested and flown.

Concept



Concept art



Test pilot Rolf Mödel tries out the prone position

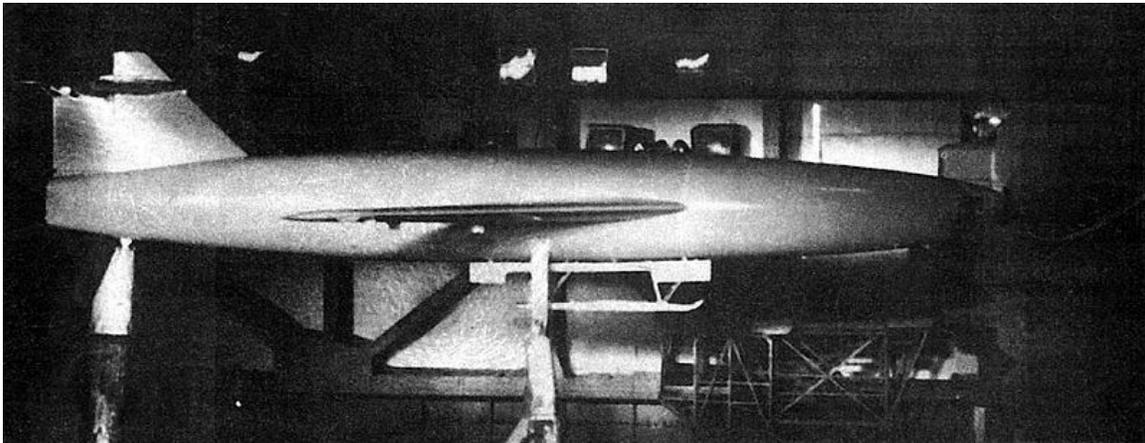
The DFS 346 was a parallel project to the DFS 228 high-altitude reconnaissance aircraft. While the DFS 228 was essentially of conventional sailplane design, the DFS 346 had highly-swept wings and a highly streamlined fuselage that its designers hoped would enable it to break the sound barrier. Like its stablemate, it also featured a self-contained escape module for the pilot, a feature originally designed for the DFS 54 prior to the war. The pilot was to fly the machine from a prone position, a feature decided from experience with the first DFS 228 prototype, mainly because of better g-force handling and aim of reducing the fuselage cross-section as much as possible.

The 346 design was intended to be air-launched from the back of a large aircraft, the baseline being the Dornier Do 217. After launch from the bomber the plane's Walter 509B/C (*ZhRD-109-510*) engine, which consisted of two superimposed combustion chambers, one above the other, with the lower unit of 400 kg (880 lb) thrust for cruising and the upper unit used only for takeoff, in a so-called "sharp start" directly from the ground, or for short periods when the maximum thrust was necessary, would accelerate the craft to proposed speed of Mach 2.6 and altitude of 30,500 meters, at which point the engine would turn off. In an operational use the plane would then glide over England for a photo-reconnaissance run, descending as it flew but still at a high speed. After the run was complete the engine would be briefly turned on again, to raise the altitude for a long low-speed glide back to a base in Germany or northern France.

Design

The DFS-346 was a midwing design of all-metal construction. The front fuselage of the 346 was a rotation body based on the NACA-Profile 0,0121-0,66-50. The middle part was cylindrical and narrowed to the square in the back. Probably for capacity and weight reasons the DFS-346 was equipped with landing skids, both in the original German design and in the later Soviet prototypes; this caused trouble several times. The wings had a 45° swept NACA 0,012-0,55-1,25 profile of 12% thickness. The continuously varying profile shape caused a stall in certain flight conditions, which caused complete loss of control. This was later corrected by use of fences on the top of the wings.

Development

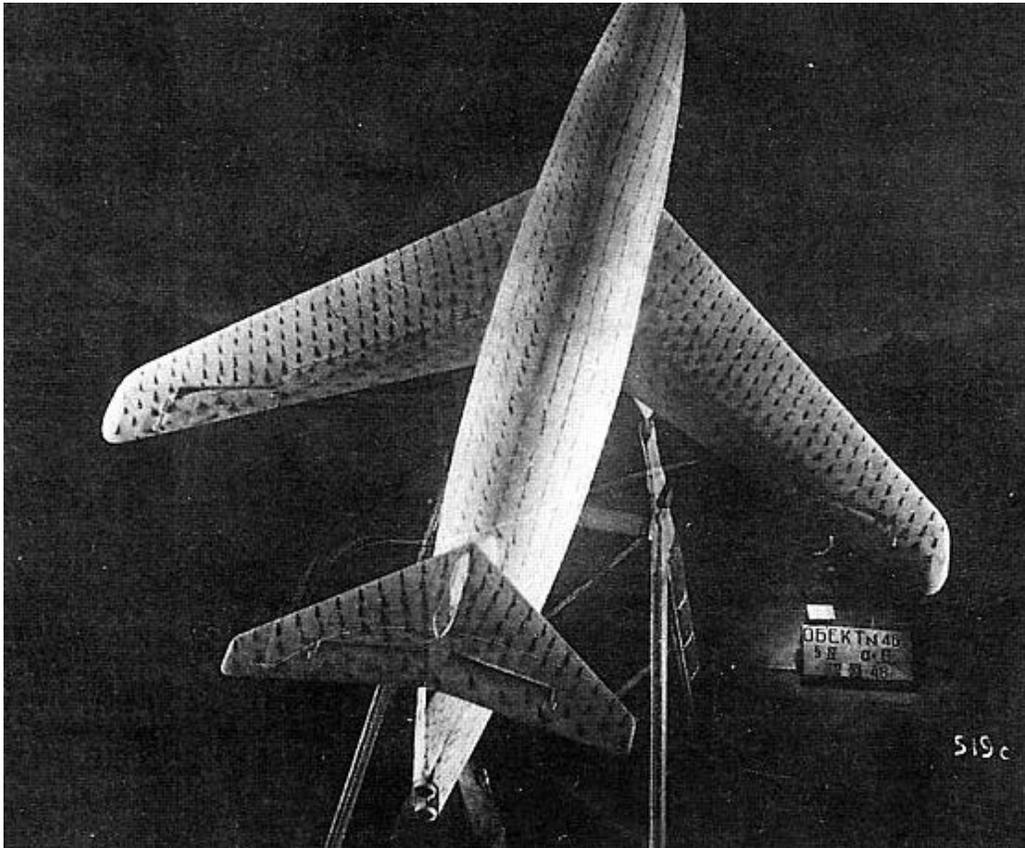


First model in Siebel windtunnel

World War II

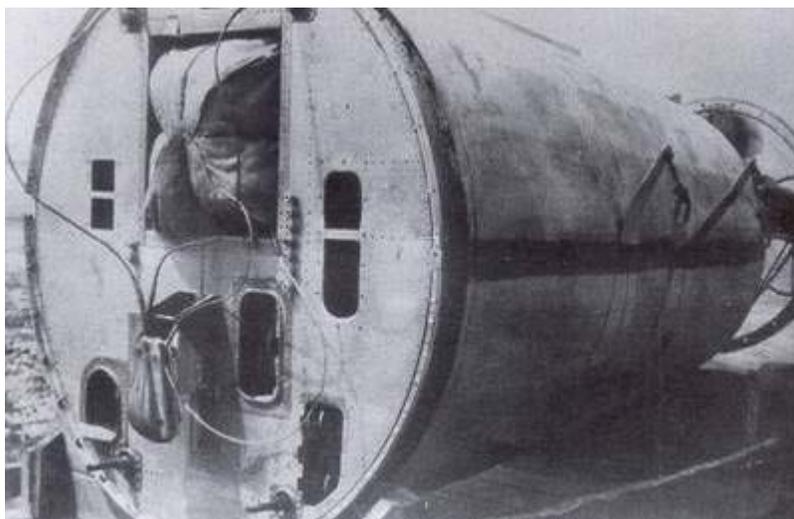
Felix Kracht and his team at DFS began selecting a suitable airframe design in the late World War II period. Since the aircraft was to be of all-metal construction, the DFS lacked the facilities to build it and construction of the prototype was assigned to Siebel Werke located in Halle, where the first windtunnel models and partially built prototype were captured by the advancing Red Army.

Post-War



Plane model in TsAGI wind tunnel

On 22 October 1946, the Soviet OKB-2 (Design Bureau 2), under the direction of Hans Rössing and Alexandr Berezhnyak, was tasked with continuing its development.



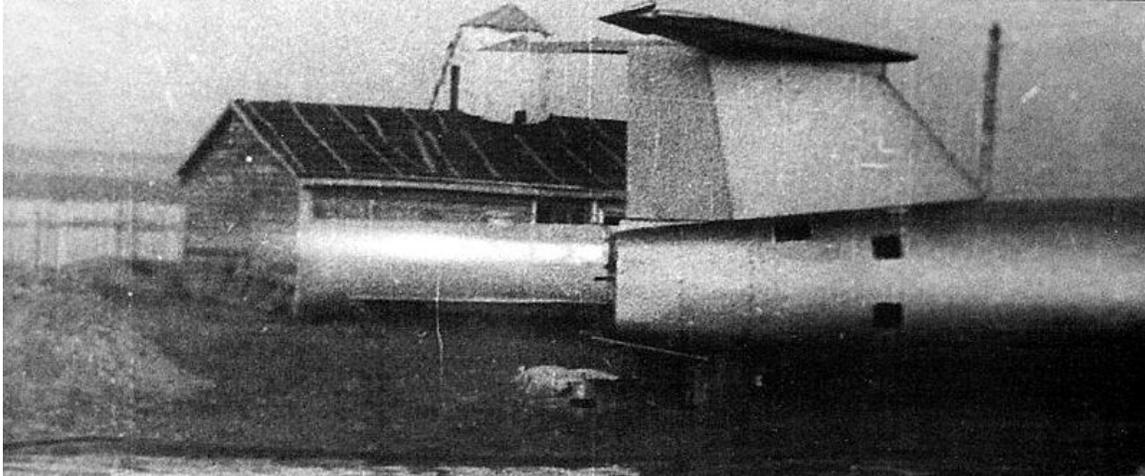
Escape capsule prepared for droptests

The captured DFS 346, now simply called "**Samolyot 346**" ("Samolyot" - *Aircraft*) to distance it from its German origins, was completed and tested in TsAGI wind tunnel T-101. Tests revealed some aerodynamic deficiencies which would result in unrecoverable stalls at certain angles of attack. This phenomenon involved a loss of longitudinal stability of the airframe. After the wind tunnel tests, two wing fences were installed on a more advanced, longer version of the DFS-346, to correct the airstream separation. This solution was used on the majority of the Soviet planes with sweptback wings of the 1950s and 1960s. In the meantime, the escape capsule system was tested from a B-25J and proved promising. Despite results from studies showing that the plane would not have been able to pass even Mach 1, it was ordered to proceed with construction and further testing.

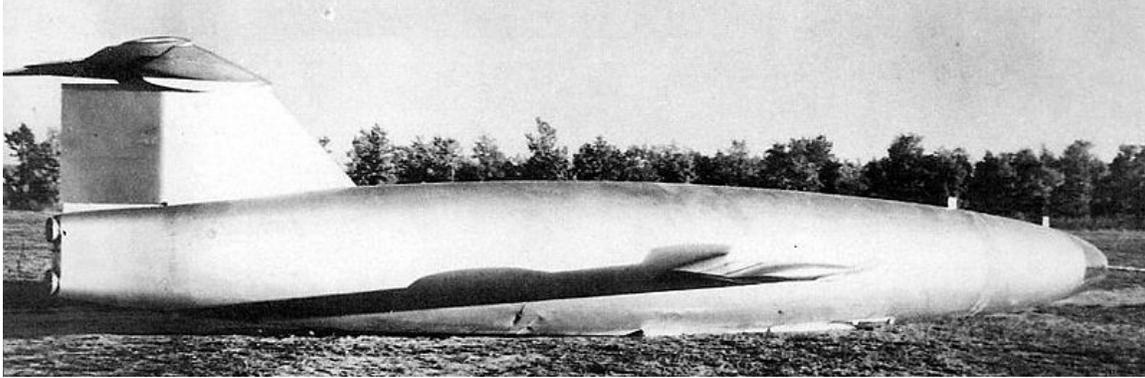
Operational use

In 1947, an entirely new 346 prototype was constructed, incorporating refinements suggested by the tests. This was designated **346-P** ("P" for *planer* - "glider"). No provision was made for a powerplant, but ballast was added to simulate the weight of an engine and fuel. This was carried to altitude by a B-29 Superfortress captured in Vladivostok and successfully flown by Wolfgang Zeise in a series of tests. This led to the construction of three more prototypes, intended to lead to powered flight of the type.

First accidents



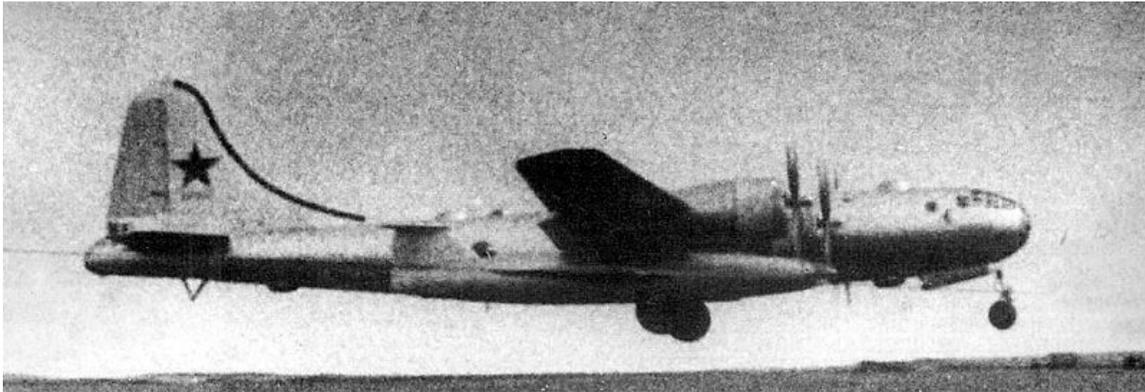
Engine test on ground



Minor landing difficulties resulted with landing on the snow without landing gear

Newly built **346-1** incorporated minor aerodynamic refinements over the 346-P, and was first flown by Zeise on September 30, 1948, with dummy engines installed. The glider was released at an altitude of 9700 m, and the pilot realised that he hardly could maintain control of the aircraft. Consequently, while attempting to land, he descended too fast (his speed was later estimated at 310 km/h). After first touching the ground he bounced up to a height of 3–4 m and flew 700–800 m. At the second descent, the landing ski collapsed and the fuselage hit the ground hard. The pilot seat structure and safety-belt proved to be very unreliable, because at the end of a rough braking course Zeise was thrown forward and struck the canopy with his head, losing consciousness. Luckily, he wasn't seriously injured, and after treatment in hospital he was able to return to flying. Accident investigation research team came to the conclusion that the crash was a result of pilot error, who failed to fully release the landing skid. This accident showed that the aircraft handling was still very unpredictable, as a result, all rocket-powered flights were postponed until pilots were able to effectively control the aircraft in unpowered descent, requiring further glide flights. The damaged 346-1 was later repaired and modified to **346-2** version. It was successfully flown by test pilot P.Kazmin in 1950-1951 winter, but nonetheless these flights also ended "on fuselage". Furthermore, after the last flight of these series, the airframe again required major repairs. On 10 May in 1951, Zeise returned to the program, flying final unpowered test flights with the 346-2, and from 6 June, unpowered tests of the 346-3 without accidents.

Final flights



346-3 taking-off under a wing of B-29

By the mid-1951 **346-3** was completed, and Zeise flew it under power for the first time on 13 August 1951, using only one of the plane engines. Continuing concerns about the aircraft controlling at high speeds had led to a limitation of Mach 0.9 being placed on test flights. Zeise flew it again on 2 September and 14 September. On these last flight, however, things went drastically wrong. Separating from the carrier plane at 9,300 meters (30,500 ft) above Lukovici airfield, pilot fired his engine and accelerated to a speed of 900 km/h (560 mph). The rocket engine worked as expected, and 346-3, quickly accelerating, started ascending and soon had flown in very close proximity to its carrier aircraft. Zeise then reported that the plane was not responding to the controls, and was losing altitude. Ground control commanded him to bail out. He used the escape capsule to leave the stricken aircraft at 6,500 meters (21,000 ft) and landed safely by parachute. With the loss of this aircraft, the 346 program was abandoned.

Variants

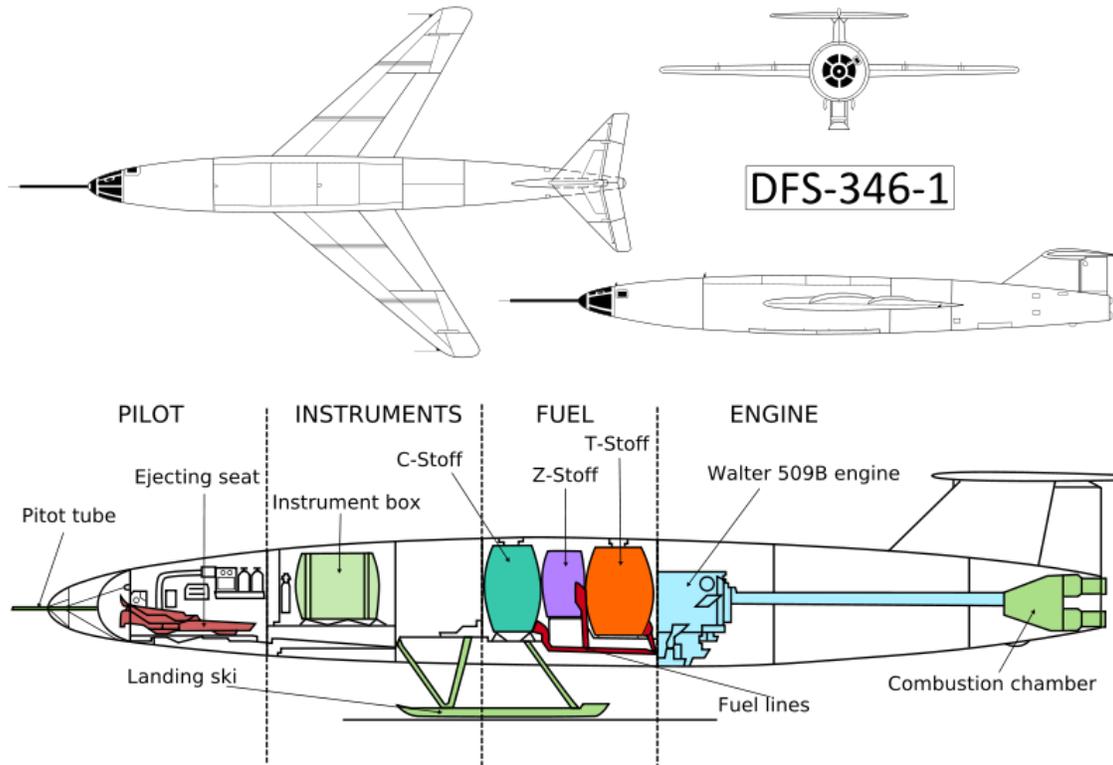
- **DFS-346** - First prototype built by Siebel Werke in the early 1940s. Later taken to USSR where the newly formed OKB-2 tested it in TsAGI wind tunnel. Later scrapped, because it was not flyable.
- **346-P** - This airframe was first post-war build of this plane, and was completed in 1948 by German engineers. Visually 346-P was identical to the earlier design, excepting a landing gear cowl which was removed primarily for lightening the airframe. This prototype also featured mounted under wing supports, to help stop the plane when landed.
- **346-1(A)** - On the 5 May 1949 construction of 346-1 was finished. It had a rocket engine mock up installed, and incorporated some minor changes in the rudder and tail design.
- **346-2(D)** - The same as 346-1, but the rocket engines fitted.
- **346-3** - Only plane that flew rocket-engine powered, and twice went transonic.

Operators

■ Soviet Union

- Soviet Air Force

Specifications (346-3)



346-3 Cross-section

General characteristics

- **Crew:** one, pilot
- **Length:** 44 ft 1 in (13.45 m)
- **Wingspan:** 29 ft 6 in (9 m)
- **Height:** 11 ft 7 in (3.54 m)
- **Wing area:** 213 ft² (19.9 m²)
- **Airfoil:** DFS 346#Design
- **Empty weight:** 4,806 lb (2,100 kg)
- **Loaded weight:** 11,506 lb (5,230 kg)
- **Powerplant:** 1× Walter HWK 109-509 rocket, 33.4 kN (7,500 lbf) 33.4 kN

Performance

- **Never exceed speed:** 2,765 km/h (estimated) (1,723 mph)

- **Maximum speed:** 900 km/h (verified) (560 mph)
- **Service ceiling:** 35,000 m (estimated) (114,800 ft)
- **Rate of climb:** 6,000 m/min (estimated) (19,680 ft/min)

Chapter- 5

Douglas Skyrocket

Douglas Skyrocket



Douglas Skyrocket D-558-2

Role	Experimental high-speed research aircraft
Manufacturer	Douglas Aircraft Company
First flight	4 February 1948
Primary user	U.S. Navy
Number built	3
Developed from	D-558-1

The **Douglas Skyrocket (D-558-2 or D-558-II)** was a rocket and jet-powered supersonic research aircraft built by the Douglas Aircraft Company for the United States Navy. On 20 November 1953, shortly before the 50th anniversary of powered flight, Scott Crossfield piloted the Douglas D-558-2 Skyrocket to Mach 2, or more than 1,290 mph (2076 km/h), the first time an aircraft had exceeded twice the speed of sound.

Design and development

The "-2" in the aircraft's designation referred to the fact that the Skyrocket was the phase-two version of what had originally been conceived as a three-phase program. The phase-one aircraft, the D-558-1, was jet powered and had straight wings. The third phase, which never came to fruition, would have involved constructing a mock-up of a combat type aircraft embodying the results from the testing of the phase one and two aircraft. The eventual D-558-3 design, which was never built, was for a hypersonic aircraft similar to the North American X-15.

When it became obvious that the D558-1 fuselage could not be modified to accommodate both rocket and jet power, the D558-2 was conceived as an entirely different aircraft. A contract change order was issued on 27 January 1947 to formally drop the final three D558-1 aircraft and substitute three new D558-2 aircraft instead.

The Skyrocket featured wings with a 35-degree sweep and horizontal stabilizers with 40-degree sweep. The wings and empennage were fabricated from aluminum and the large fuselage was of primarily magnesium construction. The Skyrocket was powered by a Westinghouse J34-40 turbojet engine fed through side intakes in the forward fuselage. This engine was intended for takeoff, climb and landing. For high speed flight, a four-chamber Reaction Motors LR8-RM-6 engine (the Navy designation for the Air Force's XLR-11 used in the Bell X-1), was fitted. This engine was rated at 6,000 lbf (27 kN) static thrust at sea level. A total of 250 gallons (946 liters) of aviation fuel, 195 gallons of alcohol, and 180 gallons of liquid oxygen were carried in fuselage tanks.

The Skyrocket was configured with a flush cockpit canopy, but visibility from the cockpit was poor, so it was re-configured with a raised cockpit with conventional angled windows. This resulted in a greater profile area at the front of the aircraft, which was balanced by an additional 14 inches (36 cm) of height added to the vertical stabilizer. Like its predecessor, the D558-1, the D558-2 was designed so that the forward fuselage, including cockpit, could be separated from the rest of the aircraft in an emergency. Once the forward fuselage had decelerated sufficiently, the pilot would then be able to escape from the cockpit by parachute.

Operational history

Douglas pilot John F. Martin made the first flight at Muroc Army Airfield (later renamed Edwards Air Force Base) in California on 4 February 1948 in an aircraft equipped only with the jet engine. The goals of the program were to investigate the characteristics of swept-wing aircraft at transonic and supersonic speeds with particular attention to pitch-up (un-commanded rotation of the nose of the aircraft upwards), a problem prevalent in high-speed service aircraft of that era, particularly at low speeds during takeoff and landing, and in tight turns.

The three aircraft gathered a great deal of data about pitch-up and the coupling of lateral (yaw) and longitudinal (pitch) motions; wing and tail loads, lift, drag and buffeting

characteristics of swept-wing aircraft at transonic and supersonic speeds; and the effects of the rocket exhaust plume on lateral dynamic stability throughout the speed range. (Plume effects were a new experience for aircraft.) The number three aircraft also gathered information about the effects of external stores (bomb shapes, drop tanks) upon the aircraft's behavior in the transonic region (roughly 0.7 to 1.3 times the speed of sound). In correlation with data from other early transonic research aircraft such as the XF-92A, this information contributed to solutions to the pitch-up problem in swept-wing aircraft.

Its flight research was done at the NACA's Muroc Flight Test Unit in California, redesignated in 1949 the High-Speed Flight Research Station (HSFRS). The HSFRS became the High-Speed Flight Station in 1954 and is now known as the NASA Dryden Flight Research Center.



The Douglas Skyrocket was dropped from a Navy B-29

The three aircraft flew a total of 313 times – 23 by the number one aircraft (Bureau No. 37973—NACA 143), 103 by the second Skyrocket (Bureau No. 37974 – NACA 144), and 87 by aircraft number three (Bureau No. 37975 – NACA 145). Skyrocket 143 flew

all but one of its missions as part of the Douglas contractor program to test the aircraft's performance.

NACA aircraft 143 was initially powered by the jet engine only, but was later fitted with the rocket engine. In this configuration, it was tested by Douglas from 1949 to 1951. After Douglas' test program, it was delivered to NACA, who stored it until 1954. In 1954-55 the contractor modified it to an all-rocket air-launch capability with the jet engine removed. In this configuration, NACA research pilot John McKay flew the aircraft only once for familiarization on 17 September 1956. The 123 flights of NACA 143 served to validate wind-tunnel predictions of the aircraft's performance, except for the fact that the aircraft experienced less drag above Mach 0.85 than the wind tunnels had indicated.

NACA 144 also began its flight program with a turbojet powerplant. NACA pilots Robert A. Champine and John H. Griffith flew 21 times in this configuration to test airspeed calibrations and to research longitudinal and lateral stability and control. In the process, during August 1949 they encountered pitch-up problems, which NACA engineers recognized as serious because they could produce a limiting and dangerous restriction on flight performance. Hence, they determined to make a complete investigation of the problem.

In 1950, Douglas replaced the turbojet with an LR-8 rocket engine, and its pilot, Bill Bridgeman, flew the aircraft seven times up to a speed of Mach 1.88 (1.88 times the speed of sound) and an altitude of 79,494 ft (24,230 m), the latter an unofficial world's altitude record at the time, achieved on 15 August 1951. In the rocket configuration, a Navy P2B (Navy version of the B-29) launched the aircraft at approximately 30,000 feet (9,000 m) after taking off from the ground with the Skyrocket attached beneath its bomb bay. During Bridgeman's supersonic flights, he encountered a violent rolling motion known as lateral instability that was less pronounced on the Mach 1.88 flight on 7 August 1951, than on a Mach 1.85 flight in June when he pushed over to a low angle of attack (angle of the fuselage or wing to the prevailing wind direction).

The NACA engineers studied the behavior of the aircraft before beginning their own flight research in the aircraft in September 1951. Over the next couple of years, NACA pilot Scott Crossfield flew the aircraft 20 times to gather data on longitudinal and lateral stability and control, wing and tail loads, and lift, drag, and buffeting characteristics at speeds up to Mach 1.878.

At that point, Marine Lt. Col. Marion Carl flew the aircraft to a new (unofficial) altitude record of 83,235 feet (25,370 m) on 21 August 1953, and to a maximum speed of Mach 1.728.

Following Carl's completion of these flights for the Navy, NACA technicians at the High-Speed Flight Research Station (HSFRS) near Mojave, California, outfitted the LR-8 engine's combustion chambers with nozzle extensions to prevent the exhaust gas from

affecting the rudders at supersonic speeds. This addition also increased the engine's thrust by 6.5 percent at Mach 1.7 and 70,000 feet (21,300 m).

Even before Marion Carl had flown the Skyrocket, HSFRS Chief Walter C. Williams had petitioned NACA headquarters unsuccessfully to fly the aircraft to Mach 2 to garner the research data at that speed. Finally, after Crossfield had secured the agreement of the Navy's Bureau of Aeronautics, NACA director Hugh L. Dryden relaxed the organization's usual practice of leaving record setting to others and consented to attempting a flight to Mach 2.

In addition to adding the nozzle extensions, the NACA flight team at the HSFRS chilled the fuel (alcohol) so more could be poured into the tank and waxed the fuselage to reduce drag. With these preparations and employing a flight plan devised by project engineer Herman O. Ankenbruck to fly to approximately 72,000 feet (21,900 m) and push over into a slight dive, Crossfield made aviation history on 20 November 1953, when he flew to Mach 2.005, 1,291 miles per hour (2,078 km/h). He became the first pilot to reach Mach 2 in this, the only flight in which the Skyrocket flew that fast.

Following this flight, Crossfield and NACA pilots Joseph A. Walker and John B. McKay flew the aircraft for such purposes as to gather data on pressure distribution, structural loads, and structural heating, with the last flight in the program occurring on 20 December 1956, when McKay obtained dynamic stability data and sound-pressure levels at transonic speeds and above.

Meanwhile, NACA 145 had completed 21 contractor flights by Douglas pilots Eugene F. May and William Bridgeman in November 1950. In this jet-and-rocket-propelled craft, Scott Crossfield and Walter Jones began the NACA's investigation of pitch-up lasting from September 1951 well into summer 1953. They flew the Skyrocket with a variety of wing-fence, wing-slat and leading edge chord extension configurations, performing various maneuvers as well as straight-and-level flying at transonic speeds. While fences significantly aided recovery from pitch-up conditions, leading edge chord extensions did not, disproving wind-tunnel tests to the contrary. Slats (long, narrow auxiliary airfoils) in the fully open position eliminated pitch-up except in the speed range around Mach 0.8 to 0.85.

In June 1954, Crossfield began an investigation of the effects of external stores (bomb shapes and fuel tanks) upon the aircraft's transonic behavior. McKay and Stanley Butchart completed the NACA's investigation of this issue, with McKay flying the final mission on 28 August 1956.

Besides setting several records, the Skyrocket pilots had gathered important data and understanding about what would and would not work to provide stable, controlled flight of a swept-wing aircraft in the transonic and supersonic flight regimes. The data they gathered also helped to enable a better correlation of wind-tunnel test results with actual flight values, enhancing the abilities of designers to produce more capable aircraft for the armed services, especially those with swept wings. Moreover, data on such matters as

stability and control from this and other early research aircraft aided in the design of the Century Series of fighter aircraft, all of which featured the movable horizontal stabilizers first employed on the X-1 and D-558 series.

Variants

All three of the Skyrockets had 35-degree swept wings.

Until configured for air launch, NACA 143 featured a Westinghouse J-34-40 turbojet engine rated at 3,000 lb force (13 kN) static thrust. It carried 260 U.S. gallons (980 l) of aviation gasoline and weighed 10,572 lb (4,795 kg) at takeoff.

NACA 144 (and NACA 143 after modification in 1955) was powered by an LR-8-RM-6 rocket engine rated at 6,000 pounds force (27 kN) static thrust. Its propellants were 345 U.S. gallons (1,306 l) of liquid oxygen and 378 US gallons (1,431 l) of diluted ethyl alcohol. In its launch configuration, it weighed 15,787 lb (7,161 kg).

NACA 145 had both an LR-8-RM-5 rocket engine rated at 6,000 lb force (27 kN) static thrust and featured a Westinghouse J-34-40 turbojet engine rated at 3,000 lb force (13 kN) static thrust. It carried 170 U.S. gallons (644 l) of liquid oxygen, 192 U.S. gallons (727 l) of diluted ethyl alcohol, and 260 U.S. gallons (984 l) of aviation gasoline for a launch weight of 15,266 lb (6,925 kg).

Aircraft serial numbers

- **D-558-2 Skyrocket**
 - **D-558-2 #1** - #37973 NACA-143, 123 flights
 - **D-558-2 #2** - #37974 NACA-144, 103 flights
 - **D-558-2 #3** - #37975 NACA-145, 87 flights

Survivors

D-558-2 #1 Skyrocket is on display at the Planes of Fame Museum, Chino, California. The number two Skyrocket, the first aircraft to fly Mach 2, is on display at the National Air and Space Museum in Washington D.C. The number three is displayed on a pedestal at Antelope Valley College, Lancaster, California.

Specifications (D-558-2 Skyrocket)

General characteristics

- **Crew:** one pilot
- **Length:** 42 ft 0 in (12.8 m)
- **Wingspan:** 25 ft 0 in (7.6 m)
- **Height:** 22 ft 8 in (3.8 m)
- **Wing area:** 175 ft² (16.2 m²)

- **Empty weight:** 9,421 lb (4,273 kg)
- **Max takeoff weight:** 15,266 lb (6,923 kg)
- **Powerplant:**
 - 1× Westinghouse J34-WE-40 turbojet, 3,000 lbf (13 kN)
 - 1× Reaction Motors XLR-8-RM-5 rocket engine, 6,000 lbf (27 kN)

Performance

- **Maximum speed:** 720 mph, 1,250 mph when air-launched (1,160 km/h, 2,010 km/h when air-launched)
- **Stall speed:** 160.1 mph (257.7 km/h)
- **Service ceiling:** 16,500 ft (5,030 m)
- **Rate of climb:** 22,400 ft/min, 11,100 ft/min under rocket power only (6,830 m/min., 3,380 m/min under rocket power only)
- **Wing loading:** 87.2 lb/ft² (426 kg/m²)
- **Thrust/weight (jet):** 0.39

Chapter- 6

Saunders-Roe SR.53 and Heinkel He 176

Saunders-Roe SR.53

Saunders Roe SR.53



The second SR.53 on display at the September 1957 Farnborough Air Show

Role	Interceptor
Manufacturer	Saunders-Roe
Designed by	Maurice Brennan
First flight	16 May 1957
Status	Experimental
Primary user	United Kingdom
Number built	2
Variants	Saunders-Roe SR.177

The **Saunders-Roe SR.53** was a prototype interceptor aircraft of mixed jet and rocket propulsion developed for the Royal Air Force in the early 1950s. Although its performance was promising, the need for such an aircraft was soon overtaken by surface-to-air missile development, consequently the project was cancelled after 56 test flights.

Design and development

The Second World War demonstrated the importance of strategic bombing to modern warfare, and as the Cold War developed, devising effective air defence against large waves of enemy bomber aircraft became a priority for many nations. Nazi Germany had looked to rocket-powered aircraft to fill this niche, with machines like the Messerschmitt Me 163 and Bachem Ba 349, which were capable of unparalleled rates-of-climb, enabling them to (at least in theory) rise to meet and intercept enemy bombers before they reached their targets. German rocket technology was studied extensively by the Allies in the aftermath of the war, and in light of the threat of the growing Soviet strategic bomber fleet and that nation's newly-developed atomic weapons, the UK's Air Ministry drafted an Operational Requirement O.R. 301 in May 1951 for a rocket-powered interceptor that could reach an altitude of 60,000 ft (18,300 m) in just 2 minutes 30 seconds. This was circulated to the nation's aircraft manufacturers the following February.

The development of the de Havilland Sprite (5,000 lb thrust) and the Armstrong Siddeley Snarler (2,000 lb thrust) for RATO use led to the possibility of a more powerful rocket engine being developed as the planned powerplant for a "point defence" interceptor. The requirements of the O.R. 301 were considered onerous including a ramp launch and landing on a skid, and with the compliance of the companies approached to tender, the amended Specification G124T allowed for a mixed powerplant configuration and a conventional undercarriage.



Colour drawing of the first SR.53

Of the six companies that tendered proposals, two were selected for development contracts, A.V. Roe with their Avro 720 and Saunders-Roe with their **SR.53**. Further refinement of the concept led to the defined Specification O.R. 337. The SR.53 itself was a sleek aircraft with a sharply pointed nose, delta-like wing, and a T-tail. The Armstrong Siddeley Viper jet and de Havilland Spectre rocket engine and exhausts were mounted one atop the other in the tail.

By September 1953, the programme to develop these aircraft came under scrutiny due to cost cuts, and the Avro 720 was abandoned, although it seemed almost ready to fly at this point. One of the reasons for preferring the SR.53 was although the aircraft was developmentally behind, its use of hydrogen peroxide as an oxidiser was viewed as less problematic than the Avro 720's use of liquid oxygen. With an original contract to build three prototypes, the SR.53 was scheduled for a first flight in July 1954 with a service introduction date set for 1957. At the same time, Saunders-Roe began work on a derivative design, the SR.177, which was large enough to carry a useful radar, essential to interception at the high altitudes where the new fighter was meant to operate, despite the fact that the specification did not require it. The new, larger aircraft was developed into versions for maritime use by the Royal Navy and for West Germany as well as for the RAF.

Operational history

The complexity of the design caused a series of setbacks, notably an explosion during ground tests of the Spectre rocket engine. The SR.53's first flight began to fall further and further behind schedule. On 16 May 1957, Squadron Leader John S. Booth DFC was at the controls of XD145 for the first test flight, following up with the maiden flight of the second prototype XD151, on 6 December 1957. Test results indicated "...an extremely docile and exceedingly pleasant aircraft to fly, with very well harmonized controls." Both prototypes flew a total of 56 test flights, with Mach 1.33 speeds being obtained.

While testing at RAE Boscombe Down, XD151 crashed on 15 June 1958 during an aborted takeoff on its 12th flight. Running off the runway, the aircraft struck a concrete approach light, exploding on impact and killing its pilot, Squadron Leader Booth. The remaining prototype continued to fly with Lt Cdr Peter Lamb taking over the flight test programme.

Cancellation

It was 1957 before the first SR.53 took to the air, just over a month after the infamous 1957 Defence White Paper had been published outlining the British government's policy to largely abandon piloted aircraft in favour of concentrating on missile development. At the same time, jet engine development had progressed a long way in the six years since the SR.53's initial design. Combined with the fact that improvements in radar had meant that any incoming bomber threat could be detected much earlier, the need for an aircraft like the SR.53 had disappeared, and the project was cancelled on 29 July 1960, with the third prototype (XD153) never built.

Aircraft on display

The first SR.53 prototype, *XD145*, is preserved at the Royal Air Force Museum Cosford near Wolverhampton.

Operators

 United Kingdom

- Ministry of Supply

Specifications

General characteristics

- **Crew:** One, pilot
- **Length:** 45 ft 0 in (13.72 m)
- **Wingspan:** 25 ft 1½ in (7.66 m)
- **Height:** 10 ft 10 in (3.30 m)
- **Wing area:** 274 ft² (25.5 m²)
- **Airfoil:** RAE102
- **Empty weight:** 7,400 lb (3,360 kg)
- **Loaded weight:** 18,400 lb (8,360 kg)
- **Powerplant:**
 - 1× Armstrong Siddeley Viper 8 turbojet, 1,640 lb (7.3 kN)
 - 1× de Havilland Spectre rocket, 8,000 lbf (35.7 kN)

Performance

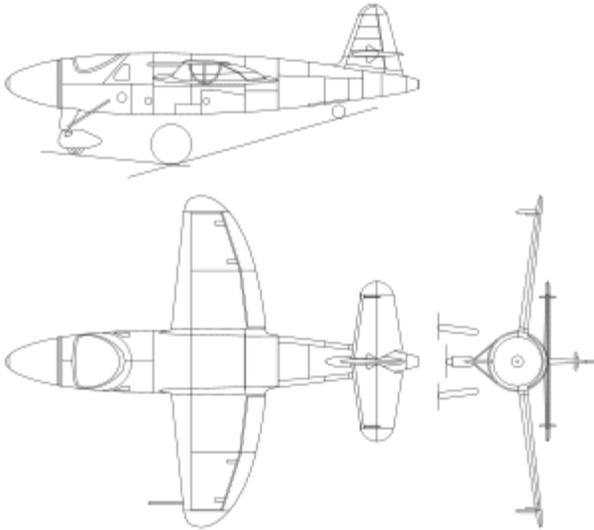
- **Maximum speed:** Mach 2.2
- **Endurance:** 7 minutes at full power
- **Service ceiling:** 67,000 ft (20,420 m)
- **Rate of climb:** 52,800 ft/min (270 m/s) : 2 min 12 sec from brakes to 50,000 ft
- **Wing loading:** 67.2 lb/ft² (328 kg/m²)
- **Thrust/weight (jet):** 0.52

Armament

- **Missiles:** 2 × de Havilland Firestreak infra-red guided missiles

Heinkel He 176

Heinkel He 176



World's first aircraft to be propelled solely by a liquid-fuelled rocket

Role	Experimental
Manufacturer	Heinkel
Designed by	Walter Günter
First flight	June 20, 1939 – at the controls Test pilot Erich Warsitz
Status	Cancelled
Number built	1

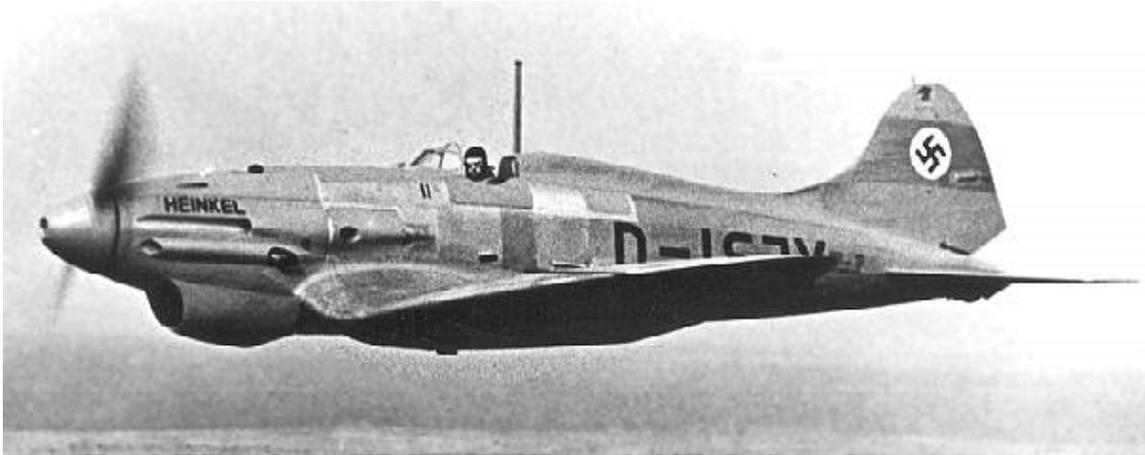
The **Heinkel He 176** was a German rocket-powered aircraft. It was the world's first aircraft to be propelled solely by a liquid-fuelled rocket, making its first powered flight on 20 June 1939 with Erich Warsitz at the controls.

Early experiments

During the 1920s, German daredevils had experimented with using solid-fuel rockets to propel cars, motorcycles, railway carriages, snow sleds, and, by 1929, aircraft such as Alexander Lippisch's *Ente* and Fritz von Opel's RAK.1. Solid-fuel rockets, however, have major disadvantages when used for aircraft propulsion, as their thrust cannot be regulated, and the engines cannot be shut down once fired.

In 1931, the Army Weapons Office testing ground at Kummersdorf had taken over research into liquid-fuel rockets. In 1932, Wernher von Braun designed a rocket of this kind which used high percentage spirit (alcohol) and liquid oxygen. With this he made

the first experiments. In 1934 he fired his second rocket type, the A2, from the North Sea island of Borkum.



A regular He 112.

During 1936 von Braun's rocketry team working at Kummersdorf investigated installing liquid-fuelled rockets in aircraft. Ernst Heinkel enthusiastically supported their efforts, supplying a He 72 and later two He 112s for the experiments. Late in 1936 Erich Warsitz was seconded by the RLM to Wernher von Braun and Ernst Heinkel, because he had been recognized as one of the most experienced test-pilots of the time, and because he also had an extraordinary fund of technical knowledge. In June 1937, at Neuhardenberg (a large field about 70 kilometres east of Berlin, listed as a reserve airfield in the event of war), one of these latter aircraft was flown by test pilot Erich Warsitz with its piston engine shut down during flight, at which time it was propelled by von Braun's rocket power alone. Despite the wheels-up landing and having the fuselage on fire, it proved to official circles that an aircraft could be flown satisfactorily with a back-thrust system through the rear.

At the same time, Hellmuth Walter's experiments into Hydrogen peroxide-based rockets were leading towards light and simple rockets that appeared well-suited for aircraft installation. Also the firm of Hellmuth Walter at Kiel had been commissioned by the RLM to build a rocket engine for the He 112, so there were two different new rocket motor designs at Neuhardenberg: whereas the von Braun's engines were powered by alcohol and liquid oxygen, Walter engines had hydrogen peroxide and calcium permanganate as a catalyst. Von Braun's engine used direct combustion and created fire, the Walter devices hot vapours from a chemical reaction, but both created thrust and provided high speed. The subsequent flights with the He 112 used the Walter-rocket instead of von Braun's; it was more reliable, simpler to operate and the dangers to test pilot Erich Warsitz and machine were less.

Heinkel He 176

Design and development

The allegation often repeated by technical experts that Heinkel made the first rocket aircraft, the He 176, as a 'black machine', without the approval of, or having been contracted by, the RLM, is totally false. In 1936, RLM awarded Heinkel a contract to build the world's first pure rocket aircraft, remaining fully informed of the project's progress and Heinkel's intentions. During the development programme at Neuhardenberg with the He 112, the term "interceptor" had been coined, and the He 176 was seen as the research machine for the project. RLM was really thinking along the lines of a new kind of fighter aircraft. With a fantastic rate of climb it would take off almost vertically to intercept enemy bomber formations at 6000 – 7000 metres, make a swift attack from below at high speed, emptying the MGs or cannons into the enemy machines and then land once the fuel tanks were dry.

Because the He 176 development was classified top secret, Heinkel set up a special department in his Rostock-Marienehe works. A wooden barrack hut was erected first for the initial testing. Only very few employees were allowed access. This "shed" was soon converted into a permanent building. The development then progressed very quickly. Meanwhile work also went ahead to build the He 176 mock-up because time was pressing.

The He 176 was built as an all-metal aircraft to utilise one of the new Walter engines (HWK RI-203). Completely new was the wing-flow profile designed for supersonic speed whose leading edges were razor sharp. This increased the danger of losing the airstream at lower speeds needed for safe landings. The wings had been designed from the beginning as fuel containers but the riveting was problematical because the wings were so flat and only explosive studs were suitable, otherwise they would never have gotten leak-proof.

The He 176 did possess an advanced, totally-enclosed cockpit, with a frameless single-piece clear nose, through which the pilot's rudder pedal mounts were visible, and a flush upper cockpit glazing which was removable for entering the aircraft, making the cockpit fit completely within the forward, bullet-like contours of the fuselage. The landing gear was a combination of conventional and tricycle gear designs, with the main gear's struts intended to retract rearwards into the fuselage, with a fixed, aerodynamically faired nose wheel and strut, and a retractable tail wheel.

A unique feature of the He 176 was its jettisonable nose escape system. Compressed air was used to separate the nose from the aircraft. A drogue parachute was used to reduce the opening force required. After the drogue was deployed, the flush-fitting cockpit canopy was released and a conventional bailout occurred.

Maiden flight



Flight Captain Erich Warsitz.

With a new kind of aircraft like this one does not simply get in and take off. Ground work began with rolling tests to establish the characteristics on the runway at Peenemünde.

Until then Heinkel had intentionally avoided demonstrating the machine to the Luftwaffe generals, but in the end a visit by an RLM party led by Udet, Milch and half the General Staff could no longer be put off.

Once Warsitz was convinced that he knew all the peculiarities and wrinkles of the aircraft through the programme of rolling trials and short leaps, one fine summer's evening (June 20, 1939) he announced spontaneously his decision to attempt the maiden flight immediately. A strange silence fell over all the engineers and assembly workers: nobody spoke, for all sensed that the decisive moment for the future was at hand.

Further flights and demonstrations

On the next day (June 21, 1939) Heinkel, Udet and a whole Staff of Peenemünde officers came to witness the second successful flight. Erich Warsitz had his confidence up this second time and made an impressive pass at low level.

After this maiden flight, systematic development work was no longer possible. Despite all the secrecy the sensational news went round the higher circles at RLM like wildfire, and after that the He 176-Team basically did nothing but give demonstration flights - with immediate effect all future flights, including short leaps, were forbidden because a display had been arranged for the Führer on July 3, 1939. The big air show for Hitler, the Party high-ups and the Luftwaffe Generals was to be at Rechlin.

Further development stopped

Heinkel was now a little bitter at not receiving the support he expected and needed, for after the first flights it seemed interest in it had died away. Not all people in the decisive area at RLM had lost interest, but war was looming and there were other things to think about. The Führer-Directive, ordering all developments not ready for mass-production within a year to be suspended with immediate effect, led to the abandonment of Heinkel's rocket propulsion programme. Testing of the He 176 ended with only one aircraft being built. It was put on display at the Berlin Air Museum and was destroyed by an Allied bombing raid in 1943.

Prior to the cancellation of the programme, plans had been drawn up for a more sophisticated rocket-plane, still designated He 176. This was never constructed, but because it bore the same designation as the aircraft that was actually flown, many books and websites mistakenly publish pictures of it to illustrate its earlier namesake.

Germany did eventually fly an operational rocket-propelled fighter, the Me 163 *Komet*, but this was made by the competing Messerschmitt firm, using an engine that was a further development of the one that powered the He 176.

Specifications (He 176 V1)

General characteristics

- **Crew:** One
- **Length:** 5.2 m (17 ft 1 in)
- **Wingspan:** 5.0 m (16 ft 5 in)
- **Height:** 1.5 m (4 ft 11 in)
- **Wing area:** 5.4 m² (58 ft²)
- **Empty weight:** 900 kg (1,980 lb)
- **Loaded weight:** 1,620 kg (3,570 lb)

Performance

- **Maximum speed:** 345 km/h [750 km/h theoretical] (215 mph [470 mph theoretical])
- **Range:** 95 km [theoretical] (60 mi)
- **Service ceiling:** 9,000 m [theoretical] (29,500 ft)
- **Rate of climb:** 60.6 m/s (199 ft/s)
- **Endurance** 50 s

Chapter- 7

SpaceShipOne



Astronaut Mike Melvill after his September 29, 2004 spaceflight



SpaceShipOne in the National Air and Space Museum in Washington D.C. with the Spirit of Saint Louis and Bell X-1 "Glamorous Glennis"

SpaceShipOne is a retired suborbital air-launched spaceplane that completed the first manned private spaceflight in 2004. That same year, it won the \$10 million Ansari X Prize and was immediately retired from active service. Its mothership was named "White Knight". Both craft were developed and flown by Mojave Aerospace Ventures, which was a joint venture between Paul Allen and Scaled Composites, Burt Rutan's aviation company. Allen provided the funding of approximately \$25 million.

Rutan has indicated that ideas about the project began as early as 1994 and the full-time development cycle time to the 2004 accomplishments was about three years. SpaceShipOne's first official spaceflight, known as flight 15P, was piloted by Mike Melvill. A few days before that flight, the Mojave Air and Space Port was licensed as the USA's first commercial spaceport. A few hours after that flight, Melvill became the first licensed U.S. commercial astronaut. The overall project name was "Tier One" which has evolved into Virgin Galactic Tier 1b with a goal of taking a successor ship's first passengers into space within the next few years.

Development and winning the X Prize



(L to R) Marion Blakely (FAA), Mike Melvill; Richard Branson, Burt Rutan, Brian Binnie, and Paul Allen reflect on a mission accomplished (October 4, 2004)

SpaceShipOne was developed by Mojave Aerospace Ventures (a joint venture between Paul Allen and Scaled Composites, Burt Rutan's aviation company, in their Tier One program), without government funding. On June 21, 2004, it made the first privately funded human spaceflight. On October 4, it won the \$10 million Ansari X Prize, by reaching 100 kilometers in altitude twice in a two-week period with the equivalent of three people on board and with no more than ten percent of the non-fuel weight of the spacecraft replaced between flights. Development costs were estimated to be \$25 million, funded completely by Paul Allen.

During its test programme, SpaceShipOne set a number of important "firsts", including first privately funded aircraft to exceed Mach 2 and Mach 3, first privately funded manned spacecraft to exceed 100km altitude, and first privately funded reusable manned spacecraft.

SpaceShipOne is an experimental air-launched rocket-powered aircraft with suborbital flight capability that uses a hybrid rocket motor. The design features a unique "feathering" atmospheric reentry system where the rear half of the wing and the twin tail

booms folded upward along a hinge running the length of the wing; this increased drag while remaining stable. The achievements of SpaceShipOne are more comparable to the X-15 than orbiting spacecraft like the Space Shuttle. Accelerating a spacecraft to orbital speed requires more than 60 times as much energy as accelerating it to Mach 3.



SpaceShipOne connected to its mother ship White Knight



SpaceShipOne landing after its June 21, 2004 space flight (Flight 15P)

SpaceShipOne is registered with the FAA as **N328KF**. *N* is the prefix for US-registered aircraft; *328KF* was chosen by Scaled Composites to stand for 328 K (abbreviation for 1000) feet (about 100 kilometers), the officially designated edge of space. The original choice of registry number, **N100KM**, was already taken. N328KF is registered as a glider, reflecting the fact that most of its independent flight is unpowered.

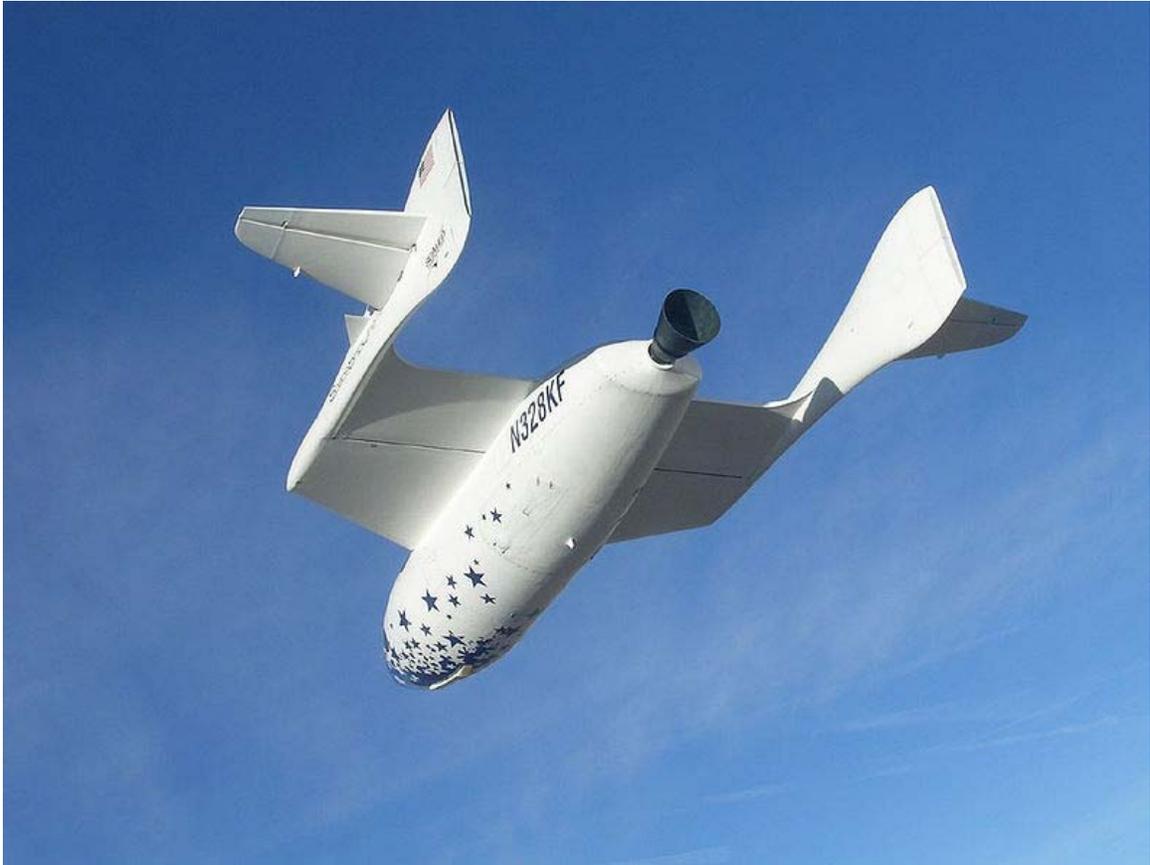
SpaceShipOne's first flight, 01C, was an unmanned captive carry flight test on May 20, 2003. Glide tests followed, starting with flight 03G on August 7, 2003. Its first powered flight, flight 11P, was made on December 17, 2003, the 100th anniversary of the first powered flight.

On April 1, 2004, Scaled Composites received the first license for sub-orbital rocket flights to be issued by the US Office of Commercial Space Transportation. This license permitted the company to conduct powered test flights over the course of one year. On June 17, 2004, Mojave Airport reclassified itself (part-time) as the Mojave Spaceport.

Flight 15P on June 21, 2004, was SpaceShipOne's first spaceflight, and the first privately funded human spaceflight. There were a few control issues, but these were resolved prior to the Ansari X PRIZE flights that followed, with flight 17P on October 4, 2004, winning the prize.

The SpaceShipOne Team was awarded the Space Achievement Award by the Space Foundation in 2005.

Flights



SpaceShipOne in flight.



Cockpit of WhiteKnight in flight, EFIS display edited to look like SpaceShipOne.

All of the flights of SpaceShipOne were from the Mojave Airport Civilian Flight Test Center. Flights were numbered, starting with flight 01 on May 20, 2003. One or two letters are appended to the number to indicate the type of mission. An appended **C** indicates that the flight was a captive carry, **G** indicates an unpowered glide, and **P** indicates a powered flight. If the actual flight differs in category from the intended flight, two letters are appended: the first indicating the intended mission and the second the mission actually performed.

In the table below, the "top speed" reported is the Mach number at burn-out (the end of the rocket burn). This is not an absolute speed.

SpaceShipOne flights					
Flight Date	Top speed	Altitude	Duration	Pilot	
01C May 20, 2003	Mach 0.53	14.63 km	1 h 48 min	unmanned	
02C July 29, 2003		14 km	2 h 06 min	Mike Melvill	
03G August 7, 2003	278 km/h	14.33 km	19 min 00 s	Mike Melvill	
04GC August 27, 2003	370 km/h	14 km	1 h 06 min	Mike Melvill	

05G	August 27, 2003	370 km/h	14.69 km	10 min 30 s	Mike Melvill
06G	September 23, 2003	213 km/h	14.26 km	12 min 15 s	Mike Melvill
07G	October 17, 2003	241 km/h	14.08 km	17 min 49 s	Mike Melvill
08G	November 14, 2003	213 km/h	14.42 km	19 min 55 s	Peter Siebold
09G	November 19, 2003	213 km/h	14.72 km	12 min 25 s	Mike Melvill
10G	December 4, 2003	213 km/h	14.75 km	13 min 14 s	Brian Binnie
11P	December 17, 2003	Mach 1.2	20.67 km	18 min 10 s	Brian Binnie
12G	March 11, 2004	232 km/h	14.78 km	18 min 30 s	Peter Siebold
13P	April 8, 2004	Mach 1.6	32.00 km	16 min 27 s	Peter Siebold
14P	May 13, 2004	Mach 2.5	64.43 km	20 min 44 s	Mike Melvill
15P	June 21, 2004	Mach 2.9	100.124 km	24 min 05 s	Mike Melvill
16P	September 29, 2004	Mach 2.92	102.93 km	24 min 11 s	Mike Melvill
17P	October 4, 2004	Mach 3.09	112.014 km	23 min 56 s	Brian Binnie

The flights were accompanied by two chase planes; an Extra 300 owned and flown by Chuck Coleman, and a Beechcraft Starship.

Astronauts

The SpaceShipOne pilots came from a variety of aerospace backgrounds. Mike Melvill is a test pilot, Brian Binnie is a former Navy pilot, and Doug Shane and Peter Siebold are engineers at Scaled Composites. They qualified to fly SpaceShipOne by training on the Tier One flight simulator and in White Knight and other Scaled Composites aircraft.

Specifications



Rear view

General characteristics

- **Crew:** one, pilot
- **Capacity:** 2 passengers
- **Length:** 16 ft 5 in (8,05 m)
- **Wingspan:** 16 ft 5 in (8,05 m)
- **Height:** ()
- **Wing area:** 161.4 ft² (15 m²)
- **Empty weight:** 2,640 lb (1,200 kg)
- **Loaded weight:** 7,920 lb (3,600 kg)
- **Powerplant:** 1× N2O/HTPB SpaceDev Hybrid rocket motor, 7,500 kgf (74 kN)
- **I_{sp}:** 250 s (2450 Ns/kg)
- **Burn time:** 87 seconds
- **Aspect Ratio:** 1.6

Performance

- **Maximum speed:** Mach 3.09 (2,170 mph, 3,518 km/h)
- **Range:** 35 nm (40 mi, 65 km)
- **Service ceiling:** 367,360 ft (112,000 m)
- **Rate of climb:** 82,000 ft/min (416.6 m/s)
- **Wing loading:** 49.07 lb/ft² (240 kg/m²)
- **Thrust/weight:** 2.08

Retirement



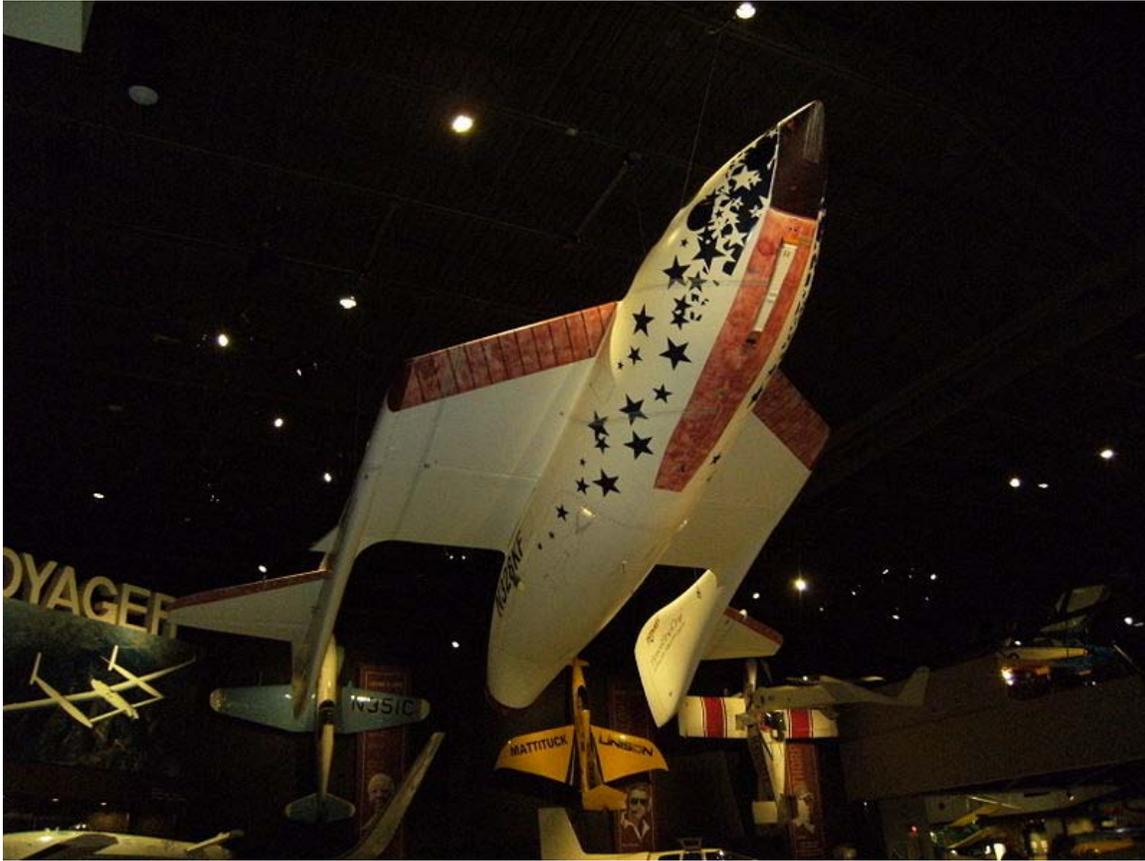
SpaceShipOne now hangs in the National Air and Space Museum in Washington D.C.

SpaceShipOne's spaceflights were watched by large crowds at Mojave Spaceport. A fourth suborbital flight, Flight 18P, was originally scheduled for October 13, 2004. However, Burt Rutan decided not to risk damage to the historic craft, and cancelled it and all future flights.

On July 25, 2005 SpaceShipOne was taken to the Oshkosh Airshow in Oshkosh, Wisconsin. After the airshow, Mike Melvill and crew flew the White Knight, carrying SpaceShipOne, to Wright-Patterson Air Force Base in Dayton, Ohio, where Mike spoke to a group of about 300 military and civilian personnel. Later in the evening, Mike gave a presentation at the Dayton Engineers Club, entitled "Some Experiments in Space Flight", in honor of Wilbur Wright's now famous presentation to the American Society of Mechanical Engineers in 1901 entitled "Some Experiments in Flight." The White Knight then transported SpaceShipOne to the Smithsonian Institution's National Air and Space Museum to be put on display. It was unveiled on Wednesday October 5, 2005 in the Milestones of Flight gallery and is now on display to the public in the main atrium between the Spirit of St. Louis and the Bell X-1.

SpaceShipOne became a popular model rocket in 2004. Estes Industries currently offers several flying model rockets of SpaceShipOne. A piece of SpaceShipOne's carbon fiber material was launched aboard the New Horizons mission to Pluto in 2006.

Replica



SpaceShipOne Replica in normal configuration

A year after its appearance in the Oshkosh Airventure airshow, the Experimental Aircraft Association featured a full-scale replica of the spacecraft in a wing of its museum which housed other creations of Burt Rutan. Using the same fiberglass molds as the original, it was so exact in its replication - despite not having any doors or interior - that it was dubbed "Serial 2 Scaled" by Scaled Composites. Each and every painstaking detail in its appearance was matched, down to the N328KF registration number on its fuselage. It is so precise that, during a video presentation held every hour in the museum, it can display the two different modes of its 'feathering' ability, albeit through the aid of pulleys and wires (there is no machinery in the replica).

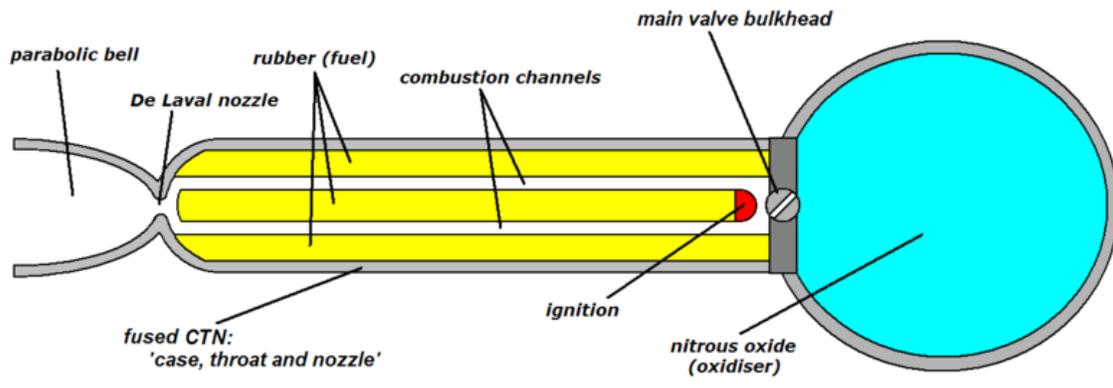
Another full-scale replica of SpaceShipOne hangs in the rotunda of the William Thomas Terminal at Meadows Field Airport in Bakersfield and a third is on display in the Mojave Spaceport's Legacy Park alongside the original Roton Atmospheric Test Vehicle.

Future efforts

With the success of Tier One meeting its project goals, a successor project started in 2004 was Virgin Galactic Tier 1b. The successor ship names SpaceShipTwo and White Knight Two. The name of the joint venture between Virgin Group and Scaled Composites is called The Spaceship Company, with a goal of carrying passengers under the name Virgin Galactic spaceliner with an initial target of a commercial fleet of five spacecraft.

In August 2005, Virgin Galactic stated that if the upcoming suborbital service with SpaceShipTwo is successful, the follow-up SpaceShipThree.





Hybrid rocket engine detail of SpaceShipOne

Chapter- 8

North American X-15

X-15



Role	Experimental high-speed rocket-powered research aircraft
Manufacturer	North American Aviation
First flight	8 June 1959
Introduced	17 September 1959
Retired	December 1970
Primary users	United States Air Force NASA
Number built	3

The **North American X-15** rocket-powered aircraft/spaceplane was part of the X-series of experimental aircraft, initiated with the Bell X-1, that were made for the USAAF/USAF, NACA/NASA, and the USN. The X-15 set speed and altitude records in the early 1960s, reaching the edge of outer space and returning with valuable data used in aircraft and spacecraft design. As of 2011, it holds the official world record for the fastest speed ever reached by a manned rocket powered aircraft.

During the X-15 program, 13 of the flights (by eight pilots) met the USAF spaceflight criteria by exceeding the altitude of 50 miles (80.5 km, 264,000 ft), thus qualifying the

pilots for astronaut status. The USAF pilots qualified for USAF astronaut wings, while the civilian pilots were later awarded NASA astronaut wings.

Of all the X-15 missions, two flights (by the same pilot) qualified as space flights per the international (Fédération Aéronautique Internationale) definition of a spaceflight by exceeding 100 kilometres (62.1 mi, 328,084 ft) in altitude.

Design and development



X-15 just after release.



X-15 touching down on its skids. Compare jettisoned lower ventral fin with color picture, top.

The X-15 was based on a concept study from Walter Dornberger for the NACA for a hypersonic research aircraft. The requests for proposal were published on 30 December 1954 for the airframe and on 4 February 1955 for the rocket engine. The X-15 was built by two manufacturers: North American Aviation was contracted for the airframe in November 1955, and Reaction Motors was contracted for building the engines in 1956.

Like most X-series aircraft, the X-15 was designed to be carried aloft, under the wing of a NASA B-52, the *Balls 8*. Release took place at an altitude of about 8.5 miles (13.7 km, 45,000 ft), and a speed of about 805 km/h (500 mph, 223.5 m/s). The X-15 fuselage was long and cylindrical, with rear fairings that flattened its appearance, and thick, dorsal and ventral wedge-fin stabilizers. Parts of the fuselage were heat-resistant nickel alloy (Inconel-X 750). The retractable landing gear comprised a nose-wheel carriage and two rear skis. The skis did not extend beyond the ventral fin, which required the pilot to jettison the lower fin (fitted with a parachute) just before landing. The two XLR-11 rocket engines for the initial **X-15A** model delivered 16,000 lb_f (71 kN) maximum thrust each, for a total of 32,000 pounds-force. The main engine (installed later) was a single XLR-99 rocket engine delivering 57,000 lb_f (250 kN) at sea level, and 70,000 lb_f (310 kN) at peak altitude. The idle thrust of the XLR-99 was 15,000 lb_f (67 kN).

Engines and fuel

Early flights used two Reaction Motors XLR11 engines. Later flights were undertaken with a single Reaction Motors Inc XLR99 rocket engine generating 57,000 pounds-force (250 kN) of thrust powered the aircraft. This engine used ammonia and liquid oxygen for propellant and hydrogen peroxide to drive the high-speed turbopump that delivered fuel to the engine. The XLR99 could be throttled, and were the first such controllable engines that were "man-rated", that is, declared safe to operate with a human aboard.

Operational history

Three X-15s were built, flying 199 test flights, the last on 24 October 1968. The first X-15 flight was an unpowered test flight by Scott Crossfield, on 8 June 1959; he also piloted the first powered flight, on 17 September 1959, with his first XLR-99 flight on 15 November 1960. Twelve test pilots flew the X-15; among them were Neil Armstrong (first man to walk on the moon) and Joe Engle (later a space shuttle commander). In July and August 1963, pilot Joe Walker crossed the 100 km altitude mark, joining the NASA astronauts and Soviet Cosmonauts as the only humans to have crossed the barrier into outer space (Soviet Yuri Gagarin was the first person in space, reaching 327 km in apogee of his orbital flight, while Alan Shepard was the first American in space, reaching 187 km during suborbital flight) and becoming the first to exceed this threshold twice.

U.S. Air Force test pilot Major Michael J. Adams was killed on 15 November 1967 in X-15 Flight 191 when his craft (X-15-3) entered a hypersonic spin while descending, then oscillated violently as aerodynamic forces increased after re-entry. As his craft's flight control system operated the control surfaces to their limits, the craft's acceleration built to 15 g vertical and 8 g lateral. The airframe broke apart at 60,000 ft (18,000 m) altitude, scattering the craft's wreckage for 50 square miles (130 km²). On 8 June 2004, a monument was erected at the cockpit's locale, near Randsburg, California. Major Adams was posthumously awarded Air Force astronaut wings for his final flight in craft X-15-3, which had reached 81.1 km (50.4 mi, 266,000 ft) of altitude. In 1991, his name was added to the Astronaut Memorial.



Bomber NB-52A (s/n 52-003), permanent test variant, carrying an X-15, with mission markings; horizontal X-15 craft silhouettes denote glide flights, diagonal silhouettes denote powered flights.

The second X-15A was rebuilt after a landing accident. It was lengthened 2.4 feet (0.73 m), a pair of auxiliary fuel tanks attached under the fuselage, and a heat-resistant surface treatment applied. Re-named the **X-15A-2**, it first flew on 28 June 1964, reaching 7,274 km/h (4,520 mph, 2,021 m/s).

The altitudes attained by the X-15 aircraft do not match that of Alan Shepard's 1961 NASA space capsule flight nor subsequent NASA space capsules and space shuttle flights. However, the X-15 flights did reign supreme among rocket-powered aircraft until the second spaceflight of Space Ship One in 2004.

Five aircraft were used for the X-15 program: three X-15s, two B-52 bombers:

- **X-15A-1** – 56-6670, 82 powered flights
- **X-15A-2** – 56-6671, 53 powered flights
- **X-15A-3** – 56-6672, 64 powered flights
- **NB-52A** – 52-003 (retired in October 1969)
- **NB-52B** – 52-008 (retired in November 2004)

A 200th flight over Nevada was slated for 21 November 1968, piloted by William J. Knight. Technical problems and bad weather delayed the flight six times, and on 20 December 1968, the 200th flight was finally cancelled. The X-15 was detached from the NB-52A wing and prepared for indefinite storage.

X-15 gallery



X-15A-2 on the flight line



X-15 on Boeing B-52 Mothership wing pylon



Dryden Flight Research Center ECN-1770 Photographed 1967
X-15 #2 full scale seal coat (NASA photo)



X-15 in full scale ablative coating



X-15 on display at the National Air and Space Museum



X-15 nose

Current static displays



X-15 at the National Air and Space Museum

- X-15-1 (s/n 56-6670) is on display in the National Air and Space Museum "Milestones of Flight" gallery, Washington, D.C.
- X-15-2A (s/n 56-6671) is at the National Museum of the United States Air Force, at Wright-Patterson Air Force Base, near Dayton, Ohio. It was retired to the Museum in October 1969. The aircraft is displayed in the Museum's Research & Development Hangar alongside other "X-planes", including the Bell X-1 and X-3 Stiletto.
- X-15-3 (s/n 56-6672) was destroyed. Parts have been recovered at the crash site as late as the 1990s.

Mock-ups

- Dryden Flight Research Center, Edwards AFB, California, USA (painted with s/n 56-6672)
- Pima Air Museum, Tucson, Arizona (painted with s/n 56-6671)
- Evergreen Aviation Museum, McMinnville, Oregon (painted with s/n 56-6672). A full-scale wooden mock-up of the X-15, displayed along with one of the rocket motors.

Stratofortress motherships

- NB-52A (s/n 52-003) is at the Pima Air and Space Museum, Tucson, Arizona. It launched the X-15 #1 30 times, the X-15 #2, 11 times, and the X-15 #3 31 times (as well as the M2-F2 four times, the HL-10 11 times and the X-24A twice).

- NB-52B (s/n 52-008) is at the Dryden Flight Research Center, Edwards AFB, California, USA. It launched the majority of X-15 flights.

Aftermath

Before 1958, USAF and NACA, (later NASA), officials discussed an orbital X-15 spacecraft—the **X-15B**—for launching to outer space atop an SM-64 Navajo missile. This was canceled when NACA became NASA, and Project Mercury was approved instead. By 1959, the X-20 Dyna-Soar space-glider program became the USAF's preferred means for launching military manned spacecraft into orbit; however, this program was canceled in the early 1960s before an operational vehicle could be built.

Record flights

Highest flights

There are two definitions of how high a person must go to be referred to as an astronaut. The USAF decided to award astronaut wings to anyone who achieved an altitude of 50 miles (80.5 km) or more. However, the FAI set the limit of space at 100 kilometres (62.1 mi). Thirteen X-15 flights went higher than 50 miles and two of these reached over 100 kilometres.

X-15 flights higher than 50 mi (80 km)				
Flight	Date	Top speed	Altitude	Pilot
Flight 62	17 July 1962	3,831 mph (6,165 km/h)	59.6 miles (95.9 km)	Robert M. White
Flight 77	17 January 1963	3,677 mph (5,918 km/h)	51.4 miles (82.7 km)	Joe Walker
Flight 87	27 June 1963	3,425 mph (5,512 km/h)	53.9 miles (86.7 km)	Robert Rushworth
Flight 90	19 July 1963	3,710 mph (5,970 km/h)	65.8 miles (105.9 km)	Joe Walker
Flight 91	22 August 1963	3,794 mph (6,106 km/h)	67.0 miles (107.8 km)	Joe Walker
Flight 138	29 June 1965	3,431 mph (5,522 km/h)	53.1 miles (85.5 km)	Joseph H. Engle
Flight 143	10 August 1965	3,549 mph (5,712 km/h)	51.3 miles (82.6 km)	Joseph H. Engle
Flight 150	28 September 1965	3,731 mph (6,004 km/h)	55.9 miles (90.0 km)	John B. McKay
Flight 153	14 October 1965	3,554 mph (5,720 km/h)	50.4 miles (81.1 km)	Joseph H. Engle
Flight	1 November	3,750 mph	58.1 miles	Bill Dana

174	1966	(6,040 km/h)	(93.5 km)	
Flight 190	17 October 1967	3,856 mph (6,206 km/h)	53.1 miles (85.5 km)	Pete Knight
Flight 191	15 November 1967	3,569 mph (5,744 km/h)	50.3 miles (81.0 km)	Michael J. Adams [†]
Flight 197	21 August 1968	3,443 mph (5,541 km/h)	50.6 miles (81.4 km)	Bill Dana

[†] fatal

Fastest flights

X-15 10 fastest flights				
Flight	Date	Top Speed	Altitude	Pilot
Flight 45	9 November 1961	4,092 mph (6,585 km/h)	19.2 miles (30.9 km)	Robert M. White
Flight 59	27 June 1962	4,104 mph (6,605 km/h)	23.4 miles (37.7 km)	Joe Walker
Flight 64	26 July 1962	3,989 mph (6,420 km/h)	18.7 miles (30.1 km)	Neil Armstrong
Flight 86	25 June 1963	3,910 mph (6,290 km/h)	21.7 miles (34.9 km)	Joe Walker
Flight 89	18 July 1963	3,925 mph (6,317 km/h)	19.8 miles (31.9 km)	Robert Rushworth
Flight 97	5 December 1963	4,017 mph (6,465 km/h)	19.1 miles (30.7 km)	Robert Rushworth
Flight 105	29 April 1964	3,905 mph (6,284 km/h)	19.2 miles (30.9 km)	Robert Rushworth
Flight 137	22 June 1965	3,938 mph (6,338 km/h)	29.5 miles (47.5 km)	John B. McKay
Flight 175	18 November 1966	4,250 mph (6,840 km/h)	18.7 miles (30.1 km)	Pete Knight
Flight 188	3 October 1967	4,519 mph (7,273 km/h)	36.3 miles (58.4 km)	Pete Knight

X-15 pilots

X-15 pilots and their achievements during the program

Pilot	Organization	Total Flights	USAF space flights	FAI space flights	Max Mach	Max speed (mph)	Max altitude (miles)
Michael J. Adams [†]	U.S. Air Force	7	1	0	5.59	3,822	50.3
Neil Armstrong	NASA	7	0	0	5.74	3,989	39.2

Scott Crossfield	North American Aviation	14	0	0	2.97	1,959	15.3
Bill Dana	NASA	16	2	0	5.53	3,897	58.1
Joseph H. Engle	U.S. Air Force	16	3	0	5.71	3,887	53.1
Pete Knight	U.S. Air Force	16	1	0	6.70	4,519	53.1
John B. McKay	NASA	29	1	0	5.65	3,863	55.9
Forrest S. Petersen	U.S. Navy	5	0	0	5.3	3,600	19.2
Robert A. Rushworth	U.S. Air Force	34	1	0	6.06	4,017	53.9
Milt Thompson	NASA	14	0	0	5.48	3,723	40.5
Joe Walker	U.S. Air Force	25	3	2	5.92	4,104	67.0
Robert M. White*	U.S. Air Force	16	1	0	6.04	4,092	59.6

† Killed • * White was backup for Captain Iven Kincheloe

Chapter- 9

Messerschmitt Me 163

Messerschmitt Me 163 *Komet*



Me 163B-1a at the National Museum of Flight in Scotland

Role	Interceptor
Manufacturer	Messerschmitt
Designed by	Alexander Lippisch
First flight	Me 163 A V4 in 1 September 1941
Introduction	1944
Primary user	<i>Luftwaffe</i>
Number built	~370

The **Messerschmitt Me 163 *Komet***, designed by Alexander Martin Lippisch, was a German rocket-powered fighter aircraft. As of 2011, it remains the only rocket-powered fighter aircraft to have ever been operational. Its design was revolutionary, and the Me 163 was capable of performance unrivaled at the time. Messerschmitt test pilot Rudy Opitz in 1944 reached 1,123 km/h (698 mph). Over 300 aircraft were built, however the *Komet* proved ineffective as a fighter, having been responsible for the destruction of only about nine Allied aircraft (16 air victories for 10 losses, according to other sources).

Development

Work on the design started under the aegis of the *Deutsche Forschungsanstalt für Segelflug* (DFS) - the German Institute for the Study of sailplane flight. Their first design was a conversion of the earlier Lippisch Delta IV known as the **DFS 39** and used purely as a glider testbed of the airframe.

A larger follow-on version with a small propeller engine started as the DFS 194. This version used wingtip-mounted rudders, which Lippisch felt would cause problems at high speed. He later redesigned them to be mounted on a conventional vertical stabilizer at the rear of the aircraft. The design included a number of features from its glider heritage, notably a skid used for landings, which could be retracted into the aircraft's keel in flight. For takeoff, a pair of wheels, each mounted onto the ends of a specially designed cross-axle, together comprising a takeoff "dolly" mounted under the landing skid, were needed due to the weight of the fuel, but these were released shortly after takeoff. It was planned to move to the Walter R-1-203 *cold engine* of 400 kg (880 lb) thrust when available.

Heinkel had also been working with Hellmuth Walter on his rocket engines, mounting them in the He 112 for testing, and later in the first purpose-designed rocket aircraft, the He 176. Heinkel had also been selected to produce the fuselage for the DFS 194 when it entered production, as it was felt that the highly volatile fuel would be too dangerous in a wooden fuselage, with which it could react. Work continued under the code name *Projekt X*.

However the division of work between DFS and Heinkel led to problems, notably that DFS seemed incapable of building even a prototype fuselage. Lippisch eventually requested to leave DFS and join Messerschmitt instead. On 2 January 1939, he moved along with his team and the partially completed DFS 194 to the Messerschmitt works at Augsburg.

The delays caused by this move allowed the engine development to "catch up". Once at Messerschmitt, the decision was made to skip over the propeller-powered version and move directly to rocket power. The airframe was completed in Augsburg and shipped to Peenemünde West in early 1940 to receive its engine. Although the engine proved to be extremely unreliable, the aircraft had excellent performance, reaching a speed of 342 mph (550 km/h) in one test.

Me 163 A



Bundesarchiv, Bild 146-1072-058-02
Foto: o. Ang. | 1941

The Me 163 A V4 prototype, in 1941.

Production of a prototype series started in early 1941, known as the *Me 163*. Secrecy was such that the number, 163, was actually that of the earlier, pre-July 1938 Messerschmitt Bf 163 project to produce a small two-passenger light plane, which had competed against the Fieseler Fi 156 *Storch* for a production contract. It was thought that intelligence services would conclude any reference to the number "163" would be for that earlier design. The **Me 163 A V4** was shipped to Peenemünde to receive the HWK RII-203 engine on May 1941. By 2 October 1941, the Me 163 A V4, bearing the radio call sign letters, or *Stammkennzeichen*, "KE+SW", set a new world speed record of 1,004.5 km/h (624.2 mph), piloted by Heini Dittmar. This would not be officially approached until the postwar period by the new jet fighters of the British and U.S., and was not surpassed until the American Douglas Skystreak turbojet-powered research aircraft did so on 20 August 1947. Five prototype Me 163 *Anton* A-series experimental V-aircraft were built, adding to the original DFS 194 (V1), followed by eight pre-production examples designated as "Me 163 A-0".

During testing, the jettisonable main landing gear arrangement was a serious problem. The landing gear caused many aircraft to be damaged at takeoff, when the wheels rebounded and crashed into the aircraft. Malfunctioning hydraulic dampers in the skid could cause back injuries to the pilot when landing, as the aircraft lacked steering or braking control during landing, and was unable to avoid obstacles. Once on the ground,

the aircraft had to be retrieved by a tractor-like vehicle, towing a special retrieval trailer that rolled on a pair of short continuous-track setups (one per side), with twin trailing lifting arms, that lifted the stationary aircraft off the ground, from under each wing. The tractor was originally meant for agricultural use, the three-wheeled *Scheuch-Schlepper*, as the *Komet* was unpowered and lacked wheels at this point.

During flight testing, the superior gliding capability of the *Komet* proved detrimental to safe landing. The aircraft would rise back into the air with the slightest updraft. Since the approach was unpowered, there was no opportunity to make another landing pass. For production models, a set of landing flaps allowed somewhat more-controlled landings. This issue remained a problem throughout the program.

Nevertheless, the overall performance was tremendous, and plans were made to put Me 163 squadrons all over Germany in 40-kilometre rings (25 mi). Development of an operational version was given the highest priority.

Me 163 B



An **Me 163B** on display at the National Museum of the USAF - the small red rectangles on the rudder and elevons are control locks to prevent wind-damage to the control surfaces while on the ground, and are removed before flight

Meanwhile, Walter had started work on the newer HWK 109-509 *hot engine*, which added a true fuel of hydrazine hydrate and methanol, designated *C-Stoff*, that burned with the oxygen-rich exhaust from the *T-Stoff*, used as the oxidizer, for added thrust. This resulted in the significantly modified **Me 163 B** of late 1941. Due to the *Reichsluftfahrtministerium* (RLM) requirement that it should be possible to throttle the engine, the original power plant grew complicated and lost reliability. The new fuel proved an unfortunate choice as well, since hydrazine hydrate was also used in the launcher of the V-1 "Doodlebug" flying bomb and was in short supply throughout the 1943-45 period.

The fuel system was particularly troublesome, as leaks experienced during hard landings easily caused fires and explosions. Metal fuel lines and fittings, which failed in unpredictable ways, were used as this was the best technology available. Both fuel and oxidizer were toxic and required extreme care when loading in the aircraft, yet there were occasions when *Komet*s exploded on the tarmac. The corrosive nature of the liquids required special protective gear for the pilots.

Two prototypes were followed by 30 **Me 163B-0** aircraft armed with two 20 mm MG 151/20 cannon and some 400 **Me 163B-1** planes armed with two 30 mm (1.18-inch) MK 108 cannons, but which were otherwise similar to the B-0. Occasional references to B-1a or Ba-1 subtypes are found in the literature on the aircraft, but the meanings of these designations are somewhat unclear. Early in the war, when German aircraft firms created versions of their aircraft for export purposes, the **a** was added to export (*ausland*) variants (B-1a) or to foreign-built variants (Ba-1) but for the Me 163, there were neither export nor a foreign-built version. Later in the war, the "a" and successive letters were used for aircraft using different engine types: as Me 262A-1a with Jumo engines, A-1b with BMW engines. As the Me 163 was planned with an alternative BMW P3330A rocket engine, it is quite safe to assume the "a" was used for this purpose on early examples. Only one Me 163, the V10, was tested with the BMW engine, so this designation suffix was soon dropped. The Me 163 B-1a didn't have any wingtip "washout" built into it, and as a result, it had a much higher critical Mach number than the Me 163 B-1.

The Me 163B had very docile landing characteristics, mostly due to its integrated leading edge slots, located directly forward, along the wing's leading edge, of the elevon control surfaces. It would neither stall nor spin. One could fly the *Komet* with the stick full back, and have it in a turn and then use the rudder to take it out of the turn, and not fear it snapping into a spin. It would also slip well. Because it was derived from a glider, it had excellent gliding qualities, and had tendency to continue flying above the ground due to ground effect. On the other hand, making a too close turn from base onto final, the sink rate would increase, and one could quickly lose altitude and come in short. Another main difference from a propeller-driven aircraft is that there was no slipstream over the rudder. On takeoff, one had to attain the speed at which the aerodynamic controls become effective - about 129 km/h (80 mph) - and that was always a critical factor. Pilots used to flying propeller driven aircraft had to be careful the control stick wasn't somewhere in the corner when the control surfaces began working. These, like many other specific Me 163 problems, would be resolved by specific training.

The performance of the Me 163 far exceeded that of contemporary piston engine fighters. At a speed of over 320 km/h (200 mph) the aircraft would take off, in a so-called "sharp start" from the ground, from its two-wheeled dolly. The aircraft would be kept at low altitude until the best climbing speed of around 676 km/h (420 mph) was reached, at which point it would jettison the dolly, pull up into a 70° angle of climb, and rapidly climb to a bomber's altitude. It could go higher if required, reaching 12,000 m (39,000 ft) in an unheard-of three minutes. Once there, it would level off and quickly accelerate to speeds around 880 km/h (550 mph) or faster, which no Allied fighter could match. The usable Mach Number was similar to the Me-262, but because of the high thrust to drag ratio, it was much easier for the pilot to lose track of the onset of severe compressibility and loss of control. A Mach warning system was installed as a result. The aircraft was remarkably agile and docile to fly at high speed. According to Rudolf Opitz, chief test pilot of the Me 163, it could "fly circles around any other fighter of its time".

By this point, Messerschmitt was completely overloaded with production of the Bf 109 and attempts to bring the Me 210 into service. Production in a dispersed network was handed over to Klemm, but quality control problems were such that the work was later given to Junkers, who was, at that time, underworked. As with many German designs of World War II, parts of the airframe (especially wings) were made of wood by furniture manufacturers.



Me 163 S model in Soviet post-war test livery

The older Me 163A and first Me 163B prototypes were used for training. It was planned to introduce the **Me 163 S**, which removed the rocket engine and tank capacity and placed a second seat for the instructor above and behind the pilot, with its own canopy. The 163 S would be used for glider landing training, which as explained above, was

essential to operate the Me 163. It appears the 163 Ss were converted from the earlier Me 163B series prototypes.

In service, the Me 163 turned out to be difficult to use against enemy aircraft. Its tremendous speed and climb rate meant a target was reached and passed in a matter of seconds. Although the Me 163 was a stable gun platform, it required excellent marksmanship to bring down an enemy bomber. The *Komet* was equipped with two 30 mm (1.18 inch) MK 108 cannons which had a relatively low muzzle velocity, with the characteristic ballistic drop of such a weapon. The drop meant they were only accurate at short distance, and that it was almost impossible to hit a slow-moving bomber when the *Komet* was traveling very fast. Plus, four or five hits were typically needed to take down a B-17.

A number of innovative solutions were implemented to ensure kills by less experienced pilots. The most promising was a unique weapon called the *Sondergerät 500 Jägerfaust*. This consisted of a series of single-shot, short-barreled 50 mm (2-inch) guns pointing upwards. Five were mounted in the wing roots on each side of the aircraft. The trigger was tied to a photocell in the upper surface of the aircraft, and when the *Komet* flew under the bomber, the resulting change in brightness caused by the underside of the aircraft could cause the rounds to be fired. As each shell shot upwards, the disposable gun barrel that fired it was ejected downwards, thus making the weapon recoilless. It appears that this weapon was used in combat only once, resulting in the destruction of a Halifax bomber, though other sources say it was a Boeing B-17.

Later versions



Model of the Me 163 C



Model of the Me 163 BV18 (alias D)

The biggest concern about the design was the short flight time, which never met the projections made by Walter. With only seven and a half minutes of powered flight, the fighter truly was a dedicated point defense interceptor. To improve this, the Walter firm began developing two more advanced versions of the 509A rocket engine, the 509B and C, each with two separate combustion chambers of differing sizes, oriented one above the other, with greater efficiency. The upper chamber, intended as the motor's primary power output, was larger, and supported by the "thrust tube" exactly as the 509A motor's single chamber had been. It was tuned for "high power" for takeoff and climb. The smaller-volume, lower chamber, with approximately 400 kg (880 lb) of thrust at its top performance level, was intended for more efficient, lower-power cruise flight. This HWK 109-509 C would improve endurance by as much as 50%. Two 163 Bs, models V6 and V18, were experimentally fitted with the new engine, a retractable tailskid, and tested in spring 1944. On 6 July 1944, the Me 163 B V18 (VA+SP) set a new world speed record of 1,130 km/h (702 mph), piloted by Heini Dittmar, and landed with almost all of the vertical rudder surface broken away from flutter. This record was not broken in terms of absolute speed until 6 November 1947 by Chuck Yeager in a flight that was part of the Bell X-1 test program, with a 1,434 km/h (891 mph), or Mach 1.35 supersonic speed, recorded at an altitude of nearly 14,820 m (48,620 ft) altitude. However, the X-1 never exceeded Dittmar's speed from a normal runway liftoff. Heini Dittmar had reached the 1,130 km/h (702 mph) performance, after a normal "sharp start" ground takeoff, without an air drop from a mother ship. Neville Duke exceeded Heini Dittmar's record mark in 31

August 1953, with the Hawker Hunter F Mk3 at a speed of 1,171 km/h (728 mph), after a normal ground start. Aircraft of the configuration the Me 163 used were found to have serious stability problems when entering transonic flight, like the similarly configured, and turbojet powered, Northrop X-4 Bantam and de Havilland DH 108, which made the V18's record with the Walter 509C "cruiser" rocket more remarkable.

Waldemar Voigt (aerospace engineer) of Messerschmitt's *Oberammergau* project and development offices started a redesign of the 163 to incorporate the new engine, as well as fix other problems. The resulting **Me 163 C** design featured a larger wing through the addition of an insert at the wing root, an extended fuselage with extra tank capacity through the addition of a "plug" insert behind the wing, and a new pressurized cockpit topped with a bubble canopy for improved visibility. The additional tank capacity and cockpit pressurization allowed the maximum altitude to increase to 15,850 m (52,000 ft), as well as improving powered time to about twelve minutes, almost doubling combat time (from about five minutes to nine). Three **Me 163C-1a** prototypes were planned, but it appears only one was flown, without its intended engine.

By this time the project was moved to Junkers. There, a new design effort under the direction of Heinrich Hertel at Dessau attempted to improve the *Komet*. The Hertel team had to compete with the Lippisch team and their Me 163C. Hertel investigated the Me 163 and found it was not well suited for mass production and not optimized as a fighter aircraft, with the most glaring deficiency being the lack of retractable landing gear. For this, the Me 163V-18 was equipped with a non-retractable tricycle landing gear. (This prototype is often called the "Me 163D", but it is now clear that there never was a 163 D.) The resulting *Junkers Ju 248* used a three-section fuselage to ease construction. The V1 prototype was completed for testing in August 1944, and was glider tested behind a Junkers Ju 188. Some sources state that the Walter 109-509 C engine was fitted in September, but it was probably never tested under this power. At this point the RLM re-assigned the project to Messerschmitt, where it became the *Me 263*. This appears to have been a formality only, with Junkers continuing the work and planning production.

By the time the design was ready to go into production, the plant where it was to be built was overrun by Soviet forces. While it did not reach operational status, the work was briefly continued by the Soviet Mikoyan-Gurevich (MiG) design bureau as the Mikoyan-Gurevich I-270.

Operational history

Active combat operations began in May 1944, although on a small scale. As expected, the aircraft was extremely fast; and for a time, the Allied fighters were at a complete loss as what to do about it. Singly or in pairs, the *Komets* attacked, often faster than the opposing fighters could dive in an attempt to intercept them. A typical Me 163 tactic was to zoom through the bomber formations at 9,000 m (30,000 ft), rise up to an altitude of 10,700–12,000 m (35,100–39,000 ft), then dive through the formation again. This approach afforded the pilot two brief chances to fire a few rounds from his cannons

before gliding back to his airfield. The pilots reported that it was possible to make four passes on a bomber, but only if it was flying alone.

As the cockpit was unpressurized, the operational ceiling was limited by what the pilot could endure for several minutes while breathing oxygen from a mask, without losing consciousness. Pilots underwent altitude-chamber training to harden them against the rigors of operating in the thin air of the stratosphere without a pressure suit. Special low-fiber diets were prepared for pilots, as gas in the gastrointestinal tract would expand rapidly during ascent.

More than three years passed before Major Wolfgang Späte could form the first Me 163 combat wing, (*Jagdgeschwader 400* (JG 400)), in Brandis near Leipzig, which followed the establishment of the *Erprobungskommando 16* Me 163B-dedicated test and evaluation unit at Peenemunde-West eleven months earlier. JG 400's purpose was to provide additional protection for the Leuna synthetic gasoline works which were raided particularly heavily and frequently at the end of 1944. A further group was stationed at Stargard near Stettin to protect the large synthetic plant at Pölitz (today Police, Poland). Further defensive units of rocket fighters were planned for Berlin, the Ruhr and the German Bight.

The first actions involving the Me 163 occurred at the end of July, when two USAAF B-17 Flying Fortress were attacked without confirmed kills. Combat operations continued from May 1944 to spring 1945. During this time, there were nine confirmed kills with 14 Me 163s lost. Feldwebel Siegfried Schubert was the most successful pilot, with three bombers to his credit.

Allied fighter pilots soon noted the short duration of the powered flight. They would wait, and when the engine died they would pounce on the unpowered *Komet*. However, the *Komet* was extremely manoeuvrable and could pull out of a turn much later than any Allied fighter. Another Allied method was to attack the fields the Komets operated from, and strafed them after the Me 163s landed. Establishing a defensive perimeter with anti-aircraft guns ensured that Allied fighters avoided these bases. At the end of 1944, 91 aircraft had been delivered to JG 400 but a continuous lack of fuel had kept most of them grounded. It was clear that the original plan for a huge network of Me 163 bases was never going to happen. Up to that point, JG 400 had lost merely six aircraft due to the enemy actions. Nine were lost to other causes, remarkably low for such a revolutionary and technically advanced aircraft. In those last days of the Third Reich the Me 163 was given up in favour of the more successful and threatening Me 262. In May 1945, Me 163 operations were stopped, the JG 400 disbanded, and many of their pilots sent to fly Me 262s.

In any operational sense, the *Komet* was a failure. Although they shot down 16 aircraft, mainly expensive four-engined bombers, that did not warrant the efforts put into the project. With the projected Me 263, things could have turned out differently, but the *Komet* was an ineffective fighter aircraft. Due to fuel shortages late in the war, few went

into combat, and it took an experienced pilot with excellent shooting skills to achieve "kills" with the Me 163.

The *Komet* was a remarkable design that pointed the way to the future. It was one more piece of evidence that the day of the propeller fighter was over, and it also spawned later weapons like the Bachem Ba 349 Natter and Convair XF-92. Ultimately, the point defense role that the Me 163 played would be taken over by the surface-to-air missile (SAM), Messerschmitt's own example being the Enzian. The airframe designer, Alexander Martin Lippisch went on to design delta-winged supersonic aircraft for the Convair Corporation.

Flying the Me 163

Capt. Eric Brown, CBE, DSC, AFC, RN, Chief Naval Test Pilot and C.O. Captured Enemy Aircraft Flight, that tested the Me 163 at the RAE Farnborough, said that "The Me 163 was an aeroplane that you could not afford to just step into the aircraft and say 'You know, I'm going to fly it to the limit.' You had very much to familiarise with yourself with it because it was state-of-the-art and the technology used."

Acting unofficially, after a spate of accidents involving Allied personnel flying captured German aircraft resulting in official disapproval of such flights, Brown was determined to fly a powered *Komet*, and on around the 17th of May 1945, he flew an Me 163B at Husum with the help of a co-operative German ground crew, after initial towed flights in an Me 163A to familiarise himself with the handling. The day before the flight, Brown and his ground crew had performed an engine run on the chosen Me 163B to ensure that everything was running correctly, the German crew being apprehensive should an accident befall Brown, until being given a disclaimer signed by him to the effect that they were acting under his orders. On the take-off the next day, after dropping the take-off trolley and retracting the skid, Brown later described the resultant climb as "like being in charge of a runaway train", the aircraft reaching 32,000ft in two and a three-quarter minutes. During the flight, while practising attacking passes at an imaginary bomber, he was surprised at how well the *Komet* accelerated in the dive with the engine shut down. When the flight was over Brown had no problems on the approach to the airfield apart from the rather restricted view from the cockpit due to the flat angle of glide, the aircraft touching down at 125 mph. Once down safely, Brown and his much-relieved ground crew celebrated with a drink.

However, apart from Brown's unauthorised flight, the British never tested the Me 163 under power themselves, from the danger of its hypergolic propellants - it was only flown in unpowered form in their postwar tests, Brown himself flying the RAE's *Komet VF241* on a number of occasions, the rocket motor being replaced with test instrumentation.

Surviving aircraft

It has been claimed that at least 29 *Komets* were shipped out of Germany after the war and that of those at least 10 have been known to survive the war to be put on display in

museums around the world. Most of the 10 surviving Me 163s were part of JG 400, and were captured by the British at Husum, the squadron's base at the time of Germany's surrender in 1945. According to the RAF museum, 48 aircraft were captured intact and 24 were shipped to the United Kingdom for evaluation, although only one, *VF241*, was test-flown (unpowered).

United States

- Five Me 163s were originally brought to the United States in 1945, receiving the Foreign Equipment numbers FE-495 and FE-500 to 503. An Me 163 B-1a, Werknummer (serial number) *191301*, arrived at Freeman Field, Indiana, during the summer of 1945, and received the foreign equipment number FE-500. On 12 April 1946, it was flown aboard a cargo aircraft to the U.S. Army Air Forces facility at Muroc dry lake in California for flight testing. Testing began on 3 May 1946 in the presence of Dr. Alexander Lippisch and involved towing the unfueled *Komet* behind a B-29 to an altitude of 9,000–10,500 m (30,000–34,400 ft) before it was released for a glide back to earth under the control of test pilot Major Gus Lundquist. Powered tests were planned, but not carried out after delamination of the aircraft's wooden wings was discovered. It was then stored at Norton AFB, California until 1954, when it was transferred to the Smithsonian Institution. The aircraft remained on display in an unrestored condition at the museum's Paul E. Garber Restoration and Storage Facility in Suitland, Maryland, until 1996, when it was lent to the Mighty Eighth Air Force Museum in Pooler, Georgia for restoration and display but has since been returned to the Smithsonian for display at the Steven F. Udvar-Hazy Center near Washington D.C.. Werknummer *191301* is held by NASM, Silver Hill.
- Me 163 B, Werknummer *191095* is held at the USAFM and was gifted from the National Aviation Museum, Ottawa in 1999. It was placed on display at the National Museum of the United States Air Force near Dayton, Ohio on 10 December 1999. The aircraft had been owned and restored by the Canadian National Aviation Museum. *Komet* test pilot Rudolf "Rudi" Opitz was on hand for the dedication of the aircraft and discussed his experiences of flying the rocket-propelled fighter to a standing room only crowd. During the aircraft's restoration in Canada it was discovered that the aircraft had been assembled by French "forced labourers" who had deliberately sabotaged it by placing stones between the rocket's fuel tanks and its supporting straps. There are also indications that the wing was assembled with contaminated glue. Inside the fuselage was found patriotic French writing. The aircraft is displayed without any unit identification or Werk Nummer.
- Me 163 B, Werknummer *191660*, "Yellow 3", is held by the Flying Heritage Collection. Between 1961 and 1976, this aircraft was displayed at the Imperial War Museum in London. In 1976, it was moved the Imperial War Museum Duxford. It underwent a lengthy restoration, beginning in 1997, that was frequently halted as the restorers were diverted to more pressing projects. In May

2005, it was sold, reportedly for £800,000, to raise money for the purchase of a de Havilland/Airco DH.9 as the Duxford museum had no examples of a World War I bomber in its collection. Permission for export was granted by the British government's Department for Culture, Media and Sport as three other *Komet*s were held in British museums. "Yellow 3" has since been sold to Paul Allen.

United Kingdom

Of the 21 aircraft that were captured by the British, at least three have survived until today. They were assigned the British serial numbers *AM200* to *AM220*.

- Me 163 B, Werknummer *191316*, "Yellow 6", has been on display at the Science Museum in London, England since 1964 with the Walter motor removed for separate display. A second Walter motor and a takeoff dolly are part of the museum's reserve collection and are not generally on display to the public.
- Me 163 B, Werknummer *191614*, has been at the RAF Museum site at RAF Cosford, since 1975. Before then, it was at the Rocket Propulsion Establishment at Westcott, Buckinghamshire. This aircraft last flew on 22 April 1945, when it shot down an RAF Lancaster.
- Me 163 B-1a, Werknummer *191659* and RAF Air Ministry serial number *AM215*, "Yellow 15", was captured at Husum in 1945 and was sent to the College of Aeronautics at Cranfield, England in 1947. After many years of touring airshows and various outdoor gatherings around the UK it was finally loaned to the National Museum of Flight at East Fortune Airfield, East Lothian, Scotland in 1976.

Germany



Messerschmitt Me 163 at the *Luftwaffenmuseum* in Berlin-Gatow

- A Me 163 B, Werknummer *191904*, "Yellow 25", belonging to JG 400 was captured by the RAF at Husum in 1945. It was sent to England, arriving first at Farnborough, receiving the RAF Air Ministry number *AM219* and then transferred to Brize Norton on 8 August 1945, before finally being placed on display at the Station Museum at Colerne. When the museum closed in 1975 the aircraft went to RAF St Athan, receiving the ground maintenance number *8480M*. On 5 May 1988 the aircraft was returned to the *Luftwaffe* and moved to the *Luftwaffe* Alpha Jet factory at the air base in Oldenburg (JBG 43). The airframe was in good condition but the cockpit had been stripped and the rocket engine was missing. Eventually an elderly German woman came forward with Me 163 instruments that her late husband had collected after the war, and the engine was reproduced by a machine shop owned by Me 163 enthusiast Reinhold Opitz. The factory closed in the early 1990s and the "Yellow 25" was moved to a small museum created on the site. The museum contained aircraft that had once served as gate guards, monuments and other damaged aircraft previously located on the air base. In 1997 "Yellow 25" was finally moved to the official Luftwaffe Museum located at the former RAF base at Berlin-Gatow, where it is displayed today alongside a restored Walter HWK 109-509 rocket engine. This particular Me 163B is one of the very few World War II-era German military aircraft, restored and preserved in a German aviation museum, to have a swastika national marking of the Third Reich, in a "low-visibility" white outline form, currently displayed on the tailfin. The marking could likely be in violation of the German criminal law section known as Strafgesetzbuch § 86a.
- Me 163 B, Werknummer *120370*, "Yellow 6" of JG 400, is displayed at the Deutsches Museum, Munich. It was originally sent to Britain, where it had received the RAF Air Ministry number *AM210*. It was given to the Deutsches museum by RAF Biggin Hill station. Some claim this is *191316*, but that is still at the London Science Museum.

Canada



Me 163 B Komet, Werknummer 191914 at the Canada Aviation and Space Museum

- Me 163 B, Werknummer *191659 (AM215)* or *191914 (AM220)*, is held at the Canada Aviation and Space Museum, Ottawa. Like two of the British Komets, this aircraft was part of JG 400 and captured at Husum. It was shipped to Canada in 1946.

Werknummer *19116* (but more probable *191916*) and *191095 (AM211)* also seem to have been held at one time in this museum.

Australia

- Me 163 B, Werknummer *191907*, is part of the collection of the Australian War Memorial. This aircraft was also part of JG 400 and captured at Husum.

Japanese versions

As part of their alliance, Germany provided the Japanese Empire with plans and an example of the Me 163. One of the two submarines carrying Me 163 parts did not arrive

in Japan, so at the time, the Japanese lacked a few important parts, including the turbopump which they could not make themselves. The Japanese Me 163 crashed on its first flight and was completely destroyed. The Japanese versions were designed as trainers, fighters, and interceptors. Differences between the versions were fairly minor. The Mitsubishi Ki-200 *Shusui* ("Shu" means "autumn", "sui" means "water" in Japanese) was the equivalent of the 163 B, armed with two 30 mm (1.18 in) Ho 155-II cannon. The Navy version, the Mitsubishi J8M1 *Shusui*, simply replaced the Ho 155 cannon with the Navy's 30 mm (1.18 in) Type 5.

Mitsubishi also planned on producing a version of the 163 C for the Navy, known as the J8M2 *Shusui* Model 21. A version of the 163 D/263 was known as the J8M3 *Shusui* for the Navy with the Type 5 cannon, and a Ki-202 *Shusui-kai* ("kai" means "modified" in Japanese) with the Ho 155-II for the Army.

Trainers were planned, roughly the equivalent of the Me 163 A-0/S. These were known as the Yokoi Ku-13 *Akigusa* ("Aki" means also "autumn" and "*gusa (kusa)*" means "grass" in Japanese) or Ki-200 *Syusui* Rocket Interceptor practice glider ("Syusui" with "y").

Other trainer variants included:

- **Yokoi Experimental Ki-13 *Shusui* Heavy Glider.** This glider was created as the Ki-200 *Syusui* Rocket Interceptor practice glider. The project was cancelled due to high costs.
- **Kugisho/Yokosuka MXY-8 *Akigusa* Rocket Interceptor practice glider (Experimental *Shusui* Light Glider).** Created as the J8M1 *Syusui* Rocket Interceptor practice glider.
- **Kugisho/Yokosuka MXY-9 Experimental *Shusui* Heavy Glider.** This glider was created as the J8M1 *Syusui* Rocket Interceptor practice glider, but was cancelled due to high costs.
- **Kugisho/Yokosuka MXY-9 *Shuka* Rocket Interceptor Operative training glider.** This aircraft would have used the Hitachi "Hatsukaze-11" fan jet engine on the MXY-8 "*Akigusa*" airframe.

Replicas



Me 163 replica glider.

A flying replica Me 163 was constructed between 1994 and 1996 by Joseph Kurtz, a former *Luftwaffe* pilot who trained to fly Me 163s, but who never flew in combat. He subsequently sold the aircraft to EADS. The replica is an unpowered glider whose shape closely matches that of an Me 163, although its weight and internal construction differ considerably. Reportedly, it has excellent flying characteristics.

XCOR Aerospace, an aerospace and rocketry company, proposed a rocket-powered replica, the *Komet II*. Although outwardly the same as a wartime aircraft, the design would have differed considerably for safety reasons. It would have been partially constructed with composite materials, powered by one of XCOR's own simpler and safer, pressure fed, liquid oxygen/alcohol engines, and retractable undercarriage would have been used instead of a takeoff trolley and landing skid. The project is no longer discussed on the company's website, and it appears work has ceased on this project.

Several static replicas of the aircraft are exhibited in museums.

Specifications: Me 163 B-1

General characteristics

- **Crew:** 1
- **Length:** 5.70 m (18 ft 8 in)

- **Wingspan:** 9.33 m (30 ft 7 in)
- **Height:** 2.75 m (9 ft 0 in)
- **Wing area:** 18.5 m² (200 ft²)
- **Empty weight:** 1,905 kg (4,200 lb)
- **Loaded weight:** 3,950 kg (8,710 lb)
- **Max takeoff weight:** 4,310 kg (9,500 lb)
- **Powerplant:** 1× Walter HWK 109-509A-2 liquid-fuel rocket, 17 kN (3,800 lbf)

Performance

- **Maximum speed:** 1,060 km/h (596 mph)
- **Range:** 40 km (25 mi)
- **Service ceiling:** 12,100 m (39,700 ft)
- **Rate of climb:** 160 m/s (31500 ft/min)
- **Wing loading:** 213 kg/m² (43 lb/ft²)
- **Thrust/weight:** 0.42

Armament

- **Guns:** *2 × 30 mm (1.18 in) Rheinmetall Borsig MK 108 cannons (60 rpg)

The oft quoted top speed of 596 mph (959 km/h) up to the tropopause is impossible, as it corresponds to a Mach Number of over .89—the Me-163B ran into severe compressibility above .82 and complete loss of control at M=.84. This anomaly has not been explained,

Chapter- 10

Mitsubishi J8M

Mitsubishi J8M



Role	Interceptor
Manufacturer	Mitsubishi
First flight	7 July 1945
Primary users	IJA Air Service IJN Air Service
Produced	1944-1945
Number built	7
Developed from	Messerschmitt Me 163
Variants	Yokosuka MXY8 Yokosuka MXY9

The **Mitsubishi J8M *Shūsui*** (Japanese: 三菱 J8M 秋水, literally "Autumn Water", used as a poetic term meaning "Sharp Sword" deriving from the swishing sound swords make) was a Japanese World War II rocket-powered interceptor aircraft closely based on the German Messerschmitt Me 163 *Komet*.

Design and development

The J8M1 was intended to be a licence-built copy of the Messerschmitt Me 163 *Komet*. Difficulties in shipping an example to Japan meant that the aircraft eventually had to be

reverse-engineered from a flight operations manual and other limited documentation. A single prototype was tested before the end of World War II.

The Japanese were quite aware of the results of the strategic bombing of Germany, and knew that the B-29 Superfortress would be bombing Japan and the resultant problems which would arise from trying to combat this. Japanese military attachés had become aware of the *Komet* during a visit to the *Luftwaffe* squadron evaluation aircraft centre *Erprobungskommando 16*. They negotiated the rights to licence-produce the aircraft and its Walter HWK 509A rocket engine. The engine license alone cost the Japanese 20 million *Reichsmarks*.

The agreement was for Germany to provide the following by spring 1944:

- Complete blueprints of the Me 163B *Komet* and the HWK 509A engine.
- One complete *Komet*; two sets of sub-assemblies and components.
- Three complete HWK 509A engines.
- Inform Japan of any improvements and developments of the *Komet*.
- Allow the Japanese to study the manufacturing processes for both the *Komet* and the engine.
- Allow the Japanese to study *Luftwaffe* operational procedures for the *Komet*.

The broken-down aircraft and engine were sent to Kobe, Japan in early 1944. It is probable that the airframe was on the Japanese submarine *RO-501* (ex-*U-1224*), which left Kiel, Germany on 30 March 1944 and was sunk in the mid-Atlantic on 13 May 1944 by the hunter-killer group based on the escort carrier *USS Bogue*. Plans and engines were on the Japanese submarine *I-29*, which left Lorient, France on 16 April 1944 and arrived in Singapore on 14 July 1944, later sunk by the submarine *USS Sawfish* on 26 July 1944, near the Philippines, after leaving Singapore.

The Japanese decided to attempt to copy the Me 163 using a basic instructional manual on the *Komet* in the hands of naval mission member Commander Eiichi Iwaya who had travelled to Singapore in the *I-29* and flown on to Japan when the submarine docked.

From its inception, the project was a joint Imperial Japanese Army Air Service (JAAF)/Imperial Japanese Navy Air Service (JNAF) venture. The JAAF wanted a new design to be drawn up. The JNAF, on the other hand, felt the design should mimic the German *Komet* because it had already proven to be a stable aerodynamic body. It was the JNAF which won and issued the *19-shi* specification in July 1944 for the design of the rocket-powered defence fighter. The contract went to Mitsubishi *Jukogyo* KK, which would produce both the JNAF version the J8M1 *Shūsui* and the JAAF version Ki-200.

The project was headed by Mijiro Takahashi. The JAAF, however decided to undertake their own design to meet the *19-shi* specifications, working at their *Rikugun Kokugijitsu Kenkyujo* (JAAF Aerotechnical Institute) in secret.

At the 1st Naval Air Technical Arsenal in Yokosuka, in association with Mitsubishi and Yokosuka Arsenal, work began to adapt the Walter HWK 509A engine to Japanese manufacturing capabilities and techniques. This was also where efforts were underway to produce a glider version of the J8M to provide handling data. While working on this glider, the MXY8 *Akigusa* (秋草, "Autumn Grass"), Mitsubishi completed a mock-up of the J8M1 in September 1944.

Both the JAAF and JNAF approved its design and construction and a prototype was built. In December 1944, the MXY8 was completed and, on 8 December 1944, at the Hyakurigahara Airfield, Lieutenant-Commander Toyohiko Inuzuka took the controls of the MXY8. Once in the air, Inuzuka found the MXY8 almost perfectly emulated the handling characteristics of the *Komet*. Two additional MXY8 gliders were constructed in the naval yard at Yokosuka, one being delivered to the *Rikugun Kokugijitsu Kenkyujo* (JAAF Aerotechnical Institute) at Tachikawa for evaluation. The JNAF initiated the construction another prototype, production designation Ku-13. This was to use water ballast to simulate the weight of an operational J8M complete with engine and weapons. This variant was to be built by Maeda Aircraft Institute, while the JAAF version was to be constructed by *Yokoi Koku KK* (Yoki Aircraft Co). The JNAF also proposed a more advanced trainer, designated the MXY9 *Shūka* (秋火, "Autumn Fire") which would be powered by a 441 lbf (1.96 kN) thrust Tsu-11 ducted-fan engine. The war, however, ended before this model could be built.

Mitsubishi and partners Nissan and Fuji proceeded with development of the airframe and Yokosuka Arsenal was adapting the engine for Japanese production, designated the Ro.2. The Japanese succeeded in producing prototypes that outwardly looked very much similar to the *Komet*. The J8M1 had a wet weight that was 900 lb (410 kg) lighter, the aircraft having a plywood main spar and wooden vertical tail. The designers had also dispensed with the armoured glass in the cockpit and the aircraft carried less ammunition and slightly less fuel.

The Ki-200 and the J8M1 differed only in minor items, but the most obvious difference was the JAAF's Ki-200 was armed with two 30 mm (1.18 in) Type 5 cannon (with a rate of fire of 450 rounds per minute and a muzzle velocity of 2,350 ft/s (720 m/s), while the J8M1 was armed with two 30 mm (1.18 in) Ho-105 cannon (rate of fire 400 rounds per minute, muzzle velocity 2,460 ft/s (750 m/s). The Ho-105 was the lighter of the two and both offered a higher velocity than the MK 108 cannon of the Me 163 (whose muzzle velocity was 1,705 ft/s (520 m/s). The Toko Ro.2 (KR10) rocket motor did not offer the same thrust rating as the original, and Mitsubishi calculated that the lighter weight of the J8M1 would not offset this. Performance would not be as good as that of the *Komet*, but was still substantial.

The engine still used the German propellants of T-Stoff oxidizer and C-Stoff fuel (hydrogen peroxide/methanol-hydrazine), known in Japan as *Ko* and *Otsu* respectively.

A total of 60 of the training version (Ku-13, Ki-13, MXY-8, MXY-9) were produced by Yokosuka, Yokoi and Maeda. Seven of the operational version (J8M1/Ki-200) were built by Mitsubishi.

Operational history

In 8 January 1945, one of the two J8M1 prototypes was towed aloft, water ballast added in place of the fuel tank and rocket engine to test its aerodynamics. The test flights confirmed the design. Training courses for JAAF and JNAF pilots began on the Ku-53 glider, which shared a similar configuration to the J8M1. The 312th Naval Air Group was selected to operate the first J8M1. Mitsubishi, Fuji Hikoki, and Nissan Jidosha all had tooling for mass production well into the advanced stages, ready to produce both the J8M1 and the J8M2 variant, which differed from the J8M1 in sacrificing one of the Type 5 cannon for a small increase in fuel capacity. The first J8M1 prototype to be equipped with the Toko Ro.2 (KR10) was ready in June 1945. They were then transferred from the Nagoya plant to Yokosuka for final checks before powered flight testing, after final glide tests with the engine installed.

The J8M took to the air for its first powered flight on 7 July 1945, with Lieutenant Commander Toyohiko Inuzuka at the controls; Inuzuka successfully jettisoned the dolly upon becoming airborne and began to gain speed, climbing skywards at a 45° angle. At an altitude of 396 m (1,300 ft), the engine stopped abruptly and the J8M1 stalled. Inuzuka managed to glide the aircraft back, but clipped a small building at the edge of the airfield while trying to land, causing the aircraft to burst into flames. Inuzuka died the next day. While Mitsubishi and naval technicians sought to find the cause of the accident, all future flights were grounded. The engine cutout had occurred because the angle of climb, coupled with the fuel tanks being half-filled for this first flight, caused a shifting of the fuel, which in turn caused an auto cutout device to activate because of an air lock in the fuel line. Requests to continue flight testing were denied pending the modification of the fuel pumps in the aircraft. The sixth and seventh prototypes were to be fitted with the modified Ro.2 engine.

Full scale production readiness was almost at hand and in fact, component construction was already underway. Flight testing was to resume, despite another explosion of the fuel mixture during a ground test days after the crash, in late August 1945 and the J8M2 design was finalized. But on 15 August 1945, the war ended for the Japanese and all work on the J8M ceased. The end of the war also spelled the end of the JAAF's Ki-202 *Shūsui-Kai* (Modified *Shūsui*), whose design had begun in secret months before. The Ki-202 was to offer improved flight endurance over the Ki-200 and was slated to be the priority fighter for the JAAF in 1946, but no metal was cut on this fighter before Japan's surrender.

Germany tried to send another *Komet* on *U-864*, but this submarine was sunk near Bergen by British submarine HMS *Venturer* in February 1945.

Variants

J8M1

J8M2 *Shūsui* Model 21(?)

Long-range version for Navy, identical to J8M1, but armament reduced to a single 30 mm (1.18 in) cannon.

J8M3 *Shūsui* Model 22 (Ki-202 *Shūsui-kai*)

Long-range version for Army and Navy, with fuselage and wingspan lengthened to 7.10 m (23 ft 3 in) and 9.75 m (32 ft 0 in) respectively. Powered by 19.6 kN (4,410 lbf) Tokuro-3, projected maximum speed 900 km/h (560 mph).

Yokosuka MXY-8 "*Akigusa*" (Yokoi Ku-13)

Training glider using J8M airframe for Navy and Army.

Yokosuka MXY-9 "*Shuka*"

Training version using J8M airframe, powered by Tsu-11 thermojet engine.

Operators

- Japan
 - Imperial Japanese Army Air Service
 - Imperial Japanese Navy Air Service

Survivors



The J8M1 at the Planes of Fame Museum.

In November 1945, two aircraft were taken from Yokosuka to the United States for evaluation aboard USS *Barnes*. FE-300/T2-300 (USA ident) (Japanese ident 403) is now exhibited in the Planes of Fame Museum. The other was at NAS Glenview in October 1946 (identity unknown), but was scrapped.

In the 1960s, a nearly complete (but badly damaged) fuselage was discovered in a cave in Japan. This was on display at a Japanese Air Force Base near Gifu until 1999, when it was restored and completed by Mitsubishi for display in the company's internal Komaki Plant Museum.

Specifications (J8M1/Ki-200)

General characteristics

- **Crew:** one, pilot
- **Length:** 6.05 m (19 ft 10 in)
- **Wingspan:** 9.50 m (31 ft 2 in)
- **Height:** 2.70 m (8 ft 10 in)
- **Wing area:** 17.73 m² (190 ft²)
- **Empty weight:** 1,505 kg (3,311 lb)
- **Loaded weight:** 3,885 kg (8,547 lb)
- **Powerplant:** 1× Mitsubishi KR10 (Toku Ro.2) Rocket, 14.7 kN (1,500 kgf / 3,300 lbf)

Performance

- **Maximum speed:** 900 km/h (560 mph)
- **Cruise speed:** 347 km/h
- **Service ceiling:** 12,000 m (39,370 ft)
- **Rate of climb:** 2,858 m/min (9,374 ft/min)
- **Endurance :** 5 min 30 seconds

Armament

- **J8M1 :** 2 × 30 mm Ho-105 cannons
- **Ki-200 :** 2 × 30 mm Type 5 cannons

Chapter- 11

Northrop HL-10

HL-10



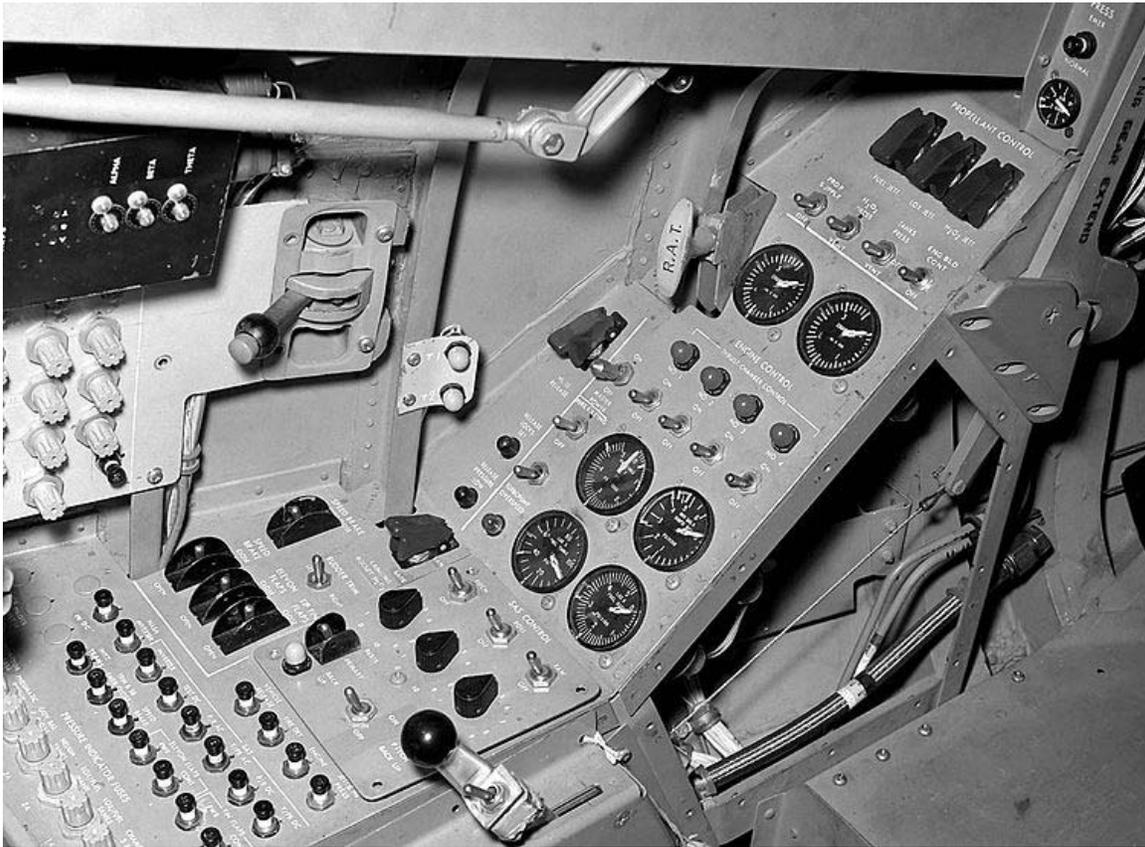
Role	Lifting body
Manufacturer	Northrop
Designed by	Langley Research Center
First flight	22 December 1966
Retired	17 July 1970
Status	On display
Primary user	NASA
Number built	1

The **Northrop HL-10** was one of five heavyweight lifting body designs flown at NASA's Flight Research Center (FRC—later Dryden Flight Research Center), Edwards, California, from July 1966 to November 1975 to study and validate the concept of safely maneuvering and landing a low lift-over-drag vehicle designed for reentry from space. It was a NASA design and was built to evaluate "inverted airfoil" lifting body and delta planform. It currently is on display at the entrance to the Dryden Flight Research Center, Edwards Air Force Base, California.

Development

Northrop Corporation built the HL-10 and Northrop M2-F2, the first two of the fleet of "heavy" lifting bodies flown by the NASA Flight Research Center. The contract for construction of the HL-10 and the M2-F2 was \$1.8 million. "HL" stands for horizontal landing, and "10" refers to the tenth design studied by engineers at NASA's Langley Research Center, Hampton, Virginia. Main gear was a modified T-38 system retracted manually, and lowered by nitrogen pressure. Nose gear was modified T-39 unit, retracted manually and lowered with nitrogen pressure. Pilot Ejection System was a modified F-106 system. Silver zinc batteries provided electrical power for control system, flight instruments, radios, cockpit heat, and stability augmentation system. To assist in pre-landing flare, four throttleable hydrogen peroxide rockets provided up to 400 lbf (1.8 kN) of thrust.

Operational history



Cockpit of the HL-10 lifting body.

After delivery to NASA in January 1966, the HL-10 made its first flight on December 22, 1966, with research pilot Bruce Peterson in the cockpit. Although the XLR-11 rocket engine (same type used in the Bell X-1) was installed, the first 11 drops from the B-52 launch aircraft were unpowered glide flights to assess handling qualities, stability, and

control. In the end, the HL-10 was judged to be the best handling of the three original heavy-weight lifting bodies (M2-F2/F3, HL-10, X-24A).

The HL-10 was flown 37 times during the lifting body research program and logged the highest altitude and fastest speed in the lifting body program. On February 18, 1970, Air Force test pilot Peter Hoag piloted the HL-10 to Mach 1.86 (1,228 mph). Nine days later, NASA pilot Bill Dana flew the vehicle to 90,030 feet (27,440 m), which became the highest altitude reached in the program.

During a typical lifting body flight, the B-52—with the research vehicle attached to the pylon mount on the right wing between the fuselage and inboard engine pod—flew to a height of about 45,000 feet (14,000 m) and a launch speed of about 450 mph (720 km/h).

Moments after being dropped, the XLR-11 was lit by the pilot. Speed and altitude increased until the engine was shut down by choice or fuel exhaustion, depending upon the individual mission profile. The lifting bodies normally carried enough fuel for about 100 seconds of powered flight and routinely reached from 50,000 feet (15,000 m) to 80,000 feet (24,000 m) and speeds above Mach 1.

Following engine shutdown, the pilot maneuvered the vehicle through a simulated return-from-space corridor into a pre-planned approach for a landing on one of the lakebed runways on Rogers Dry Lake at Edwards. A circular approach was used to lose altitude during the landing phase. On the final approach leg, the pilot increased his rate of descent to build up energy. At about 100 feet (30 m) altitude, a "flare out" maneuver dropped air speed to about 200 mph (320 km/h) for the landing.

Unusual and valuable lessons were learned through the successful flight testing of the HL-10. During the early phases of the Space Shuttle development program, lifting bodies patterned on the HL-10 shape were one of three major types of proposals. These were later rejected as it proved difficult to fit cylindrical fuel tanks into the always-curving fuselage, and from then on most designs focused on more conventional delta wing craft.

- HL-10 pilots
 - John A. Manke - 10 flights
 - William H. Dana - 9 flights
 - Jerauld R. Gentry - 9 flights
 - Peter C. Hoag - 8 flights
 - Bruce Peterson - 1 flight

Unrealized space flight

According to the book "Wingless Flight", by project engineer R. Dale Reed, if he had had his way, the HL-10 would have flown in space in the early to mid-1970s. Following the cancellation of the Apollo moon project, Reed realized that there would be substantial Apollo hardware left over, including several flight-rated command modules and Saturn V rockets.

His plan was to heavily modify the HL-10 at the Flight Research Center with the addition of an ablative heat shield, reaction controls, and other additional subsystems needed for manned spaceflight. The now space-rated vehicle would have then flown on the Apollo-Saturn V launch vehicle in the same space which originally held the Lunar Module.

Once in Earth orbit, it was planned that a robotic extraction arm would remove the vehicle from the rocket's third stage and place it adjacent to the manned Apollo CSM spacecraft. One of the astronauts, who would be trained to fly the vehicle, would then spacewalk from the Apollo and board the lifting body to perform a pre-reentry check on its systems.

It was planned that there would be two flights in this program. In the first, the lifting body pilot would return to the Apollo and send the HL-10 back to earth unmanned. If this flight was successful, on the next launch, he would then pilot the HL-10 back to earth for a planned landing at Edwards AFB.

Reportedly, Wernher von Braun thought it was a wonderful idea and offered to prepare two Saturn Vs and Apollo Command Service Modules for the mission. Flight Research Center director Paul Bickle said no, stating that this was beyond his expertise or area of interest.

HL-10 flights

Vehicle Flight #	Date	Pilot	Mach	Velocity /km/h	Altitude /m	Duration	Comments
HL-10 #1	December 22, 1966	Peterson	0.693	735	13,716	00:03:07	First HL-10 Flight Unpowered glide
HL-10 #2	March 15, 1968	Gentry	0.609	684	13,716	00:04:03	Unpowered glide
HL-10 #3	April 3, 1968	Gentry	0.690	732	13,716	00:04:02	Unpowered glide
HL-10 #4	April 25, 1968	Gentry	0.697	739	13,716	00:04:18	Unpowered glide
HL-10 #5	May 3, 1968	Gentry	0.688	731	13,716	00:04:05	Unpowered glide
HL-10 #6	May 16, 1968	Gentry	0.678	719	13,716	00:04:25	Unpowered glide
HL-10 #7	May 28, 1968	Manke	0.657	698	13,716	00:04:05	Unpowered glide
HL-10 #8	June 11, 1968	Manke	0.635	697	13,716	00:04:06	Unpowered glide
HL-10 #9	June 21, 1968	Gentry	0.637	700	13,716	00:04:31	Unpowered glide

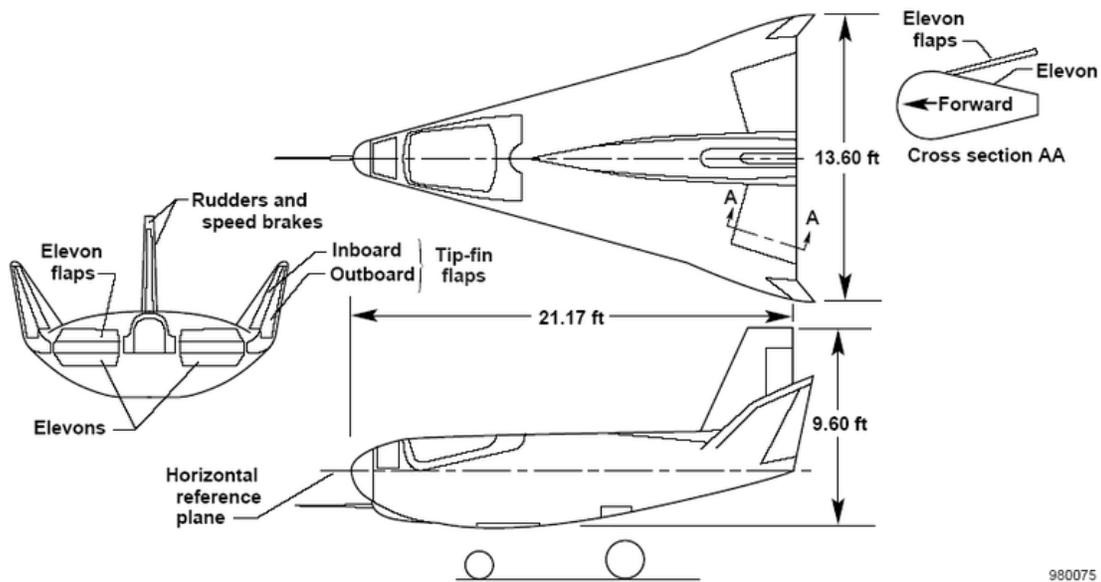
HL-10 #10	September 24, 1968	Gentry	0.682 723	13,716	00:04:05	Unpowered glide XLR-11 installed
HL-10 #11	October 3, 1968	Manke	0.714 758	13,716	00:04:03	Unpowered glide 1st powered flight engine malfunction landed Rosamond
HL-10 #12	October 23, 1968	Gentry	0.666 723	12,101	00:03:09	3 tries to light engine
HL-10 #13	November 13, 1968	Manke	0.840 843	13,000	00:06:25	-
HL-10 #14	December 9, 1968	Gentry	0.870 872	14,454	00:06:34	-
HL-10 #15	April 17, 1969	Manke	0.994 974	16,075	00:06:40	-
HL-10 #16	April 25, 1969	Dana	0.701 744	13,716	00:04:12	Unpowered glide 1st lifting body supersonic flight
HL-10 #17	May 9, 1969	Manke	1.127 1,197	16,246	00:06:50	-
HL-10 #18	May 20, 1969	Dana	0.904 959	14,966	00:06:54	-
HL-10 #19	May 28, 1969	Manke	1.236 1,312	18,959	00:06:38	-
HL-10 #20	June 6, 1969	Hoag	0.665 727	13,716	00:03:51	Unpowered glide
HL-10 #21	June 19, 1969	Manke	1.398 1,484	19,538	00:06:18	-
HL-10 #22	July 23, 1969	Dana	1.444 1,350	19,446	00:06:13	-
HL-10 #23	August 6, 1969	Manke	1.540 1,656	23,195	00:06:12	1st four chambered flight
HL-10 #24	September 3, 1969	Dana	1.446 1,542	23,762	00:06:54	-
HL-10 #25	September 18, 1969	Manke	1.256 1,341	24,137	00:07:06	-
HL-10 #26	September 30, 1969	Hoag	0.924 980	16,383	00:07:16	-

HL-10 #27	October 27, 1969	Dana	1.577	1,675	18,474	00:06:57	-
HL-10 #28	November 3, 1969	Hoag	1.396	1,482	19,544	00:07:19	-
HL-10 #29	November 17, 1969	Dana	1.594	1,693	19,687	00:06:48	-
HL-10 #30	November 21, 1969	Hoag	1.432	1,532	24,165	00:06:18	-
HL-10 #31	December 12, 1969	Dana	1.310	1,402	24,372	00:07:08	-
HL-10 #32	January 19, 1970	Hoag	1.310	1,399	26,414	00:06:50	-
HL-10 #33	January 26, 1970	Dana	1.351	1,444	26,726	00:06:51	-
HL-10 #34	February 18, 1970	Hoag	1.861	1,976	20,516	00:06:20	Fastest lifting body flight
HL-10 #35	February 27, 1970	Dana	1.314	1,400	27,524	00:06:56	Highest lifting body flight
HL-10 #36	June 11, 1970	Hoag	0.744	810	13,716	00:03:22	Lift/Drag powered approach
HL-10 #37	July 17, 1970	Hoag	0.733	803	13,716	00:04:12	Last flight

Aircraft serial number

- **Northrop HL-10** - NASA 804, 37 flights

Specifications (Northrop HL-10)



(d) The HL-10 vehicle.

NASA HL-10 Lifting Body Diagram

General characteristics

- **Crew:** one pilot
- **Length:** 21 ft 2 in (6.45 m)
- **Wingspan:** 13 ft 7 in (4.15 m)
- **Height:** 9 ft 7 in (2.92 m)
- **Wing area:** 160 ft² (14.9 m²)
- **Empty:** 5,285 lb (2,397 kg)
- **Loaded:** 6,000 lb (2,721 kg)
- **Maximum takeoff:** 10,009 lb (4,540 kg) (propellant wt 3,536 lb - 1,604 kg)
- **Powerplant:** 1 x Reaction Motors XLR-11 four-chamber rocket engine. 8,000 lbf (35.7 kN) thrust

Performance

- **Maximum speed:** 1,228 mph (1,976 km/h)
- **Range:** 45 miles (72 km)
- **Service ceiling:** 90,303 ft (27,524 m)
- **Rate of climb:** ft/min (m/min)
- **Wing loading:** 62.5 lb/ft² (304.7 kg/m²)
- **Thrust-to-weight:** 1:0.99

Chapter- 12

Buran (spacecraft)

Buran Буран



Buran on launch pad 110/37

Country	 Soviet Union
Named after	"Snowstorm"
Status	Decommissioned; destroyed in a 2002 hangar collapse
First flight	1K1 15 November 1988
Last flight	1K1 15 November 1988

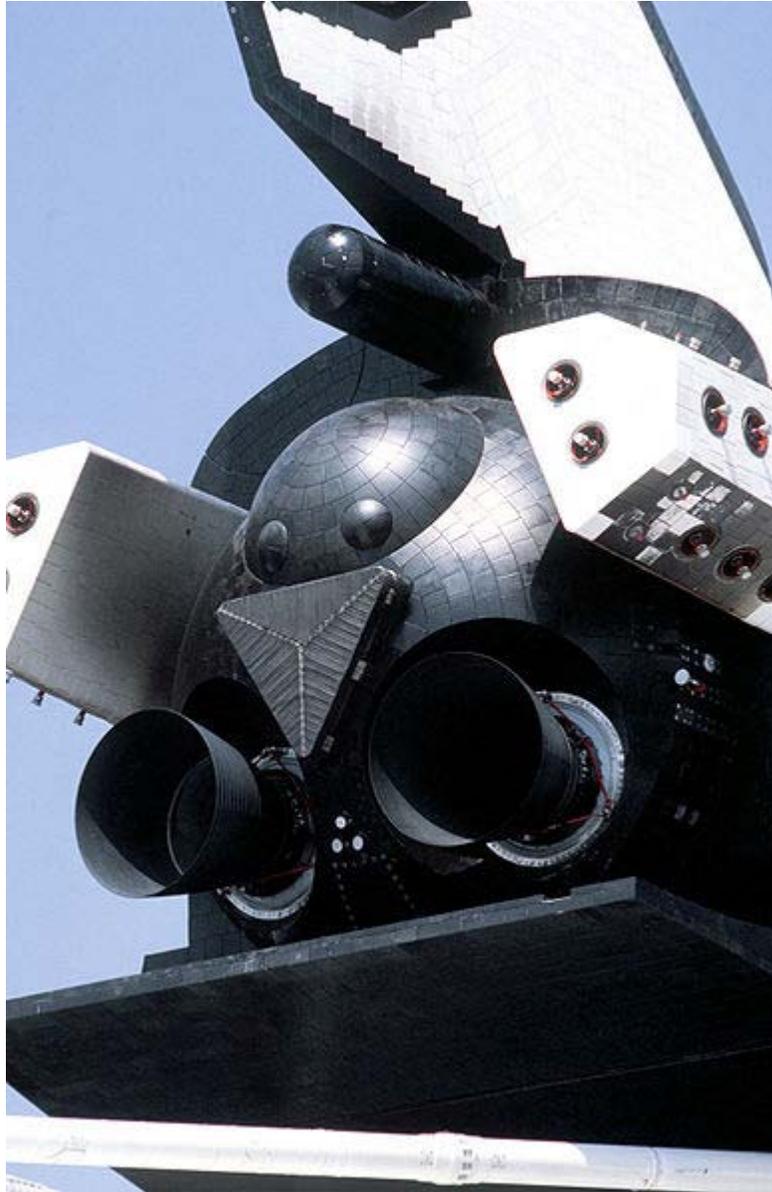
Number of missions 1
Crews 0
Time spent in space 3 hours
Number of orbits 2



Buran being carried by the Antonov An-225.



Buran at an airshow (1989)



Aft end of orbiter (1989)

The **Buran spacecraft** GRAU index *11F35 K1* is a Russian (Soviet) orbital vehicle (in Russian terminology: "орбитальный самолет", - "orbital airplane") analogous in function to the U.S. Space Shuttle and developed by Chief Designer Gleb Lozino-Lozinsky of Energia rocket corporation. To this day Buran remains the only space shuttle vehicle from the Soviet Buran program that was launched in space before the program closure. The Buran completed one unmanned spaceflight in 1988 before the cancellation of the program in 1993 and was later stored in a hangar at Baykonur cosmodrome before a hangar collapse accident in 2002 destroyed both the hangar and the orbital vehicle.

Overview

The Buran orbital vehicle program was developed in response to the U.S. Space Shuttle program, which in the 80s raised considerable concerns among the Russian military and especially minister Dmitry Ustinov. An authoritative biographer of the Russian space program, Academic Boris Chertok recounts how the program came into being.

According to Chertok, after the U.S. developed its Space Shuttle program, the Russian military became suspicious as to whether it could be used for military purposes. The enormous payload, times exceeding that of hitherto existing U.S. spaceships, raised the suspicions of pretty much all defense-related organizations of the USSR of that time. The Soviet government asked the Russian CNIIMASH (ЦНИИМАШ, Central Institute of Machine-building, a major player in defense analysis) for an expert opinion. Institute director, Gen. Mozzhorin, recalls that for a long time the institute could not make up its mind as to what civilian payload was so large as to require a vehicle of that capacity. Based on this as well as on US profitability analyses of that time, which showed that the Space Shuttle would be economically efficient only with a large number of launches (one every week or so), Mozzhorin concluded that the vehicle had a military purpose, although he himself was at a loss to say exactly what. The Soviet program received further impulse after minister Dmitry Ustinov received a report that, at least in theory, analysts could not rule out the Space Shuttle being used to deploy nuclear bombs over Russian territory. Chertok recounts that Ustinov was so worried by the possibility that he put the Soviet response program as a top priority.

Officially the Buran spacecraft was designed for the delivery to orbit and return to Earth of spacecraft, cosmonauts, and supplies, although Chertok and interviews with Gleb Lozino-Lozinsky before his passing in 1999 suggest that from the very beginning, the program was military in nature. The exact military capabilities, or intended capabilities, of the Buran program however up to the present day remain classified. Like its American counterpart, the *Buran*, when in transit from its landing sites back to the launch complex, was transported on the back of a large jet aeroplane. It was suspended on top of an Antonov An-225 Mriya transport aircraft, which was designed in part for this task and remains the largest aircraft in the world.

Flight into space

The only orbital launch of *Buran* occurred at 3:00 UTC on 15 November 1988 from Baikonur Cosmodrome Site 110/37. It was lifted into orbit unmanned by the specially designed Energia rocket, which to this day remains the heaviest rocket running on liquid fuel. Unlike the Space Shuttle, which is propelled by a combination of solid boosters and the Shuttle's own liquid-fuel engines sourcing fuel from a large fuel tank, the Energia-Buran system used only thrust from the rocket's four RD liquid-fuel engines developed by Valentin Glushko. From the very beginning Buran was intended to be used in both fully automatic and manual mode. Although the program accumulated a several-years delay, to this day Buran remains the only space shuttle to ever perform an unmanned flight in fully automatic mode. The automated launch sequence performed as specified, and the Energia rocket lifted the vehicle into a temporary orbit before the orbiter

separated as programmed. After boosting itself to a higher orbit and completing two revolutions around the Earth, ODU (engine control system) engines fired automatically to begin the descent into the atmosphere. Exactly 206 minutes into the mission, the Buran orbiter landed, having lost only five of its 38,000 thermal tiles over the course of the flight. The automated landing took place on a runway at Baikonur Cosmodrome where, despite a lateral wind speed of 61.2 kilometres per hour (38.0 mph), it landed only 3 metres (9.8 ft) laterally and 10 metres (33 ft) longitudinally from the target mark. The unmanned flight was the first time that a spacecraft of this size and complexity had been launched, completed maneuvers in orbit, re-entered the atmosphere, and landed under automatic guidance.

Program Closure

The Buran program was officially closed in 1993, but Mikhail Gorbachev's negative attitude towards the program left little doubt that its first launch would be the last as well, according to the memoirs of acad. Chertok. Gorbachev did not attend the launch himself and sent a formulaic congratulation from a distance, being on a visit to the Saratov district. Former aerospace and defense workers recall that he often used the word "minarets" to refer to rockets.

Projected flights

In 1989, it was projected that *Buran* would have an unmanned second flight in 1993, with a duration of 15–20 days. Due to the cancellation of the project after the break up of the Soviet Union, this never took place. Several scientists looked into trying to revive the Buran program, especially after the Space Shuttle Columbia disaster. More recently, the director of Moscow's Central Machine Building Institute has said the Buran project will be reviewed in the hopes of restarting a similar manned spacecraft design, with rocket test launches as soon as 2015. Russia also continues work on the PPTS but has abandoned the Kliper program, due to differences in vision with its European partners.

Destruction

On 12 May 2002 a hangar housing *Buran* in Kazakhstan collapsed, due to poor maintenance. The collapse killed eight workers and destroyed the orbiter as well as a mock-up of an Energia carrier rocket.