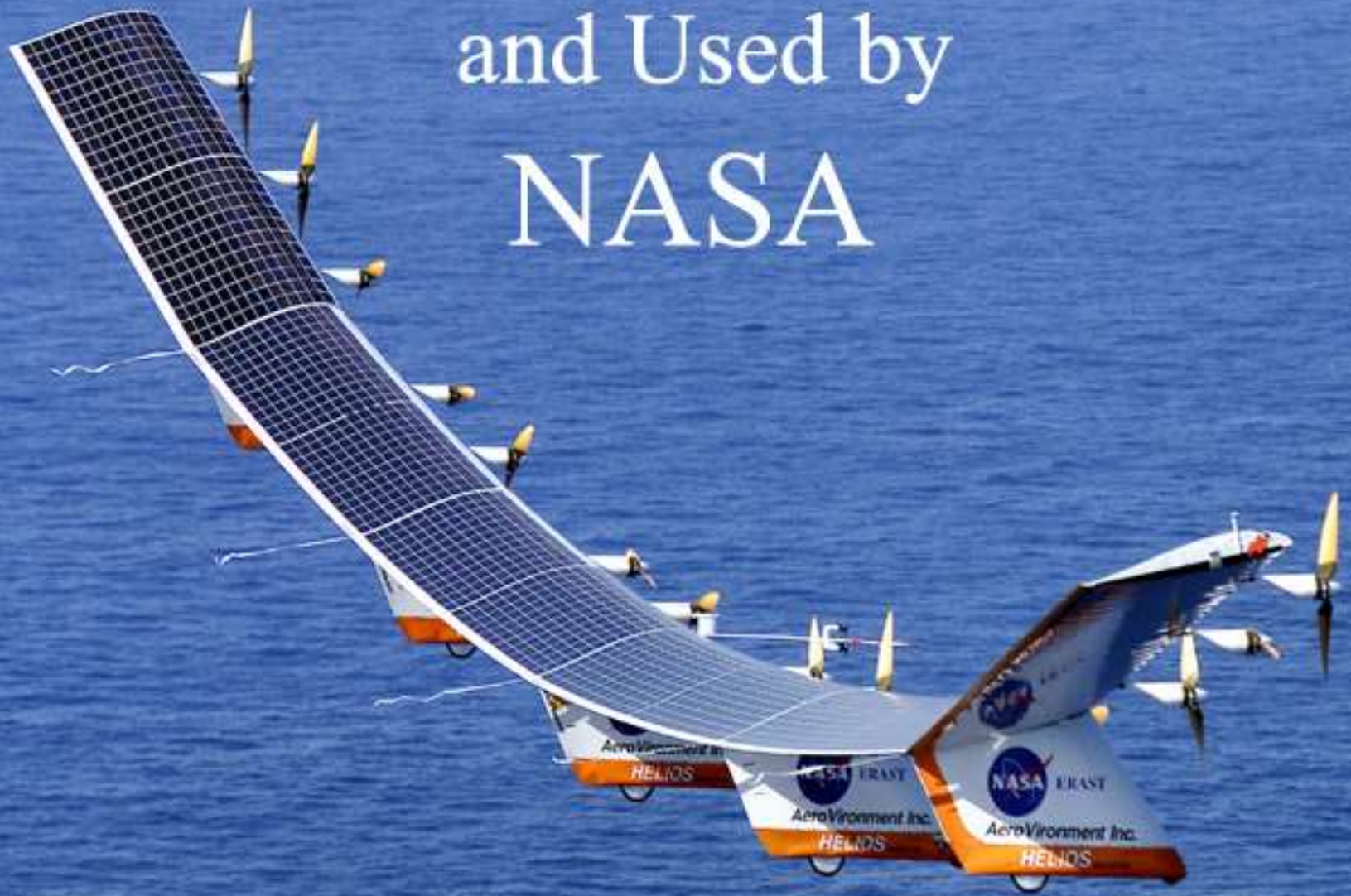
Aircrafts Developed and Used by NASA



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Chapter- 1

Douglas F5D Skylancer

F5D Skylancer

Douglas F5D Skylancer prototype in use by NASA for Dyna-Soar abort training

Role	Fighter aircraft
Manufacturer	Douglas Aircraft Company
First flight	21 April 1956
Primary users	United States Navy United States Marine Corps
Number built	4
Developed from	F4D Skyray

The United States **Douglas F5D Skylancer** was a development of the F4D Skyray jet fighter for the United States Navy. Starting out as the **F4D-2N**, an all-weather version of the Skyray, the design was soon modified to take full advantage of the extra thrust of the Pratt & Whitney J57 eventually fitted to the Skyray instead of the Westinghouse J40 originally planned.

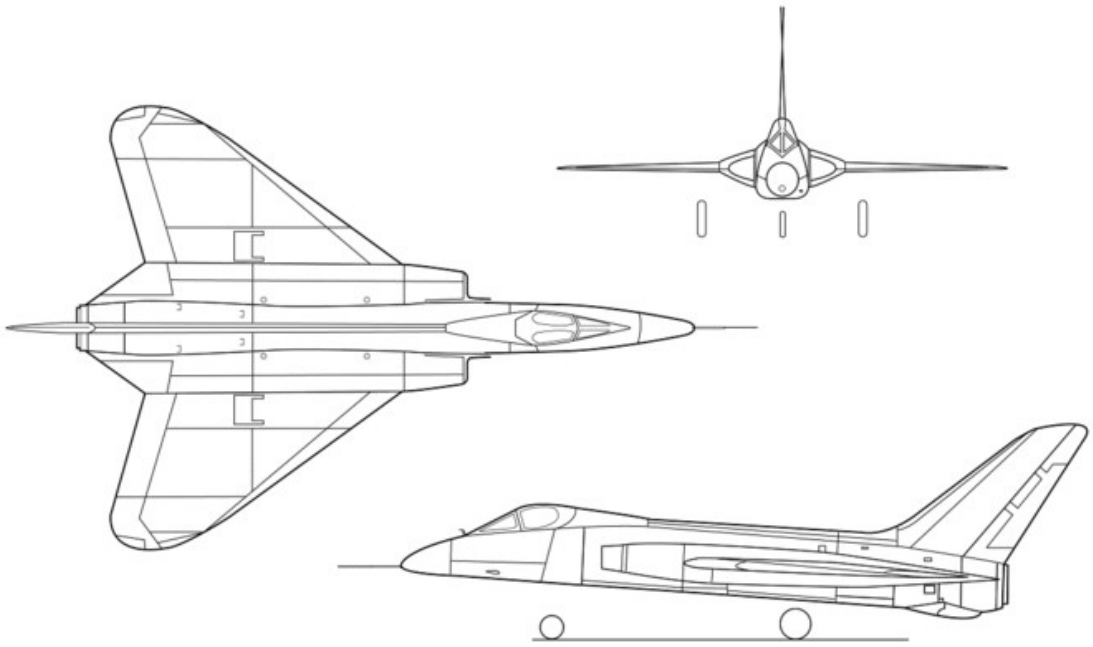
Design and development

Soon the design became too different from the Skyray to be considered just a variation of it, and the aircraft was assigned a new designation as the F5D Skylancer. Almost every part of the airframe was modified, though the basic form remained the same as did the wing shape, though it became much thinner. The wing skinning was reinforced,

correcting a problem found in the F4D. The fuselage was 8 ft (2.4 m) longer and area ruled to reduce transonic drag, being thinner in the region of the wing roots. Everything was shaped to reduce drag and increase stability at high speed.

F5D

F5D



3view

Although the four 20 mm (.79 in) cannon in the wing roots were retained, primary armament was to be missiles or rockets; four AIM-9 Sidewinders or two AIM-7 Sparrows, and/or a battery of spin-stabilized unguided 2 in (51 mm) rockets.

Nine test airframes were ordered, with a 51-aircraft production order to follow. Production aircraft were to be powered by the more powerful J57-P-14 engine, while there were plans to use the even more powerful General Electric J79.

Operational history

The first flight was on 21 April 1956 and was supersonic; the aircraft proved easy to handle and performed well. After four aircraft had been constructed, however, the Navy cancelled its order. The stated reason was that the aircraft was too similar to the already-ordered F8U Crusader, but it is believed by some historians that politics played as big a part; Douglas was already building a very large proportion of the Navy's planes, and giving them the F5D contract would have made it even closer to monopoly.The project

test pilot was Lt.Cmdr Alan B. Shepard Jr. whose report stated that it was not needed by the Navy.

Neil Armstrong's Skylancer, on display at the Armstrong Air and Space Museum.

NASA use

The four aircraft continued to fly in various military test programs. Two were grounded in 1961, but the other two: F5D-1 (Bu. No. 139208) NASA 212, later becoming NASA 708 and F5D-1 (Bu. No. 142350) NASA 213, later becoming NASA 802 continued to fly. Transferred to NACA (soon to become NASA) in the early 1960s, one was used as a testbed for the American supersonic transport program, fitted with an ogival wing platform (the type eventually used on Concorde; data from the program was shared with the European designers). This aircraft was retired in 1968. NASA 802 was used for simulation of abort procedures for the X-20 DynaSoar, because it had a very similar shape and handling characteristics. Following the DynaSoar cancellation, it was used as a chase plane and for various other programs until it was retired in 1970.

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: EC71-02569 Date: February 1971 Photo By: NASA

F5D Skylancer in flight

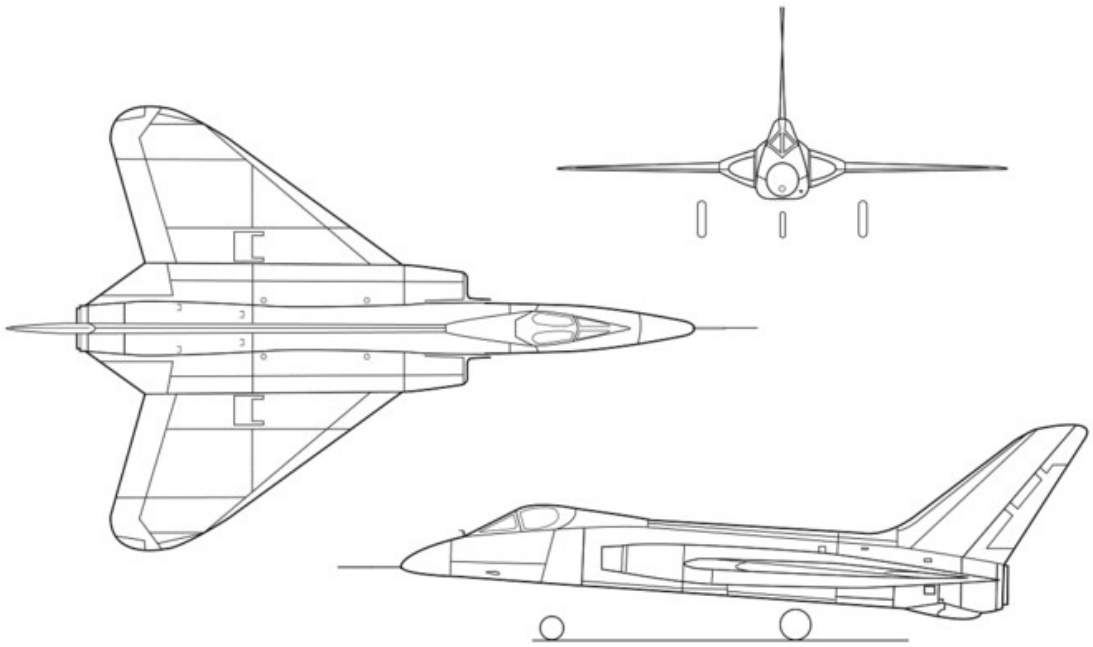
F5D in flight

F5D on ramp in Edwards

Survivors

NASA 802 still exists at the Neil Armstrong Air and Space Museum at Wapakoneta, Ohio, since Neil Armstrong flew the aircraft during the DynaSoar research program. NASA 708 still in NASA markings exists as part of Merle Maine's private collection in Ontario, Oregon.

Specifications (F5D)



Data from The American Fighter

General characteristics

- **Crew:** 1
- **Length:** 53 ft 9¾ in (16.40 m)
- **Wingspan:** 33 ft 6 in (10.21 m)
- **Height:** 14 ft 10 in (4.52 m)
- **Wing area:** 557 ft² (51.7 m²)
- **Empty weight:** 17,444 lb (7,912 kg)
- **Loaded weight:** 24,445 lb (11,088 kg)
- **Max takeoff weight:** 28,072 lb (12,733 kg)
- **Powerplant:** 1× Pratt & Whitney J57-P-8 turbojet
  - **Dry thrust:** 10,200 lbf (45 kN)
  - **Thrust with afterburner:** 16,000 lbf (71 kN)

Performance

- **Maximum speed:** 990 mph (860 kn, 1,590 km/h)
- **Range:** 1,335 mi (1,160 nmi, 2,148 km)
- **Service ceiling:** 57,500 ft (17,500 m)
- **Rate of climb:** 20,730 ft/min (105.3 m/s)
- **Wing loading:** 43.9 lb/ft² (214 kg/m²)
- **Thrust/weight:** 0.65

Armament

- **Guns:** 4 × 20 mm (0.79 in) cannon
- **Rockets:** 72 × 2 in (51 mm) rockets
- **Missiles:**
  - 4 × AIM-9 Sidewinder *or*
  - 2 × AIM-7B Sparrow

Avionics

- X-24A radar

Chapter- 2

Shuttle Training Aircraft

C-11A Shuttle Training Aircraft

Role	Advanced trainer
Manufacturer	Grumman
Status	Operational
Primary user	NASA
Number built	4
Developed from	Grumman Gulfstream II
Variants	Grumman C-11

The **Shuttle Training Aircraft** (STA) is a NASA training vehicle that duplicates the Space Shuttle's approach profile and handling qualities, allowing Space Shuttle pilots to simulate Shuttle landings under controlled conditions before attempting the task on board the orbiter.

Development

The aircraft's exterior has been modified to withstand the high aerodynamic forces incurred during training sorties. A redesigned cockpit provides a high-fidelity simulation of the Shuttle Orbiter's controls and pilot vantage point; even the seats are fitted in the same position as those in the Space Shuttle.

Operational history

The four STAs are normally located at the NASA Forward Operating Location in El Paso, Texas and rotated through Ellington Field (southeast of Houston, Texas) for maintenance. The STA is also used at Kennedy Space Center in Florida. It is primarily flown by astronauts practicing landings at the Shuttle Landing Facility and White Sands Space Harbor as well as to assess weather conditions prior to Space Shuttle launches and landings.

Flight profile

The STA is particularly critical for Shuttle pilots in training because the Orbiter lacks the atmospheric engines that would allow the craft to "go around" after a poor approach. After re-entry, the Shuttle is a very heavy glider (it is sometimes referred to as a 'flying brick'), and as such has only one chance to land.

In order to match the descent rate and drag profile of the real Shuttle at 37,000 feet (11,300 m), the main landing gear is lowered (the nose gear stays retracted due to wind load constraints) and engine thrust is reversed. Its flaps may deflect upwards to decrease lift as well as downwards to increase lift.

Covers are placed on the left hand cockpit windows to provide the same view as from a Shuttle cockpit, and the left-hand pilot's seat is fitted with the same controls as a Shuttle. The STA's normal flight controls are moved to the right, where the instructor sits. Both seat positions have a Head Up Display (HUD).

In a normal exercise, the pilot descends to 20,000 feet (6,000 m) at an airspeed of 280 knots (519 km/h), 15 miles (24 km) from the landing target. The pilot then rolls the STA at 12,000 feet (3,700 m), 7 miles (11 km) from landing. The nose of the aircraft is then dropped to increase speed to 300 knots (560 km/h), descending at a 20-degree angle on the Outer Glide Slope (OGS). The Outer Glide Slope aiming point is 7500ft short of the runway threshold, and uses PAPI's for visual guidance in addition to the MLS system. At 2000ft the guidance system changes to pre-flare and shortly after, at 1,700 feet (518 m), the pilot starts the flare maneouver to gradually reduce the descent angle and transition to the Inner Glide Slope (IGS) which is 1.5 degrees from 300ft onwards, using a "Ball-bar" system for visual guidance. The shuttle landing gear release is simulated at 300 feet (90 m) above the ground surface, since the STA main gear has been down for the

whole simulation. The nose gear of the STA is lowered at 150 ft (46 m) AGL in case of an inadvertent touchdown with the runway surface.

If the speed is correct, a green light on the instrument panel simulates shuttle landing when the pilot's eyes are 32 feet (10 m) above the runway. This is the exact position that the pilot's head would be in during actual landing. In the exercise, the STA is still flying 20 feet (6 m) above the ground. The instructor pilot deselects the simulation mode, stows the thrust reversers, and the instructor flies around the runway, never actually landing the aircraft.

Avionics

The Shuttle Training Aircraft's cockpit. The commander's side of the cockpit, at left, features a Shuttle-type heads-up display (HUD), a rotational hand controller (RHC) used to fly the vehicle, and multi-function displays. The instructor pilot, who occupies the right-hand side of the STA cockpit, has access to a similar heads-up display, as well as conventional aircraft controls and instruments.

A sophisticated computer system installed on board the STA simulates the flight dynamics of the orbiter with nearly perfect accuracy. The STA's highly realistic simulation of the Orbiter is not limited to handling characteristics, but also implements the shuttle control interfaces for the pilot.

The pilot then navigates the STA around a heading alignment cone (HAC), a maneuver which aligns the shuttle's (or training aircraft's) flight path with the landing runway.

An onboard computer called the Advanced Digital Avionics System (ADAS) controls the Direct Lift Control (DLC) and the in-flight reverse thrust during Simulation Mode.

Every Shuttle Commander has practiced at least 1000 landings in this manner, as has each mission's Shuttle Pilot.

List of Shuttle Training Aircraft

Four Gulfstream II aircraft constitute the current STA fleet, although other Gulfstream II aircraft, lacking STA capabilities, are also used by NASA for personnel transport purposes. Although the majority of the fleet have markings similar to those pictured above, paint schemes do vary slightly across aircraft. Current STA tail numbers are:

- N944NA (sn144)
- N945NA (sn118)
- N946NA (sn146)
- N947NA (sn147)

Other uses

In the event NASA's T-38 Talons are not available, the STAs are used for transporting crewmembers between major sites, namely from Johnson Space Center in Houston to Kennedy Space Center in Cape Canaveral, Florida.

Chapter- 3

Shuttle Carrier Aircraft

Shuttle Carrier Aircraft

Shuttle *Atlantis* returning to Kennedy Space Center on the SCA in 1998

Role	Outsize cargo freight aircraft
Manufacturer	Boeing (aircraft & modifications)
Introduced	1977
Primary user	NASA
Number built	2
Developed from	Boeing 747-100

The **Shuttle Carrier Aircraft** (**SCA**) are two extensively modified Boeing 747 airliners that NASA uses to transport Space Shuttle orbiters. One is a 747-100 model, while the other is a short range 747-100SR.

The SCAs are used to ferry space shuttles from landing sites back to the launch complex at the Kennedy Space Center, or more specifically, the NASA Shuttle Landing Facility, and to and from other locations too distant for the orbiters to be delivered by ground transport. The orbiters are placed on top of the SCAs by Mate-Demate Devices, large

gantry-like structures that hoist the orbiters off the ground for post-flight servicing, and then mate them with the SCAs for ferry flights.

In approach and landing test flights conducted in 1977, a test shuttle was released from an SCA during flight and glided to a landing under its own control.

Atlantis atop a Shuttle Carrier.

SCA approaching *Endeavour* suspended in the Mate-Demate Device (MDD), April, 1994

SCA mating with *Endeavour* in the Mate-Demate Device (MDD), April, 1994

SCA ferry flights, 1992

Design and development

The first aircraft, a Boeing 747-100 registered N905NA, was originally manufactured for American Airlines and still carried visible American side stripes while testing *Enterprise* in the 1970s. It was acquired in 1974 and initially used for trailing wake vortex research as part of a broader study by NASA Dryden, as well as Shuttle tests involving an F-104 flying in close formation and simulating a "release" from the 747.

N905NA (Space Shuttle Enterprise) in 1978, with American Airlines livery

The aircraft was extensively modified by Boeing in 1976. Its cabin was stripped, mounting struts added, and the fuselage strengthened; vertical stabilizers were added to the tail to aid stability when the Orbiter was being carried. The avionics and engines were also upgraded, and an escape tunnel system similar to that used on Boeing's first 747 test flights was added. The flight crew escape tunnel system was later removed following the completion of the Approach and Landing Tests (ALT) due to concerns over possible engine ingestion of an escaping crew member.

The C-5 Galaxy was considered for the shuttle-carrier role by NASA, but rejected in favor of the 747—in part due to the 747's low-wing design in comparison to the C-5's high-wing design, and also because the U.S. Air Force would have retained ownership of the C-5, while NASA could own the 747s outright.

Atlantis being mated to SCA N911NA at Dryden Flight Research Center

Flying with the additional drag and weight of the Orbiter imposes significant fuel and altitude penalties. The range is reduced to 1,000 nautical miles (1,850 km), compared to an unladen range of 5500 nautical miles (10,100 km), requiring an SCA to stop several times to refuel on a transcontinental flight. The SCA has an altitude ceiling of 15,000 feet and a maximum cruise speed of Mach 0.6 with the orbiter attached. A crew of 170 takes a week to prepare the shuttle and SCA for flight.

Space Shuttle *Columbia* atop SCA N905NA, flying by the Vehicle Assembly Building (VAB) at Kennedy Space Center (KSC), 1990. Note that N905NA no longer has American Airlines' pinstriping.

Studies were conducted to equip the SCA with aerial refueling equipment, a modification already made to the U.S. Air Force E-4 (modified 747-200s) and 747 tanker transports for the IIAF. However, during formation flying with a tanker aircraft to test refueling approaches, minor cracks were spotted on the tailfin of N905NA. While these were not likely caused by the test flights, it was felt that there was no sense taking unnecessary risks. Since there was no urgent need to provide an aerial refueling capacity, the tests were suspended.

Takeoff of SCA N905NA carrying *Enterprise*. Note the American Airlines pinstriping.

Enterprise separating from N905NA.

By 1983, SCA N905NA no longer bore the distinct American Airlines red, white, and blue cheatline. NASA replaced it with its own livery, consisting of a white fuselage and a single blue cheatline. That year, this aircraft was also used to fly Shuttle Enterprise on a tour in Europe, with refuelling stops in Goose Bay, Canada, Keflavik, Iceland, England and West Germany. It then went to the Paris Air Show.

In 1988, in the wake of the *Challenger* accident, NASA procured a surplus 747-100SR from Japan Airlines. Registered N911NA it entered service with NASA in 1990 after undergoing modifications similar to N905NA. It was first used in 1991 to ferry the new

shuttle *Endeavour* from the manufacturers in Palmdale, California to Kennedy Space Center.

Humorous note on Orbiter Mount reminding technicians how to connect the orbiter to the transport.

The two aircraft are functionally identical, although N911NA has five upper-deck windows on each side, while N905NA has only two. The rear mounting points on both aircraft are labeled with similar tongue-in-cheek instructions to "Attach Orbiter Here" or "Place Orbiter Here", clarified by the precautionary note "Black Side Down". Both are currently based at the Dryden Flight Research Center within Edwards Air Force Base in California.

Shuttle Carriers are capable of operating from alternate shuttle landing sites such as those in the United Kingdom, Spain and France. Due to the reduced range of the Shuttle Carrier

while mated to an orbiter, additional preparations such as removal of the payload from the orbiter may be necessary to reduce its weight.

Boeing transported its Phantom Ray unmanned combat air vehicle (UCAV) demonstrator from St. Louis, Missouri, to Edwards AFB, California, on a Shuttle Carrier on December 11, 2010.

After the Shuttle program ends in 2011, the two Shuttle Carriers will be used to transport the orbiters to their final destinations. The carrier aircraft will likely retire sometime afterwards.

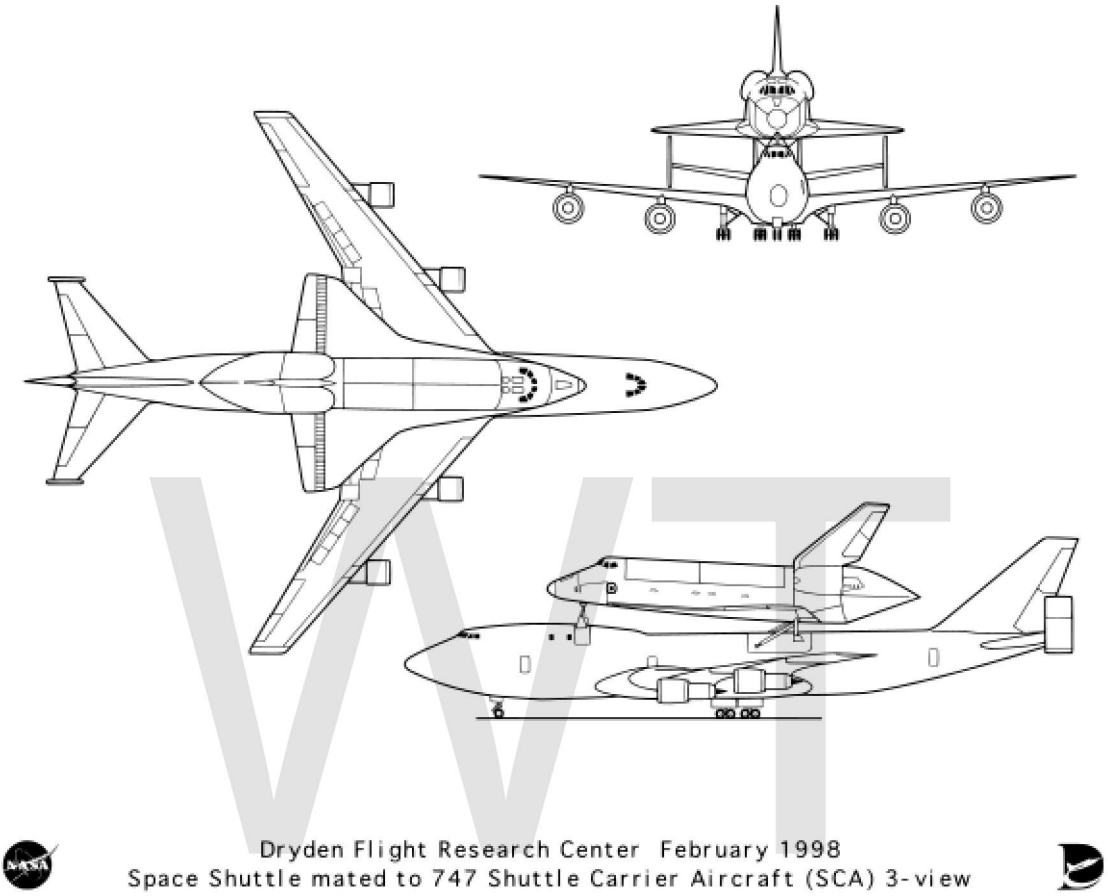
Shuttle Carrier carries *Discovery* from Edwards AFB to Kennedy Space Center, Florida

One of the SCAs at its Dryden Flight Research Center home, with a very wet Rogers Dry Lake behind it.

Aft end of the interior. Note the large stuffed spider mounted on the aft pressure bulkhead.

The first class section in the nose of N905NA. This is the only area on the main deck that has not been stripped to the bare metal

Specifications



Data from Boeing 747-100 specifications Jenkins 2000

General characteristics

- **Crew:** 4: pilot, co-pilot, 2 flight engineers (1 flight engineer when not carrying Shuttle)
- **Length:** 231 ft 4 in (70.5 m)
- **Wingspan:** 195 ft 8 in (59.7 m)
- **Height:** 63 ft 5 in (19.3 m)
- **Wing area:** 5,500 ft² (510 m²)
- **Empty weight:** 318,000 lb (144,200 kg)
- **Max takeoff weight:** 710,000 lb (322,000 kg)
- **Powerplant:** 4× P&W JT9D-7J turbofans, 50,000 lbf (222 kN) each

Performance

- **Cruise speed:** Mach 0.6 (397 knots, 457 mph, 735 km/h)

- **Range:** 1,150 mi (1,000 nmi, 1,850 km) while carrying Shuttle
- **Service ceiling:** 15,000 ft (4,500 m) (with Shuttle)

Chapter- 4

NASA Pathfinder

Helios Prototype

Helios Prototype in flight

Role	Remote controlled UAV
Manufacturer	AeroVironment
Primary user	NASA ERAST Program
Number built	1

NASA's **Pathfinder**, **Pathfinder Plus**, **Centurion** and **Helios Prototype** were an evolutionary series of solar- and fuel cell system-powered unmanned aerial vehicle. AeroVironment, Inc. developed the vehicles under NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program. They were built to develop the technologies that would allow long-term, high-altitude aircraft to serve as **"atmospheric satellites"**, to perform atmospheric research tasks as well as serve as communications platforms.

Pathfinder

Pathfinder in flight over Hawaii

AeroVironment initiated its development of full-scale solar-powered aircraft with the Gossamer Penguin and Solar Challenger vehicles in the late 1970s and early 1980s, following the pioneering work of Robert Boucher, who built the first solar-powered flying models in 1974. Under ERAST, AeroVironment built four generations of long endurance unmanned aerial vehicles (UAVs), the first of which was the Pathfinder.

Development

In 1983, AeroVironment obtained funding from an unspecified US government agency to secretly investigate a UAV concept designated "High Altitude Solar" or HALSOL. The HALSOL prototype first flew in June 1983. Nine HALSOL flights took place in the summer of 1983 at Groom Lake in Nevada. The flights were conducted using radio control and battery power, as the aircraft had not been fitted with solar cells. HALSOL's aerodynamics were validated, but the investigation led to the conclusion that neither photovoltaic cell nor energy storage technology were mature enough to make the idea practical for the time being, and so HALSOL was put into storage.

In 1993, after ten years in storage, the aircraft was brought back to flight status for a brief mission by the Ballistic Missile Defense Organization (BMDO). With the addition of small solar arrays, five low-altitude checkout flights were flown under the BMDO program at NASA Dryden in the fall of 1993 and early 1994 on a combination of solar and battery power.

In 1994 the aircraft transferred to the NASA ERAST Program to develop science platform aircraft technology. It was renamed "Pathfinder" because it was "literally the pathfinder for a future fleet of solar-powered aircraft that could stay airborne for weeks or months on scientific sampling and imaging missions". A series of flights were planned to demonstrate that an extremely light and fragile aircraft structure with a very high aspect ratio (the ratio between the wingspan and the wing chord) can successfully take-off and land from an airport and can be flown to extremely high altitudes (between 50,000 feet (15,240.0 m) and 80,000 feet (24,384.0 m)) propelled by the power of the sun. In addition, the ERAST Project also wanted to determine the feasibility of such a UAV for carrying instruments used in a variety of scientific studies.

On October 21, 1995, the aircraft's fragility was aptly demonstrated when it was severely damaged in a hangar accident, but was subsequently rebuilt.

The Helios in flight

The Helios in flight

The Helios Prototype in the air. (video)

The Helios in flight over Kauai, Hawaii.

Aircraft description

Pathfinder was powered by eight electric motors — later reduced to six — which were first powered by batteries. It had a wing span of 98.4 feet (30.0 m). Two underwing pods contain the landing gear, batteries, instrumentation system, and flight control computer. By the time the aircraft was adopted into the ERAST project in late 1993, solar cells were being added, eventually covering the entire upper surface of the wing. The solar arrays provide power for the aircraft's electric motors, avionics, communications and other electronic systems. Pathfinder also had a backup battery system that can provide power for between two and five hours to allow limited-duration flight after dark.

Pathfinder flies at an airspeed of only 15 miles per hour (24 km/h) to 25 miles per hour (40 km/h). Although pitch control is maintained by the use of tiny elevators on the trailing edge of the wing, turns and yaw control are accomplished by slowing down or speeding up the motors on the outboard sections of the wing.

Flight testing and records

Major science activities of Pathfinder missions have included detection of forest nutrient status, forest regrowth after damage caused by Hurricane Iniki in 1992, sediment/algal concentrations in coastal waters and assessment of coral reef health. Science activities are

coordinated by the NASA Ames Research Center and include researchers at the University of Hawaii and the University of California. Pathfinder flight tested two ERAST-developed scientific instruments, a high spectral resolution Digital Array Scanned Interferometer (DASI) and a high spatial resolution Airborne Real-Time Imaging System (ARTIS), both developed at Ames. These flights were conducted at altitudes between 22,000 feet (6,705.6 m) and 49,000 feet (14,935.2 m) in 1997.

On September 11, 1995, Pathfinder set an unofficial altitude record for solar powered aircraft of 50,000 feet (15,240.0 m) during a 12 hour flight from NASA Dryden. This and subsequent records claimed by NASA for Pathfinder remain unofficial, as they were not validated by the FAI, the internationally-recognized aviation world record sanctioning body. The National Aeronautic Association presented the NASA-industry ERAST team with an award for one of the "10 Most Memorable Record Flights" of 1995.

After further modifications, the aircraft was moved to the U.S. Navy's Pacific Missile Range Facility (PMRF) on the Hawaiian island of Kauai. On one of seven flights there in the spring and summer of 1997, Pathfinder raised the altitude record for solar-powered aircraft — as well as propeller-driven aircraft — to 71,530 feet (21,800 m) on July 7, 1997. During those flights, Pathfinder carried two lightweight imaging instruments to learn more about the island's terrestrial and coastal ecosystems, demonstrating the potential of such aircraft as platforms for scientific research.

Pathfinder-Plus

Pathfinder-Plus in flight over Hawaii, June 2002, equipped with Skytower communications equipment

During 1998, the Pathfinder was modified into the longer-winged Pathfinder-Plus configuration. It used four of the five sections from the original Pathfinder wing, but substituted a new 44 feet (13.4 m) long center wing section that incorporated a high-altitude airfoil designed for the follow-on Centurion/Helios. The new section was twice as long as the original, and increased the overall wingspan of the craft from 98.4 feet (30.0 m) to 121 feet (36.9 m). The new center section was topped by more-efficient silicon solar cells developed by SunPower Corporation of Sunnyvale, California, which could convert almost 19 percent of the solar energy they receive to useful electrical energy to power the craft's motors, avionics and communication systems. That compared with about 14 percent efficiency for the older solar arrays that cover most of the surface of the mid- and outer wing panels from the original Pathfinder. Maximum potential power was boosted from about 7,500 watts on Pathfinder to about 12,500 watts on Pathfinder-Plus. The number of electric motors was increased to eight, and the motors used were more powerful units, designed for the follow-on aircraft.

The Pathfinder-Plus development flights flown at PMRF in the summer of 1998 validated power, aerodynamic, and systems technologies for its successor, the Centurion. On August 6, 1998, Pathfinder-Plus proved its design by raising the national altitude record to 80,201 feet (24,445 m) for solar-powered and propeller-driven aircraft.

Atmospheric satellite tests

In July 2002 Pathfinder-Plus carried commercial communications relay equipment developed by Skytower, Inc., a subsidiary of AeroVironment, in a test of using the aircraft as a broadcast platform. Skytower, in partnership with NASA and the Japan Ministry of Telecommunications, tested the concept of an "atmospheric satellite" by successfully using the aircraft to transmit both an HDTV signal as well as an IMT-2000 wireless communications signal from 65,000 feet (19,812.0 m), giving the aircraft the equivalence of a 12 miles (19.3 km) tall transmitter tower. Because of the aircraft's high lookdown angle, the transmission utilized only one watt of power, or 1/10,000 of the power required by a terrestrial tower to provide the same signal. According to Stuart Hindle, Vice President of Strategy & Business Development for SkyTower, "SkyTower platforms are basically geostationary satellites without the time delay." Further, Hindle said that such platforms flying in the stratosphere, as opposed to actual satellites, can achieve much higher levels of frequency use. "A single SkyTower platform can provide over 1,000 times the fixed broadband local access capacity of a geostationary satellite using the same frequency band, on a bytes per second per square mile basis."

Ray Morgan, president of AeroVironment, has described the concept as, "What we're trying to do is create what we call an 'atmospheric satellite,' which operates and performs many of the functions as a satellite would do in space, but does it very close in, in the atmosphere"

Centurion

Quarter scale model of Centurion

Centurion takes off from Dryden in December, 1998

Centurion, originally built for the 100,000 feet (30,000 m) altitude on solar power milestone specified by the ERAST project, was the third generation aircraft in this series. The ERAST program managers had determined that an aircraft based on the Pathfinder/Pathfinder Plus concept would be the lowest risk approach of achieving the altitude goal.

Initially, a quarter-scale model of the Centurion was test flown at El Mirage Dry Lake on March 4, 1997. The full-size Centurion's maiden flight took place at Rogers Dry Lake on November 10, 1998, and lasted a total of 1 hr and 24 minutes. At the time, it weighed in at 1,385 pounds (628.2 kg) (including a 150 pounds (68 kg) steel anvil hanging on its centerline to simulate a payload) for its first flight. The flight was nearly flawless and was followed by a second similar performance on November 19, this time before a crowd of VIPs and Media. It lasted 1 hr and 29 minutes. The third and final flight of the low altitude test series took place on December 3. On this flight the vehicle was loaded down to its maximum gross weight of 1,806 pounds (819.2 kg) to test its weight carrying capability. Total flight time on this flight was 30 minutes, as it was shortened because high winds were anticipated by mid-morning. All of these flights took place on battery power and verified the design's handling qualities, performance, and structural integrity.

Following these three flights, NASA decided to expand the aircraft into the Helios Prototype, with work starting in January, 1999.

Aircraft description

The design of Centurion resulted in an aircraft that looked very much like the Pathfinder, but with a much longer wingspan of 206 feet (62.8 m). Although the Centurion shape resembled the Pathfinder, the structure was designed to be stronger and capable of carrying numerous payloads (up to 600 pounds (272.2 kg)) more efficiently. Its wing incorporated a redesigned high-altitude airfoil and the span was increased to 206 feet (62.79 m). The number of motors was increased to 14 and the number of underwing pods to carry batteries, flight control system components, ballast, and landing gear rose to four.

Helios Prototype

Pathfinder Plus (left) and Helios Prototype (right) on the Dryden ramp

AeroVironment Chairman Paul MacCready shows a cross section of the AeroVironment/NASA Helios Prototype wing spar.

The Centurion was modified into the Helios Prototype configuration by adding a sixth 41 feet (12.5 m) wing section and a fifth landing gear and systems pod, becoming the fourth configuration in the series of solar-powered flying wing demonstrator aircraft developed by AeroVironment under the ERAST project. The larger wing on the Helios Prototype accommodated more solar arrays to provide adequate power for the sun-powered development flights that followed. The aircraft's maiden flight was on September 8, 1999.

The ERAST program had two goals when developing the Helios Prototype: 1) sustained flight at altitudes near 100,000 feet (30,480.0 m) and 2) endurance of at least 24 hours, including at least 14 of those hours above 50,000 feet (15,240.0 m). To this end, the Helios Prototype could be configured in two different ways. The first, designated HP01, focused on achieving the altitude goals and powered the aircraft with batteries and solar cells. The second configuration, HP03, optimized the aircraft for endurance, and used a combination of solar cells, storage batteries and a modified commercial hydrogen-air fuel cell system for power at night. In this configuration, the number of engines was reduced from 14 to ten.

Using the traditional incremental or stair-step approach to flight testing, the Helios Prototype was first flown in a series of battery-powered development flights in late 1999 to validate the longer wing's performance and the aircraft's handling qualities. Instrumentation that was used for the follow-on solar-powered altitude and endurance flights was also checked out and calibrated during the initial low-altitude flights at NASA Dryden.

Aircraft description

The Helios Prototype is an ultra-lightweight flying wing aircraft with a wingspan of 247 feet (75.3 m), longer than the wingspans of the U.S. Air Force C-5 military transport (222 feet (67.7 m) or the Boeing 747 (195 feet (59.4 m) or 215 feet (65.5 m), depending on the model), the two largest operational aircraft in the United States. The electrically powered Helios is constructed mostly of composite materials such as carbon fiber, graphite epoxy, Kevlar, styrofoam, and a thin, transparent plastic skin. The main tubular wing spar is made of carbon fiber. The spar, which is thicker on the top and bottom to absorb the constant bending motions that occur during flight, is also wrapped with Nomex and Kevlar for additional strength. The wing ribs are also made of epoxy and carbon fiber. Shaped styrofoam is used for the wing's leading edge and a durable clear plastic film covers the entire wing.

The Helios Prototype shares the same 8 feet (2.4 m) wing chord (distance from leading to trailing edge) as its Pathfinder and Centurion predecessors. The 247-foot wingspan gives the Helios Prototype an aspect ratio of almost 31 to 1. The wing thickness is the same from tip to tip, 11.5 inches (29.2 cm) inches or 12 percent of the chord, and it has no taper or sweep. The outer panels have a built-in 10-degree dihedral to give the aircraft more lateral stability. A slight upward twist at the tips of the trailing edge helps prevent wing tip stalls during the slow landings and turns. The wing area is 1,976 sq. ft., which gives the craft a maximum wing loading of only 0.81 lb./sq. ft. when flying at a gross weight of 1,600 lb.

The all-wing aircraft is assembled in six sections, each about 41 feet (12.5 m) long. An underwing pod is attached at each panel joint to carry the landing gear, the battery power system, flight control computers, and data instrumentation. The five aerodynamically shaped pods are made mostly of the same materials as the wing itself, with the exception of the transparent wing covering. Two wheels on each pod make up the fixed landing gear—rugged mountain bike wheels on the rear and smaller scooter wheels on the front.

The only flight control surfaces used on the Helios Prototype are 72 trailing-edge elevators that provide pitch control. Spanning the entire wing, they are operated by tiny servomotors linked to the aircraft's fight control computer. To turn the aircraft in flight, yaw control is applied by applying differential power on the motors — speeding up the motors on one outer wing panel while slowing down motors on the other outer panel. A major test during the initial flight series was the evaluation of differential engine power as a means of pitch control. During normal cruise the outer wing panels of Helios are arched upward and give the aircraft the shape of a shallow crescent when viewed from the front or rear. This configuration places the motors on the outer wing panels higher than the motors on the center panels. Speeding up the outer-panel motors caused the aircraft to pitch down and begin a descent. Conversely, applying additional power to the motors in the center panels caused Helios to pitch up and begin climbing.

Solar panels, supplied by SunPower were then installed in 2000. The cells featured a rear-contact cell design that placed wires on the underside of the cells, so as not to obstruct the cells' exposure to solar radiation.

Records

Helios with very high wing dihedral just before breaking up

Helios disintegrates as it falls towards the Pacific

Wreckage of Helios in the Pacific

On August 14, 2001, the Helios Prototype piloted remotely by Greg Kendall reached an altitude of 96,863 feet (29,523.8 m), a world record for sustained horizontal flight by a winged aircraft. The altitude reached was more than 11,000 feet (3,352.8 m) — or more than 2 miles (3.2 km) — above the previous altitude record for sustained flight by a winged aircraft. In addition, the aircraft spent more than 40 minutes above 96,000 feet (29,260.8 m).

Crash

On June 26, 2003, the Helios Prototype broke up and fell into the Pacific Ocean about ten miles (16 km) west of the Hawaiian Island Kauai during a remotely piloted systems checkout flight in preparation for an endurance test scheduled for the following month.

On the morning of the accident, weather forecasts indicated that conditions were inside the acceptable envelope, although during the preflight go/no-go review, the weather forecaster gave it a "very marginal GO." One of the primary concerns was a pair of wind shear zones off the island's coast. After a delayed take off, due to the failure of the winds to shift as predicted, Helios spent more time than expected flying through a zone of low-level turbulence on the lee side of Kauai, because it was climbing slower than normal, since it had to contend with cloud shadows and the resultant reduction in solar power.

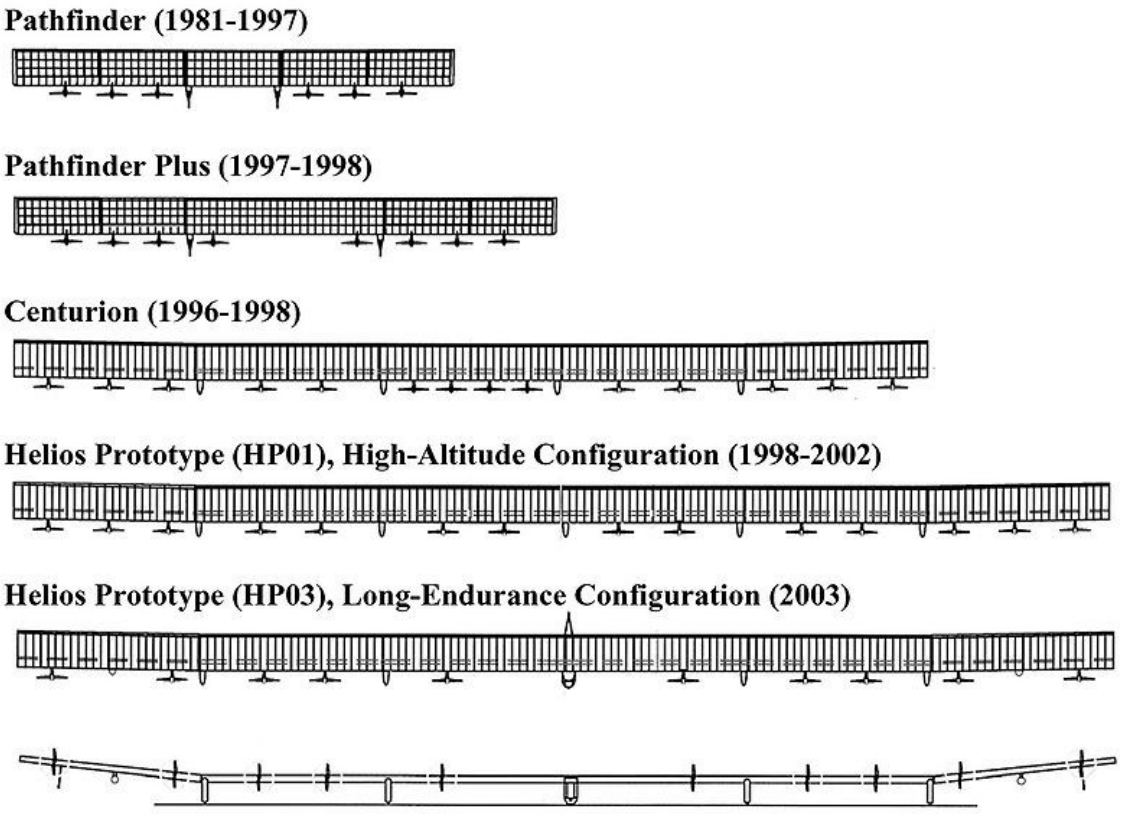
As the aircraft climbed through 2,800 feet (853.4 m), according to the subsequent mishap investigation report, "At about 30 minutes into the flight, the aircraft encountered

turbulence and morphed into an unexpected, persistent, high dihedral configuration. As a result of the persistent high dihedral, the aircraft became unstable in a very divergent pitch mode in which the airspeed excursions from the nominal flight speed about doubled every cycle of the oscillation. The aircraft's design airspeed was subsequently exceeded and the resulting high dynamic pressures caused the wing leading edge secondary structure on the outer wing panels to fail and the solar cells and skin on the upper surface of the wing to rip off. The aircraft impacted the ocean within the confines of the PMRF test range and was destroyed. Most of the vehicle structure was recovered except the hydrogen-air fuel cell pod and two of the ten engines, which sank into the ocean."

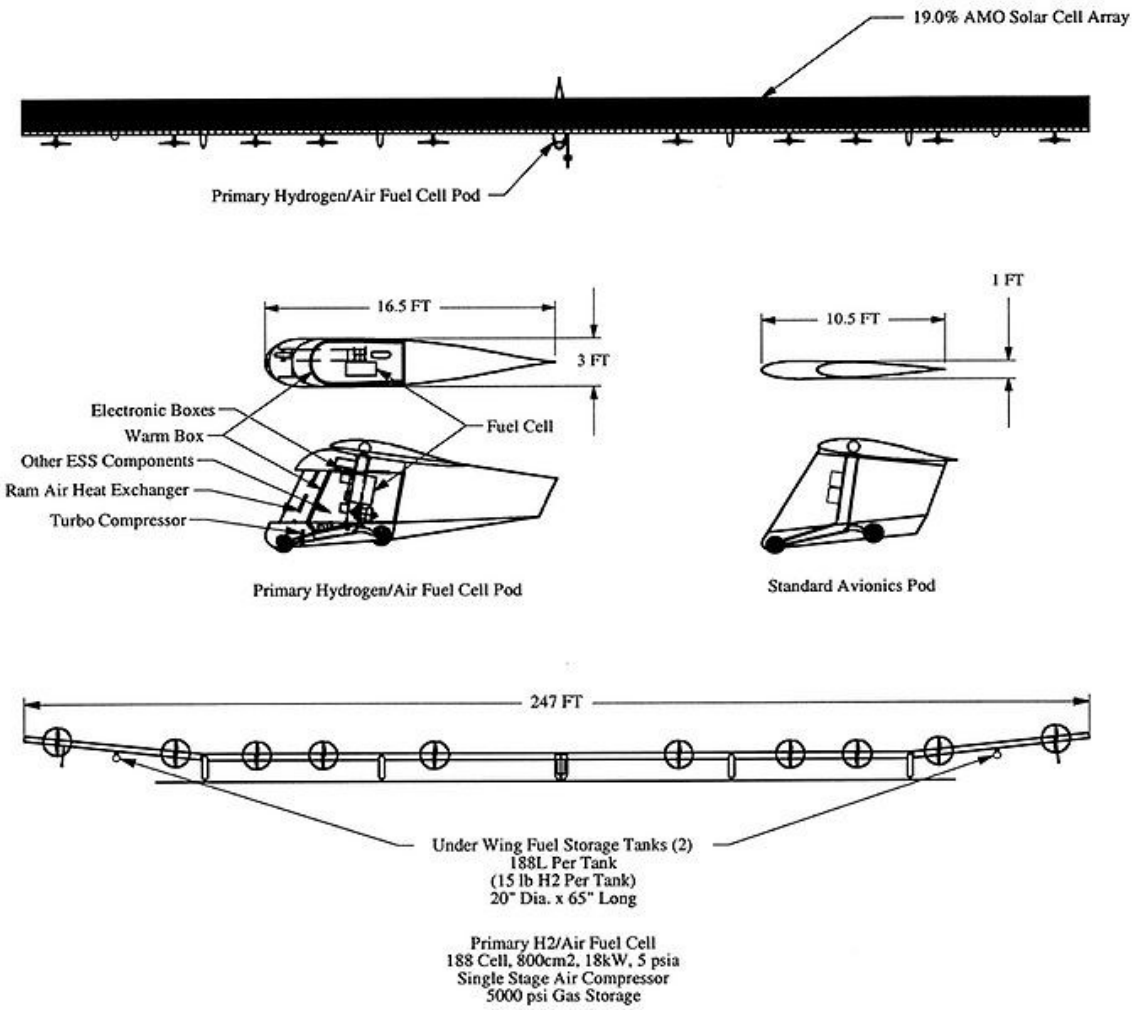
The investigation report identified a two-part root cause of the accident:

1. "Lack of adequate analysis methods led to an inaccurate risk assessment of the effects of configuration changes leading to an inappropriate decision to fly an aircraft configuration highly sensitive to disturbances."
2. "Configuration changes to the aircraft, driven by programmatic and technological constraints, altered the aircraft from a spanloader to a highly point-loaded mass distribution on the same structure significantly reducing design robustness and margins of safety."

Specifications



Solar Aircraft Evolution through the ERAST Program



Schematic of Helios HP03 Hydrogen-Air Fuel Cell Configuration

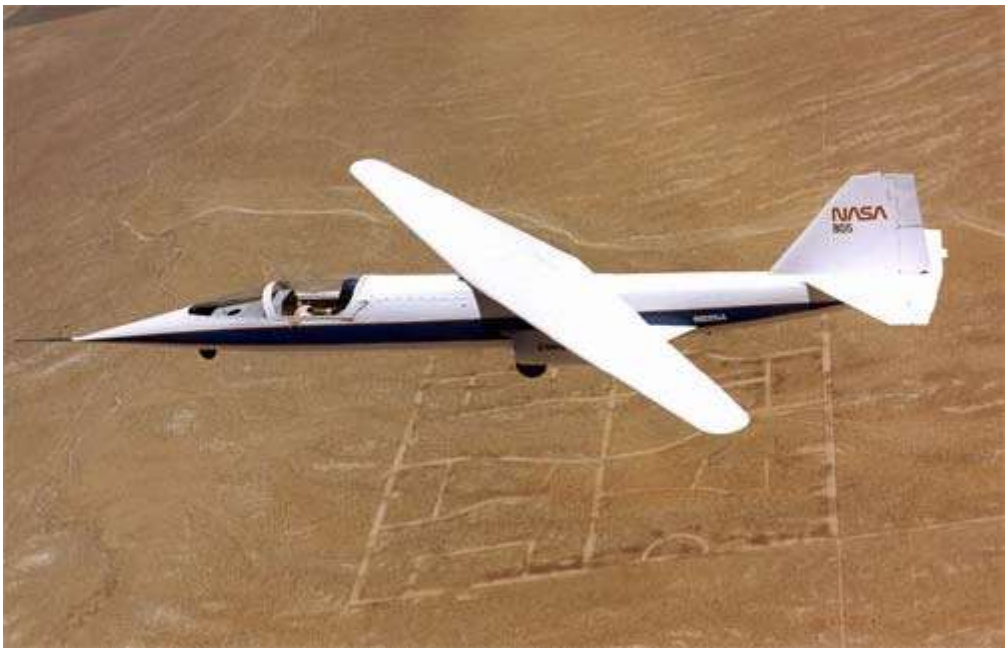
Specifications

	Pathfinder	Pathfinder-Plus	Centurion	Helios HP01	Helios HP03
Length ft(m)	12 (3.6)	12 (3.6)	12 (3.6)	12 (3.6)	16.5 (5.0)
Chord ft(m)			8 (2.4)		
Wingspan ft(m)	98.4 (29.5)	121 (36.3)	206 (61.8)	247 (75.3)	
Aspect ratio	12 to 1	15 to 1	26 to 1	30.9 to 1	
Glide ratio	18 to 1	21 to 1	?	?	?
Airspeed kts(km/h)			15-18 (27-33)	16.5-23.5 (30.6-43.5)	?
Max altitude ft(m)	71,530 (21,802)	80,201 (24,445)	n/a	96,863 (29,523)	65,000 (19,812)
Empty Wt lb(kg)	?	?	?	1,322 (600)	?
Max. weight lb(kg)	560 (252)	700 (315)	±1,900 (±862)	2,048 (929)	2,320 (1,052)

Payload lb(kg)	100 (45)	150 (67,5)	100-600 (45-270)	726 (329)	?
Engines	electric, 2 hp (1.5 kW) each				
No. of engines	6	8	14	14	10
Solar pwr output (kW)	7.5	12.5	31	?	?
Supplemental power	batteries	batteries	batteries	Li batteries	Li batteries, fuel cell

Chapter- 5

NASA AD-1



Oblique wing

The **NASA AD-1** was both an aircraft and an associated flight test program conducted between 1979 and 1982 at the NASA Dryden Flight Research Center, Edwards California, which successfully demonstrated an aircraft wing that could be pivoted obliquely from zero to 60 degrees during flight.

The unique oblique wing was demonstrated on a small, subsonic jet-powered research aircraft called the AD-1 (**Ames Dryden -1**). The aircraft was flown 79 times during the research program, which evaluated the basic pivot-wing concept and gathered information on handling qualities and aerodynamics at various speeds and degrees of pivot.

Project background

The first known oblique wing design was the Blohm & Voss P.202, proposed by Richard Vogt in 1942.

The oblique wing concept was later promoted by Robert T. Jones, an aeronautical engineer at NASA's Ames Research Center, Moffett Field, California.

Analytical and wind tunnel studies Jones initiated at Ames indicated that a transport-size oblique-wing aircraft, flying at speeds up to Mach 1.4 (1.4 times the speed of sound), would have substantially better aerodynamic performance than aircraft with more conventional wings.

At high speeds, both subsonic and supersonic, the wing would be pivoted at up to 60 degrees to the aircraft's fuselage for better high-speed performance. The studies showed these angles would decrease aerodynamic drag, permitting increased speed and longer range with the same fuel expenditure.

At lower speeds, during takeoffs and landings, the wing would be perpendicular to the fuselage like a conventional wing to provide maximum lift and control qualities. As the aircraft gained speed, the wing would be pivoted to increase the oblique angle, thereby reducing the drag and decreasing fuel consumption. The wing could only be swept in one direction, with the right wingtip moving forward.

Aircraft

The AD-1 and pilot Richard E. Gray

The AD-1 aircraft was delivered to Dryden in February 1979. The Ames Industrial Co., Bohemia, New York, constructed it, under a $240,000 USD fixed-price contract. NASA specified the overall vehicle design using a geometric configuration studied by Boeing Commercial Airplanes, Seattle, Washington. The Rutan Aircraft Factory, Mojave, California, provided the detailed design and load analysis for the intentionally low-speed, low-cost aircraft (there, the aircraft was known internally as the **Model 35**). The low speed and cost, of course, limited the complexity of the vehicle and the scope of its technical objectives.

Piloting the aircraft on its first flight December 21, 1979, was NASA research pilot Thomas C. McMurtry, who was also the pilot on the final flight August 7, 1982. Another well-known test pilot involved in the project was Pete Knight.

Powered by two small Microturbo TRS18-046 turbojet engines, each producing 220 pounds of static thrust at sea level, the aircraft was limited for reasons of safety to a speed of about 170 mph (these were essentially the same engines used in the BD-5J).

The AD-1 was 38.8 feet (11.8 m) in length and had a wingspan of 32.3 feet (9.8 m) unswept. It was constructed of plastic reinforced with fiberglass, in a sandwich with the skin separated by a rigid foam core. It had a gross weight of 2,145 pounds, and an empty weight of 1,450 pounds.

A fixed tricycle landing gear, mounted close to the fuselage to lessen aerodynamic drag, gave the aircraft a very "squatty" appearance on the ground. It was only 6.75 feet (2.06 m) high. The wing was pivoted by an electrically driven gear mechanism located inside the fuselage, just forward of the engines.

Flight research

Overhead view

The research program to validate the oblique wing concept was typical of any NASA high-risk project — to advance through each test element and expand the operating envelope, methodically and carefully. The basic purpose of the AD-1 project was to investigate the low-speed characteristics of an oblique-wing configuration.

The AD-1 made its first flight late in 1979. The wing was pivoted incrementally over the next 18 months until the full 60-degree angle was reached in mid-1981. The aircraft continued to be flown for another year, obtaining data at various speeds and wing-pivot angles until the final flight in August 1982.

The final flight of the AD-1 did not occur at Dryden, however, but at the Experimental Aircraft Association's (EAA) annual exhibition at Oshkosh, Wisconsin, where it was flown eight times to demonstrate its unique configuration.

Following the flight research, Jones still considered the oblique wing as a viable lift concept for large transoceanic or transcontinental transports. This particular low-speed, low-cost research vehicle, however, exhibited aeroelastic and pitch-roll-coupling effects that contributed to poor handling qualities at sweep angles above 45 degrees. The fiberglass structure limited wing stiffness that would have improved the aircraft's handling qualities, as an improved (and thus more expensive) control system would also have done.

NASA AD-1 on display at the Hiller Aviation Museum

Thus, although the AD-1 structure allowed completion of the program's technical objectives, there was still a need for a transonic oblique-wing research aircraft to assess the effects of compressibility, evaluate a more representative structure, and analyze flight performance at transonic speeds (those on either side of the speed of sound).

After completion of the test program, the AD-1 was retired and is now on exhibit in the Hiller Aviation Museum in San Carlos, California.

Specifications

Data from Jane's All The World's Aircraft 1980-81

General characteristics

- **Crew:** 1
- **Length:** 38 ft 4 in (11.68 m)
- **Wingspan:** 32 ft 0 in (9.75 m) spread, 16 ft 2 in (4.93 m) swept
- **Height:** 6 ft 6 in (1.98 m)
- **Wing area:** 93 sq ft (8.6 m^2)
- **Gross weight:** 2,000 lb (907 kg)
- **Powerplant:** 2 × Ames TRS-18 turbojet, 220 lbf (0.98 kN) thrust each

Chapter- 6

NASA M2-F1

M2-F1

Role	Lifting body
Manufacturer	Dryden Flight Research Center
Designed by	Ames Research Center
First flight	16 August 1963
Retired	16 August 1966
Status	On display
Primary user	NASA
Number built	1
Unit cost	US$30,000
Variants	Northrop M2-F2 Northrop M2-F3

The **NASA M2-F1** was a lightweight, unpowered prototype aircraft, developed to flight test the wingless lifting body concept. It looked like a "flying bathtub," and was designated the M2-F1, the "M" referring to "manned" and "F" referring to "flight" version. In 1962, NASA Dryden management approved a program to build a lightweight, unpowered lifting body prototype. It featured a plywood shell placed over a tubular steel frame crafted at Dryden. Construction was completed in 1963.

Development

The lifting-body concept originated in the mid-1950s at the National Advisory Committee for Aeronautics' Ames Aeronautical Laboratory, Mountain View, California. By February 1962, a series of possible shapes had been developed, and R. Dale Reed was working to gain support for a research vehicle.

The construction of the M2-F1 was a joint effort by Dryden and a local glider manufacturer, the Briegleb Glider Company. The budget was US$30,000. NASA craftsmen and engineers built the tubular steel interior frame. Its mahogany plywood shell was hand-made by Gus Briegleb and company. Ernie Lowder, a NASA craftsman who had worked on Howard Hughes' H-4 Hercules (or Spruce Goose), was assigned to help Briegleb.

Final assembly of the remaining components (including aluminum tail surfaces, push rod controls, and landing gear from a Cessna 150, which was later replaced by Cessna 180 landing gear) was done at the NASA facility.

The wingless, lifting body aircraft design was initially conceived as a means of landing a spacecraft horizontally after atmospheric reentry. The absence of wings would make the extreme heat of re-entry less damaging to the vehicle. Rather than using a ballistic reentry trajectory like a Command Module, very limited in manoeuvering range, a lifting body vehicle had a landing footprint the size of California.

Tow testing

The M2-F1 and its 1963 Pontiac convertible tow vehicle

The first flight tests of the M2-F1 were at Rogers Dry Lake, at the end of a tow rope attached to a Pontiac Catalina convertible. On April 5, 1963 test pilot Milt Thompson lifted the M2-F1's nose off the ground for the first time on-tow. Speed was 86 miles per hour (138 km/h) . The little craft seemed to bounce uncontrollably back and forth on the main landing gear, and stopped when he lowered the nose to the ground. He tried again, but each time with the same results. He felt it was a landing gear problem that could have caused the aircraft to roll on its back if he had lifted the main gear off the ground.

After looking at movies of the tests, it was decided that the bouncing was probably caused by unwanted rudder movements. Flight control system number two was replaced in favor of number one, and it never bounced again.

It was found that the car used to tow the aircraft was not powerful enough to entirely lift the M2-F1 off the ground, so the FRC arranged to have the tow car hot-rodded by Bill Straub, a conversion that tuned the engine for increased power, added a rollbar, and

turned the front passenger seat to face aft so the passenger could observe the aircraft. This proved successful and tow tests continued.

Speeds on tow inched up to 110 miles per hour (180 km/h) , which allowed Thompson to climb to about 20 feet (6.1 m) , then glide for about 20 seconds after releasing the line. That was the most that could be expected during an auto tow.

These initial tests produced enough flight data about the M2-F1 to proceed with flights behind a U.S. Navy C-47 tow plane at greater altitudes.

Flight testing

A NASA C-47 was used for all of the aero tows. The first was on August 16, 1963. The M2-F1 had recently been equipped with an ejection seat and small rockets - referred to by the test team as "instant L/D" - in the tail to extend the landing flare for about 5 seconds if needed, and Thompson prepared for the flight with a few more tows behind the Pontiac.

Forward visibility in the M2-F1 was very limited on tow, requiring Thompson to fly about 20 feet (6.1 m) higher than the C-47 so he could see the plane through the nose window. Towing speed was about 100 miles per hour (160 km/h) .

The C-47 took the craft to an altitude of 12,000 feet (3,700 m) where free flights back to Rogers Dry Lake began. Pilot for the first series of flights of the M2-F1 was NASA research pilot Milt Thompson. Typical glide flights with the M2-F1 lasted about two minutes and reached speeds of 110 to 120 miles per hour (180 to 190 km/h)

Tow release was at 12,000 feet (3,700 m) The lifting body descended at an average rate of about 3,600 feet-per-minute (1,100 m/min). At 1,000 feet (300 m) above the ground, the nose was lowered to increase speed to about 150 miles per hour (240 km/h) , flare was at 200 feet (61 m) from a 20 degree dive. The landing was smooth, and the lifting body program was on its way.

The M2-F1 was flown until August 16, 1966. It proved the lifting body concept and led the way for subsequent, metal "heavyweight" designs. Chuck Yeager, Bruce Peterson and Don Mallick also flew the M2-F1.

More than 400 ground tows and 77 aircraft tow flights were carried out with the M2-F1. The success of Dryden's M2-F1 program led to NASA's development and construction of two heavyweight lifting bodies based on studies at NASA's Ames and Langley research centers—the Northrop M2-F2 and the Northrop HL-10, both built by the Northrop Corporation, and the U.S. Air Force's X-24 program. The lifting body program also heavily influenced the Space Shuttle program.

The M2-F1 program demonstrated the feasibility of the lifting-body concept for horizontal landings of atmospheric entry vehicles. It also demonstrated a procurement

and management concept for prototype flight research vehicles that produced rapid results at very low cost (approximately $US 50,000, excluding salaries of government employees assigned to the project).

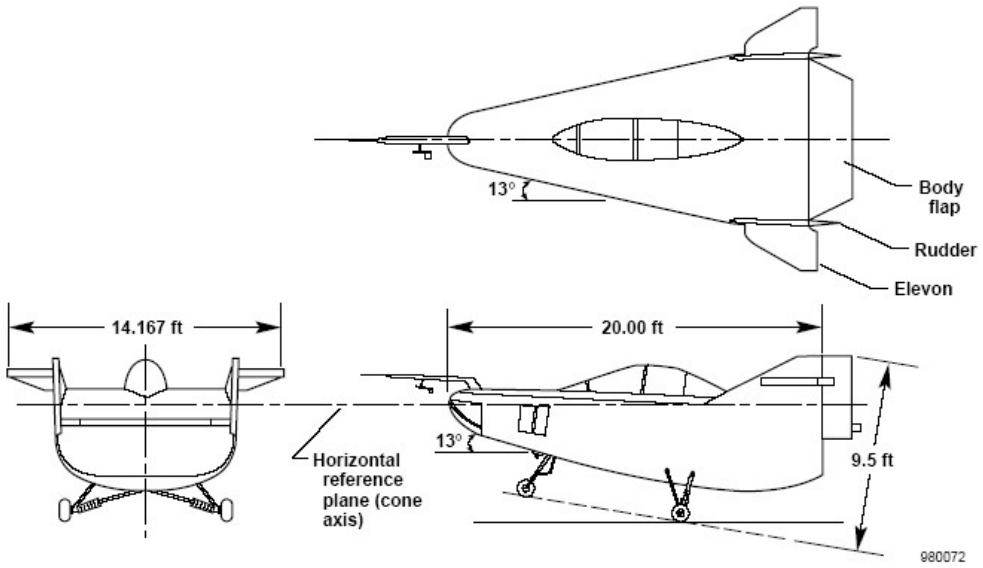
M2F1 Pilots

- Milt Thompson - 45 flights
- Bruce Peterson - 17 flights
- Chuck Yeager - 5 flights
- Donald M. Sorlie - 5 flights
- Donald L. Mallick - 2 flights
- Jerauld R. Gentry - 2 flights
- Bill Dana - 1 flight
- James W. Wood - 1 ground tow
- Fred Haise - 1 ground tow
- Joe Engle - 1 ground tow

Aircraft serial number

- **NASA M2-F1** - N86652, 77 flights, 400 ground tows

Specifications (M2-F1)



(a) The M2-F1 vehicle.

NASA M2-F1 Lifting Body Diagram

General characteristics

- **Crew:** one
- **Length:** 20 ft (6.1 m)
- **Wingspan:** 14 ft 2 in (4.32 m)
- **Height:** 9 ft 6 in (2.89 m)
- **Wing area:** 139 ft² (12.9 m²)
- **Empty weight:** 1,000 lb (454 kg)
- **Loaded weight:** 1,182 lb (536 kg)
- **Max takeoff weight:** 1,250 lb (567 kg)
- **Powerplant:** 1× Solid fuel rocket, 24 lbf (kN)

Performance

- **Maximum speed:** 150 mph (240 km/h)
- **Range:** 10 mi (16 km)
- **Wing loading:** 9 lb/ft² (44 kg/m²)

M2-F1 flights

Vehicle Flight #	Date	Pilot	Duration	Velocity (km/h)	Altitude (m)	Comments
M2-F1 #0	March 1, 1963	Thompson	-	135	0	First Ground Tow. 400 total ground tows.
M2-F1 #1	August 16, 1963	Thompson	0:02:00	240	3,650	First M2-F1 Flight. 77 total flights.
M2-F1 #2	August 28, 1963	Thompson	0:02:09	240	3,650	-
M2-F1 #3	August 29, 1963	Thompson	0:02:25	240	3,650	-
M2-F1 #4	August 30, 1963	Thompson	0:04:42	240	3,650	1st flight of day
M2-F1 #5	August 30, 1963	Thompson	-	240	3,650	2nd flight of day
M2-F1 #6	September 3, 1963	Thompson	0:04:50	240	3,650	1st flight of day
M2-F1 #7	September 3, 1963	Thompson	-	240	3,650	2nd flight of day
M2-F1 #8	October 7, 1963	Thompson	0:01:26	240	3,650	-
M2-F1 #9	October 9, 1963	Thompson	0:01:51	240	3,650	-
M2-F1 #10	October 15, 1963	Thompson	0:02:20	240	3,650	-

M2-F1 #11	October 23, 1963	Thompson	0:03:00	240	3,650	-
M2-F1 #12	October 25, 1963	Thompson	0:03:52	240	3,650	1st flight of the day
M2-F1 #13	October 25, 1963	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #14	November 8, 1963	Thompson	0:07:45	240	3,650	1st flight of the day
M2-F1 #15	November 8, 1963	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #16	November 8, 1963	Thompson	-	240	3,650	3rd flight of the day
M2-F1 #17	December 3, 1963	Thompson	0:01:00	240	3,650	-
M2-F1 #18	December 3, 1963	Yeager	0:01:35	240	3,650	-
M2-F1 #19	December 3, 1963	Peterson	0:03:15	240	3,650	1st flight of the day
M2-F1 #20	December 3, 1963	Peterson	-	240	3,650	2nd flight of the day Broke landing gear
M2-F1 #21	January 29, 1964	Thompson	-	240	3,650	1st flight of the day
M2-F1 #22	January 29, 1964	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #23	January 29, 1964	Peterson	0:04:44	240	3,650	1st flight of the day
M2-F1 #24	January 29, 1964	Peterson	-	240	3,650	2nd flight of the day
M2-F1 #25	January 29, 1964	Yeager	-	240	3,650	1st flight of the day
M2-F1 #26	January 29, 1964	Yeager	-	240	3,650	2nd flight of the day
M2-F1 #27	January 30, 1964	Yeager	-	240	3,650	1st flight of the day
M2-F1 #28	January 30, 1964	Yeager	-	240	3,650	2nd flight of the day
M2-F1 #29	January 30, 1964	Mullick	-	240	3,650	1st flight of the day
M2-F1 #30	January 30, 1964	Mullick	-	240	3,650	2nd flight of the day
M2-F1 #31	February 28, 1964	Thompson	-	240	3,650	1st flight of the day

M2-F1 #32	February 28, 1964	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #33	March 30, 1964	Peterson	0:02:25	240	3,650	-
M2-F1 #34	April 9, 1964	Thompson	-	240	3,650	1st flight of the day
M2-F1 #35	April 9, 1964	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #36	April 9, 1964	Peterson	0:08:00	240	3,650	1st flight of the day
M2-F1 #37	April 9, 1964	Peterson	-	240	3,650	2nd flight of the day
M2-F1 #38	April 9, 1964	Peterson	-	240	3,650	3rd flight of the day
M2-F1 #39	May 19, 1964	Peterson	0:04:08	240	3,650	1st flight of the day
M2-F1 #40	May 19, 1964	Peterson	-	240	3,650	2nd flight of the day
M2-F1 #41	June 3, 1964	Thompson	-	240	3,650	-
M2-F1 #42	July 24, 1964	Peterson	0:06:50	240	3,650	1st flight of the day
M2-F1 #43	July 24, 1964	Peterson	-	240	3,650	2nd flight of the day
M2-F1 #44	July 24, 1964	Peterson	-	240	3,650	3rd flight of the day
M2-F1 #45	August 18, 1964	Thompson	-	240	3,650	-
M2-F1 #46	August 21, 1964	Thompson	-	240	3,650	1st flight of the day
M2-F1 #47	August 21, 1964	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #48	August 21, 1964	Thompson	-	240	3,650	3rd flight of the day
M2-F1 #49	August 21, 1964	Thompson	-	240	3,650	4th flight of the day
M2-F1 #50	February 16, 1965	Thompson	-	240	3,650	-
M2-F1 #51	May 27, 1965	Thompson	-	240	3,650	1st flight of the day
M2-F1 #52	May 27, 1965	Thompson	-	240	3,650	2nd flight of the day

M2-F1 #53	May 27, 1965	Thompson	-	240	3,650	3rd flight of the day
M2-F1 #54	May 27, 1965	Thompson	-	240	3,650	4th flight of the day
M2-F1 #55	May 27, 1965	Sorlie	0:06:00	240	3,650	1st flight of the day
M2-F1 #56	May 27, 1965	Sorlie	-	240	3,650	2nd flight of the day
M2-F1 #57	May 27, 1965	Sorlie	-	240	3,650	3rd flight of the day
M2-F1 #58	May 28, 1965	Thompson	-	240	3,650	-
M2-F1 #59	May 28, 1965	Sorlie	0:04:30	240	3,650	1st flight of the day
M2-F1 #60	May 28, 1965	Sorlie	-	240	3,650	2nd flight of the day
M2-F1 #61	July 16, 1965	Thompson	-	240	3,650	-
M2-F1 #62	July 16, 1965	Dana	-	240	3,650	-
M2-F1 #63	July 16, 1965	Gentry	0:00:09	200	10	Rolled M2-F1 on liftoff. Recovered. Safe landing.
M2-F1 #64	August 30, 1965	Thompson	-	240	3,650	1st flight of the day
M2-F1 #65	August 30, 1965	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #66	August 30, 1965	Thompson	-	240	3,650	3rd flight of the day
M2-F1 #67	August 31, 1965	Thompson	-	240	3,650	-
M2-F1 #68	October 6, 1965	Thompson	-	240	3,650	1st flight of the day
M2-F1 #69	October 6, 1965	Thompson	-	240	3,650	2nd flight of the day
M2-F1 #70	October 8, 1965	Thompson	-	240	3,650	-
M2-F1 #71	March 28, 1966	Thompson	-	240	3,650	1st flight of the day
M2-F1 #72	March 28, 1966	Thompson	-	240	3,650	2nd flight of the day

M2-F1 #73	August 4, 1966	Peterson	0:02:00	240	3,650	-
M2-F1 #74	August 5, 1966	Peterson	0:04:00	240	3,650	1st flight of the day
M2-F1 #75	August 5, 1966	Peterson	-	240	3,650	2nd flight of the day
M2-F1 #76	August 5, 1966	Peterson	-	240	3,650	3rd flight of the day
M2-F1 #77	August 16, 1966	Gentry	-	200	10	Rolled M2-F1 on liftoff. Recovered. Fired landing rockets. Safe landing. Last flight.

Chapter- 7

Sikorsky S-72

S-72 RSRA

The S-72 in flight without a main rotor in 1984

Role	Experimental helicopter
Manufacturer	Sikorsky Aircraft
First flight	12 October 1976
Number built	2

The **Sikorsky S-72** was an experimental hybrid helicopter/fixed-wing aircraft developed by helicopter manufacturer Sikorsky Aircraft.

Design and development

RSRA

The Rotor Systems Research Aircraft (RSRA) was developed by Sikorsky for NASA and the Army. The RSRA was developed to allow the in-flight measurement of helicopter rotor characteristics. The airframe was developed using an existing Sikorsky S-61 main rotor, an S-61 roller gearbox, and a highly modified Sikorsky S-67 airframe. The RSRA could be fitted with TF34 turbofans and wings to allow compound helicopter

configurations to be experimentally investigated at speeds up to 300 knots (560 km/h). In addition, it could fly as a fixed-wing aircraft without a rotor.

Unique among helicopters of its time, it was fitted with a crew emergency extraction system. This system, when activated, fired explosive bolts that severed the main rotor blades, egress panels were blown off the roof of the aircraft and then the crew was extracted using rockets.

The RSRA was a unique pure research aircraft developed to fill the void between design analysis, wind tunnel testing, and flight results of rotor aircraft. The joint NASA/Army project began in December 1970, first flight on October 12, 1976 with the first of two aircraft arriving from Sikorsky to NASA on February 11, 1979.

One notable test performed with the RSRA was the use of the main and tail rotor load measurement system to determine the vertical drag of the airframe.

In 1981, NASA and the US Army solicited proposals for fitting a four-bladed main rotor to the RSRA. Sikorsky proposed fitting a UH-60A main rotor to the RSRA in their proposal , while Hughes Helicopters proposed fitting a YAH-64A main rotor and Boeing Vertol proposed fitting a YUH-61A or Model 347 (4-blade CH-47) main rotor . In the end, this program was not proceeded with.

The X-Wing

Sikorsky S-72 modified as the X-Wing testbed

Rotor Systems Research Aircraft / X-Wing aircraft during a 1987 high speed taxi test.

The **Sikorsky X-Wing** was developed between 1983 and 1988 by helicopter manufacturer Sikorsky with NASA and DARPA funding. Intended to take off vertically like a helicopter, the craft's rigid rotors could be stopped in mid-flight to act as X-shaped wings to provide additional lift during forward flight, as well as having more conventional wings.

Instead of controlling lift by twisting its blades as more conventional helicopters do, the craft used compressed air fed from the engines and expelled from its blades to generate a virtual wing surface, similar to blown flaps on a conventional platform. Computerized valves made sure the compressed air came from the correct edge of the rotor, the correct edge changing as the rotor rotated.

Specifications (S-72)

General characteristics

- **Crew:** 2-3
- **Length:** ft in (21.50 m)

- **Wingspan:** ft in (18.90 m)
- **Height:** ft in (4.42 m)
- **Empty weight:** lb (9,480 kg)
- **Max takeoff weight:** lb (11,815 kg)
- **Powerplant:**
  - 2× General Electric TF34-GE-400A turbofans, lbf (4180 kN) each
  - 2× General Electric T58-GE-5 turboshaft, shp (1,045 kW) each
- *** Take-off weight without auxiliary jets:** 8,300 kg
- **Empty weight without auxiliary jets:** 6,535 kg

Performance

- **Maximum speed:** 200 knots (230 mph, 370 km/h
- **Max speed without auxiliary jets:** 296 km/h)
- **Cruise speed:** 140 knots (160 mph, 258 km/h
- **Cruising speed without auxiliary jets:** 258 km/h)
- **Rate of climb:** 600 394 ft/min ()

Chapter- 8

Boeing X-48

X-48

X-48B

Role	Experimental unmanned aerial vehicle
Manufacturer	Boeing
First flight	20 July 2007
Status	In testing
Primary user	NASA
Produced	2

The **X-48** is an experimental unmanned aerial vehicle for investigation into the characteristics of blended wing body (BWB) aircraft, a type of flying wing. It is currently under development by Boeing and NASA.

Design and development

Background

Boeing had studied a blended wing body design. It found that passengers did not like the theater-like configuration of the mock-up. The company dropped the design for passenger airliners, but reserved it for military aircraft such as tankers.

McDonnell Douglas developed the X-48 concept in the late 1990s, and presented it during an annual Joint AIAA/ASME/SAE/ASEA Propulsion Conference in 2004. The McDonnell Douglas engineers were confident that their design had all the advantages mentioned, but their concept found no favor at Boeing after their merger. The most difficult problem they solved was that of ensuring passengers a safe and fast escape in case of an accident, since emergency door locations were completely different from those in a conventional aircraft.

The blended wing body (BWB) concept offers advantages in structural, aerodynamic and operating efficiencies over today's more conventional fuselage-and-wing designs. These features translate into greater range, fuel economy, reliability and life cycle savings, as well as lower manufacturing costs. They also allow for a wide variety of potential military and commercial applications.

X-48

Boeing X-48B flight test vehicle on display at the 2006 Edwards Airshow

Boeing Phantom Works is developing the blended wing body aircraft concept in cooperation with the NASA Langley Research Center. In a continuing effort to study the flight characteristics of the BWB design, a remote-controlled propeller-driven blended wing body model with a 17 ft (5.2 m) wingspan was successfully flown in 1997. The next step was to fly the 35 ft (10.7 m) wide X-48A in 2004, but that program was later canceled.

Boeing Phantom Works is focusing current research on a pair of models, called the X-48B, which were built under contract by Cranfield Aerospace in the United Kingdom. Norman Princen, Boeing's chief engineer for the project, said, "Earlier wind-tunnel testing and the upcoming flight testing are focused on learning more about the BWB's low-speed flight-control characteristics, especially during takeoffs and landings.

Knowing how accurately our models predict these characteristics is an important step in the further development of this concept."

The X-48B has a 21-foot (6.4 m) wingspan, weighs 392-pound (178 kg), and is built from composite materials. It is powered by three small turbojet engines and is expected to fly at up to 120 kn (220 km/h) and reach an altitude of 10,000 feet (3,000 m). The X-48B is a scaled down from a conceptual 240-foot wide design. Though passenger versions of the X-48B have been proposed, the design will more likely be first used for a military transport.

X-48B on its first flight

Wind tunnel testing on a 12 ft wide blended wing body model was completed in September 2005. NASA performed wind tunnel tests on X-48B Ship 1, an 8.5% scale model, at a facility shared by Langley and Old Dominion University during April and May 2006. After the wind tunnel testing, the vehicle was shipped to NASA's Dryden Flight Research Center at Edwards Air Force Base to serve as a backup to X-48B Ship 2 for flight testing. Ground testing at Dryden began in November 2006, to validate the aircraft's systems integrity, telemetry and communications links, flight-control software and taxi and takeoff characteristics.

X-48B at first flight, seen from below

The X-48B first flew on July 20, 2007. The BWB reached an altitude of 7,500 feet (2,286 m) above MSL and lasted 31 minutes. This began flight testing. The remotely-piloted aircraft was successfully stalled for the first time on September 4, 2008, with fixed leading edge slats, a forward center of gravity, and 23-degree angle of attack (2° beyond the maximum coefficient of lift). Stall testing was repeated on 11 September with a NASA pilot at the console.

NASA and Boeing successfully completed initial flight testing of the Boeing X-48B on March 19, 2010. Fay Collier, manager of the ERA Project in NASA's Aeronautics Research Mission Directorate commented on the completion of the first phase of testing saying, "This project is a huge success. Bottom line: the team has proven the ability to fly tailless aircraft to the edge of the low-speed envelope safely."

Following the installation of a new flight computer later this year, the X-48B will continue a new phase of flights tests that are to focus on additional parameter identification investigations. In addition, the team managing the project is also preparing a second hybrid wing body aircraft: the X-48C for future flight tests, which is intended to have a lower noise profile.

X-48C

A second phase of flight tests with the X-48B was to begin in September 2010. Afterwards the second X-48B will be modified into the X-48C for flight tests in 2011. The X-48C will have its vertical stabilisers moved inboard on either side of the engines,

and its fuselage extended aft, both in an attempt to reduce the aircraft's noise profile, and will be powered by two JetCat turbines, each producing 80 pounds-force (0.36 kN) of thrust.

Specifications (X-48B)

Data from

General characteristics

- **Crew:** None
- **Wingspan:** 20 ft 5 in (6.22 m)
- **Wing area:** 100.5 sq ft (9.34 m^2)
- **Aspect ratio:** 4.1
- **Gross weight:** 500 lb (227 kg)
- **Powerplant:** 3 × JetCat P200 turbojet, 52 lbf (0.23 kN) thrust each

Performance

- **Maximum speed:** 136 mph; 219 km/h (118 kn)
- **Endurance:** 40 minutes
- **Service ceiling:** 10,000 ft (3,048 m)

Chapter- 9

Douglas DC-8

DC-8

NASA Dryden DC-8 airborne laboratory refitted with CFM56 turbofan engines

Role	Narrow-body jet airliner
National origin	United States
Manufacturer	Douglas Aircraft McDonnell Douglas
First flight	May 30, 1958
Introduced	September 1959 with United Airlines and Delta Air Lines
Status	Limited cargo and VIP transport operations
Primary users	Air Transport International Astar Air Cargo Johnsons Air
Produced	1958-1972
Number built	556

The **Douglas DC-8** is a four-engined jet airliner, manufactured from 1958 to 1972 by the Douglas Aircraft Company. Launched later than the competing Boeing 707, the DC-8 nevertheless established Douglas in a strong position in the airliner market, and remained in production until 1972 when much larger designs, including the DC-10 and Boeing 747, made the DC-8 obsolete. Relegated to second-line duties, details of the DC-8 design allowed it to hold slightly more cargo than the 707; dozens of re-engined examples remain in freighter service to this day, while commercial 707 service had largely ended by 2000.

Development

Background

In the post-World War II era, Douglas held a commanding position in the commercial aircraft market. Although Boeing had pointed the way to the modern all-metal airliner in 1933 with the 247, it was Douglas that, more than any other company, had made commercial air travel a reality. Douglas produced a succession of piston-engined aircraft (DC-2, DC-3, DC-4, DC-5, DC-6, and DC-7) through the 1930s, 1940s and 1950s.

When de Havilland introduced the first jet-powered airliner, the Comet, in 1949, Douglas took the view that there was no reason to rush into anything new. Their U.S. competitors at Lockheed and Convair felt the same way: that there would be a gradual switch from piston engines to turbines, and that the switch would be to the more fuel-efficient turboprop engines rather than pure jets. All three companies were working on a new generation of piston-engined designs, with an eye to turboprop conversion in the future.

De Havilland's pioneering Comet entered airline service in 1952. Initially it was a success, but a series of fatal crashes in 1953 and 1954 resulted in the type being grounded until the cause could be discovered. The cause of the Comet crashes had nothing to do with jet engines; it was a rapid metal fatigue failure brought on by cycling the high stresses in corners of the near-square windows from pressurizing the cabin to high altitudes and back. A new understanding of metal fatigue that the Comet investigation produced would play a vital part in the good safety record of later types like the DC-8.

In 1952, Douglas remained the most successful of the commercial aircraft manufacturers. They had almost 300 orders on hand for the piston-engined DC-6 and its successor, the DC-7, which had yet to fly and was still two years away from commercial service. The Comet disasters, and the consequent airline lack of interest in jets, seemed to demonstrate the wisdom of their staying with propeller aircraft.

NASA DC-8 in baked flight over Dryden Aircraft Operations Facility

NASA DC-8 over Mint Canyon

NASA Dryden DC-8

Douglas DC-8 Airborne Laboratory in flight

NASA Dryden DC-8

Competition

In contrast, Boeing took the bold step of starting to plan a pure-jet airliner in as early as 1949. Boeing's military arm had gained extensive experience with large, long-range jets through the B-47 Stratojet (first flight 1947) and the B-52 Stratofortress (1952). With thousands of their big jet bombers on order or in service, Boeing had developed a close relationship with the US Air Force's Strategic Air Command (SAC). Boeing also supplied the SAC's refueling aircraft, the piston-engined KC-97 Stratotankers, but these proved to be too slow and low flying to easily work with the new jet bombers. The B-52, in particular, had to descend from its cruising altitude and then slow almost to stall speed to work with the KC-97, even when the latter was augmented with jet engines to boost its speed.

Believing that a requirement for a jet-powered tanker was a certainty, Boeing started work on a new all-jet aircraft that would fill this role and also be adaptable into an airliner. In the airliner role it would have similar seating capacity to the Comet, but its swept wing planform would give it considerably higher cruising speeds, and better range. First presented in 1950 as the Model 473-60C, Boeing failed to generate any interest at the airlines. Nevertheless, Boeing remained convinced that the project was worthwhile,

and decided to press ahead with a prototype, the "Dash-80". After spending $16 million of their own money (~$120 million 2005 USD) on construction, the Dash-80 rolled out on 15 May 1954, and first flew the next month.

Design phase

Boeing's plans became obvious in the industry, in spite of their "code name" intended as a disinformation tactic. Douglas secretly began jet transport project definition studies in mid-1952. By mid-1953 these had developed into a form very similar to the final DC-8; an 80-seat, low-wing aircraft with four Pratt & Whitney JT3C turbojet engines, 30° wing sweep, and an internal cabin diameter of exactly 11 ft (3.35 m) to allow five abreast seating. Maximum weight was to be 95 tons (86 tonnes), and range was estimated to be about 3,000-4,000 mi (4,800-6,400 km).

Douglas remained lukewarm about the jet airliner project, but believed that the Air Force tanker contract would go to two companies for two different aircraft, as several USAF transport contracts in the past had done. In May 1954, the USAF circulated its requirement for 800 jet tankers to Boeing, Douglas, Convair, Fairchild, Lockheed, and Martin. Boeing was already just two months away from having their prototype in the air. Just four months after issuing the tanker requirement, the USAF ordered the first 29 KC-135s from Boeing. Even leaving aside Boeing's ability to supply a jet tanker promptly, the flying-boom air-to-air refueling system — as first fitted to the KC-97 — was also a Boeing product: developing the KC-135 had been a safe bet.

DC-8 in flight

NASA DC-8

DC-8 descents with using its thrust reversers

MK Airlines DC-8

Swissair DC-8

Donald Douglas was shocked by the rapidity of the decision which, he said, had been made before the competing companies even had time to complete their bids. He protested to Washington, but without success. Having started on the DC-8 project, Douglas decided that it was better to press on than give up. Consultations with the airlines resulted in a number of changes: the fuselage was widened by 15 in (38 cm) to allow six-abreast seating. This led to larger wings and tail surfaces and a longer fuselage. The cost of the program was enormous; it was at that time the most expensive venture of any kind ever taken on by a single company. Donald Douglas provided $450 million towards it out of his own pocket.

The DC-8 was officially announced in July 1955. Four versions were offered to begin with, all based on the same 150 ft 6 in (45.9 m) long airframe with a 141 ft 1 in (43 m) wingspan, but varying in engines and fuel capacity, and with maximum weights of about 120-130 tons (109-118 tonnes). Douglas steadfastly refused to offer different fuselage sizes. The maiden flight was planned for December 1957, with entry into revenue service in 1959. Well aware that they were lagging behind Boeing, Douglas began a major push to market the product.

First orders

At the time, Douglas' previous thinking about the airliner market seemed to be coming true; the transition to turbine powered looked likely to be one to turboprops rather than turbojets. The pioneering 40–60-seat Vickers Viscount was already in service and proving enormously popular with both passengers and airlines: it was much faster, quieter and more comfortable than piston-engined types. Another British aircraft, the 90-seat Bristol Britannia, was establishing a fine reputation, and Douglas's main rival in the large, piston-engined passenger aircraft market, Lockheed, had committed to the short/medium range 80–100-seat turboprop Electra, with a launch order from American Airlines for 35 and other major orders flowing in. Meanwhile the Comet remained grounded, the French 90-passenger twin jet Sud Aviation Caravelle prototype had just flown for the first time, and the 707 was not expected to be available until late 1958. The major airlines were reluctant to commit themselves to the huge financial and technical challenge of jet aircraft. On the other hand, no-one could afford *not* to buy jets if their competitors did.

And there the matter rested until October 1955, when Pan American placed simultaneous orders with Boeing for 20 707s and Douglas for 25 DC-8s. To buy one expensive and untried jet-powered aircraft type was brave: to buy both was at the time, unheard of. In the closing months of 1955, other airlines rushed to follow suit: Air France, American, Braniff, Continental and Sabena ordered 707s; United, National, KLM, Eastern, JAL and SAS chose the DC-8. In 1956 Air India, BOAC, Lufthansa, Qantas and TWA added over 50 to the 707 order book, while Douglas sold 22 DC-8s to Delta, Swissair, TAI, Trans-Canada and UAT. By the start of 1958, Douglas had sold 133 DC-8s as against Boeing's 150 707s.

United Airlines chose the DC-8 over the Boeing 707. This Douglas DC-8-50 was photographed at Boston in 1973.

The first DC-8 was rolled out of the new factory at Long Beach in April 1958 and flew for the first time in May. Later that year, an enlarged version of the Comet finally returned to service, but too late to take a substantial portion of the market: de Havilland had just 25 orders. In October, Boeing began delivering 707s to Pan Am. Douglas made a massive effort to close the gap with Boeing, using no less than ten individual aircraft for flight testing to achieve FAA certification for the first of the many DC-8 variants in August 1959. Much had needed to be done: the original air brakes on the lower rear fuselage were found ineffective and were simply deleted as engine thrust reversers had become available; unique leading-edge slots were added to improve low-speed lift; the prototype was 25 kn (46 km/h) short of its promised cruising speed and a new, slightly larger wingtip had to be developed to reduce drag.

Douglas DC-8 72 side view

Douglas DC-8 72 over clouds

Douglas DC-8 72 just before tuchdown

DC-8 72 overflight

The DC-8 entered revenue service first with Delta Air Lines on 18 September 1959 with United also entering service later on the same day. By March 1960, Douglas had reached their planned production rate of eight DC-8s a month. Despite the large number of DC-8 early models available, all used the same basic airframe, differing only in engines, weights and details. In contrast, Boeing's rival 707 range offered several fuselage lengths and two differing wingspans: the original 144 ft (44 m) 707-120, a 135 ft (41 m) version that sacrificed space to gain longer range, and the stretched 707-320, which at 153 ft (46.5 m) overall had 10 ft (3 m) more cabin space than the DC-8. Douglas' refusal to offer different fuselage sizes made it less adaptable, and the DC-8 gradually lost market share to Boeing. After an excellent start, 1962 DC-8 sales dropped to just 26, followed by 21 in 1963 and 14 in '64, and most of these were for the Jet Trader rather than the more prestigious passenger versions. In 1967, Douglas merged with McDonnell Aircraft Corporation to become McDonnell Douglas (MDC).

On 21 August 1961 a Douglas DC-8 broke the sound barrier at Mach 1.012 (660 mph/1,062 km/h) while in a controlled dive through 41,000 ft (12,497 m). The flight was to collect data on a new leading-edge design for the wing. The DC-8 became the first civilian jet to make a supersonic flight. The aircraft was a DC-8-43 later delivered to Canadian Pacific Air Lines as CF-CPG.

Further developments

Air Canada DC-8-61 at Montréal-Pierre Elliott Trudeau International Airport

In April 1965, Douglas announced belated fuselage stretches for the DC-8, with not just one but three new models, known as the *Super Sixties*. The DC-8 program had been in danger of closing with fewer than 300 aircraft sold, but the Super Sixties brought fresh life to it. By the time production ceased in 1972, 262 of the stretched DC-8s had been made. With the ability to seat 269 passengers, the DC-8 Series 61 and 63 easily comprised the largest airliner available, and remained so until the Boeing 747 arrived in 1970.

All the earlier jetliners were noisy by modern standards. Increasing traffic densities and changing public attitudes led to complaints about aircraft noise and moves to introduce restrictions. As early as 1966 the New York Port Authority expressed concern about the noise to be expected from the then still unbuilt DC-8-61, and operators had to agree to operate it from New York at lower weights to reduce noise. By the early 1970s, legislation for aircraft noise standards was being introduced in many countries, and the 60 Series DC-8s were particularly at risk of being banned from major airports.

In the early 1970s several airlines approached McDonnell Douglas for noise reduction modifications to the DC-8 but nothing was done. Third parties had developed aftermarket hushkits but there was no real move to keep the DC-8 in service. Finally, in 1975, General Electric began discussions with major airlines with a view to fitting the new and vastly quieter Franco-American CFM56 engine to both DC-8s and 707s. MDC remained

reluctant but eventually came on board in the late 1970s and helped develop the 70 Series DC-8s.

The Super Seventies were a great success: roughly 70% quieter than the 60-Series and, at the time of their introduction, the world's quietest four-engined airliner. As well as being quieter and more powerful, the CFM56 was roughly 20% more fuel efficient than the JT3D, which reduced operating costs and extended the range.

Air Transport International DC-8-62F at Thule AB, Greenland.

By 2002, of the 1032 707s and 720s manufactured for commercial use, just 80 remained in service — though many of those 707s were converted for USAF use, either in service or for spare parts. Of the 556 DC-8s made, around 200 were still in commercial service in 2002, including about 25 50-Series, 82 of the stretched 60-Series, and 96 out of the 110 re-engined 70-Series. Most of the surviving DC-8s are now used as freighters. As of May 2009, 97 DC-8s were in service following UPS's decision to retire their remaining fleet of 44.

Variants

Early models

- **DC-8 Series 10** For U.S. domestic use and powered by 13,601 lbf (60.5 kN) Pratt & Whitney JT3C-6 turbojets. The initial **DC-8-11** model had the original, high-

drag wingtips and all examples were subsequently converted to DC-8-12 standard. The **DC-8-12** had the new wingtips and leading-edge slots inboard of each pylon. These unique devices were actuated by doors on the upper and lower surfaces that opened for low speed flight and closed for cruise. The maximum weight increased from 132 tons (120 tonnes) to 136 tons (123 tonnes). 28 DC-8-10s were manufactured. This model was originally named "DC-8A" until the series 30 was introduced.

DC-8-32 of Overseas National Airways in Zurich, 1975

- **DC-8 Series 20** Higher-powered 15,916 lbf (70.8 kN) Pratt & Whitney JT4A-3 turbojets allowed a weight increase to 138 tons (125 tonnes). 34 DC-8-20s were manufactured. This model was originally named "DC-8B" but was renamed when the series 30 was introduced.

- **DC-8 Series 30** For intercontinental routes, the three Series 30 variants combined JT4A engines with a one-third increase in fuel capacity and strengthened fuselage and landing gear. The **DC-8-31** was certified in March 1960 with 16,906 lbf (75.2 kN) JT4A-9 engines for 150 tons (136 tonnes) maximum weight. The **DC-8-32** was similar but allowed 154 tons (140 tonnes) weight. The **DC-8-33** of November 1960 substituted 17,625 lbf (78.4 kN) JT4A-11 turbojets, a modification to the flap linkage to allow a 1.5° setting for more efficient cruise, stronger landing gear, and 158 tons (143 tonnes) maximum weight. Many -31 and -32 DC-8s were upgraded to this standard. A total of 57 DC-8-30s were produced.

- **DC-8 Series 40** The first turbofan-powered airliner in the world, with delivery in 1960. The -40 was essentially the same as the -30 but with 17,625 lbf (78.4 kN) Rolls-Royce Conway turbofans for better efficiency, less noise and less smoke. The Conway was a significant improvement over the turbojets that preceded it, but the Series 40 sold poorly both because of the traditional reluctance of U.S. airlines to buy a foreign product and because the still more advanced Pratt & Whitney JT3D turbofan was due in early 1961. The **DC-8-41** and **DC-8-42** had weights of 150 tons (136 tonnes) and 154 tons (140 tonnes), the 158 ton (143 tonne) **DC-8-43** had the 1.5° flap setting of the -33 and introduced a new 4% leading edge wing extension to allow a small fuel capacity increase and a significant drag reduction - the new wing design improved range by 8%, lifting capacity by 3.3 tons (3 tonnes), and cruising speed by better than 10 kn (19 km/h). It would be included in all future DC-8s. A total of 32 DC-8-40s were manufactured.

- **DC-8 Series 50** The definitive short-fuselage DC-8 with the same engine that powered the vast majority of 707s, the JT3D. Many earlier DC-8s were converted to this standard. All bar the -55 were certified in 1961. The **DC-8-51**, **DC-8-52** and **DC-8-53** all had 17,108 lbf (76.1 kN) JT3D-1 or 18,120 lbf (80.6 kN) JT3D-3B engines, varying mainly in their weights: 139, 152 and 157 tons (126, 138 and 142 tonnes) respectively. The **DC-8-55** arrived in June 1964, retaining the JT3D-3B engines but with strengthened structure from the freighter versions and 147 tonne maximum weight. 88 DC-8-50s were manufactured.

The unique EC-24A of the US Navy in storage

- **DC-8 Jet Trader** Douglas approved development of specialized freighter versions of the DC-8 in May 1961, based on the Series 50. An original plan to fit a fixed bulkhead separating the forward ⅔ of the cabin for freight, leaving the rear cabin for 54 passenger seats was soon replaced by a more practical one to use a movable bulkhead and allow anywhere between 25 and 114 seats with the remainder set aside for cargo. A large cargo door was fitted into the forward fuselage, the cabin floor was reinforced and the rear pressure bulkhead was moved by nearly 7 ft (2 m) to make more space. Airlines were offered the option of a windowless cabin, though only one, United, took this up, with an order for 15 in 1964. The **DC-8F-54** had a maximum takeoff weight of 158 tons (143 tonnes) and the **DC-8F-55** 162 tons (147 tonnes). Both used 18,120 lbf (80.6 kN) JT3D-3B powerplants.

- **C-24** A single ex-United Airlines DC-8F-54 was used by the United States Navy as an electronic warfare training platform. Given the designation **EC-24A**, it was retired in October 1998 and is now in storage with the 309th Aerospace Maintenance and Regeneration Group.

Super sixties

- The **DC-8 Series 61** was designed for high capacity and medium range. It had the same wings, engines and pylons as the -53, and sacrificed range to gain capacity. Having decided to stretch the DC-8, Douglas inserted a 20 ft (6 m) plug in the forward fuselage and a 16 ft (5 m) plug aft, taking overall length to 187 ft (57 m) and giving the aircraft a very long, lean look that was (and is still) unique. Bending forces required strengthening of the structure, but the basic DC-8 design already had sufficient ground clearance to permit the one-third increase in cabin size without requiring longer landing gear. It was certified in September 1966 and typically carried 210 passengers, or 269 in high-density configuration. A total of 88 were sold.

  Timelines:
  First flight: March 14, 1966.
  FAA certification: September 2, 1966.
  First delivery: January 26, 1967 United Airlines.
  Entry into Service: February 25, 1967 United Airlines.

- The long-range **DC-8 Series 62** followed in April 1967. It had a much more modest stretch of just 6 feet 6 inches (1.98 m) (with 3 feet 3 inches (0.99 m) plugs fore and aft), the more powerful JT3D-7 engines as the -63, and a number of modifications to provide greater range. 3 feet (0.91 m) wingtip extensions reduced drag and added fuel capacity, and Douglas redesigned the engine pods, extending the pylons and substituting new shorter and neater nacelles, all in the cause of drag reduction. The engine pylons were redesigned to eliminate their protrusion above the wing and make them sweep forward more sharply, so that the engines were actually positioned some 40 inch further forward. The engine pods were also

modified featuring a reduction in pod diameter and the elimination of the -50 and -61 bypass duct. The changes all contributed to improve the aircraft's aerodynamic efficiency. The DC-8 Series 62 is slightly heavier than the -53 or -61 at 166 tons (151 tonnes), and able to seat 159 passengers, the -62 had a range with full payload of about 5,200 nmi (9,600 km), or about the same as the -53 but with 40 extra passengers. A total of 67 were built.

Timelines:
First flight: August 29, 1966.
FAA certification: April 27, 1967.
First delivery: May 5, 1967 Scandinavian Airlines (SAS).
Entry into Service: May 22, 1967 Scandinavian Airlines (SAS).

- The **DC-8 Series 63** was the final new build variant and entered service in June 1968. It combined the long fuselage of the -61 with the aerodynamic refinements, increased fuel capacity, and JT3D-7 turbofans of the -62. This yielded a maximum take off weight of almost 175 tons (159 tonnes) and a range with full payload of 4,110 nmi (7,600 km). A total of 107 were built, a little over half of them convertibles or dedicated freighters.

Timelines:
First flight: April 10, 1967.
FAA certification: June 30, 1967.
First delivery: July 15, 1967 KLM.
Entry into Service: July 27, 1967 KLM.
Last delivery: May 1972 Scandinavian Airlines (SAS).

Super seventies

BAX Global DC-8-71(F) at Boeing Field

- The **DC-8-72** and the **DC-8-73** were straightforward conversions of the -62 and -63, replacing the JT3D engines with 22,144 lbf (98.5 kN) CFM56-2 high-bypass turbofans in new housings built by Grumman. The **DC-8-71** achieved the same end but required considerably more modification because the -61 did not already have the improved wings and relocated engines of the -62 and -63. Maximum takeoff weights remained the same, but there was a slight reduction in payload because of the heavier engines. All three models were certified in 1982 and a total of 110 60-Series DC-8s were converted by the time the program ended in 1988.

Operators

A total of 84 DC-8 aircraft (all variants) were in commercial service as of Jult 2010; the following operators had two or more aircraft in inventory:

- UPS Airlines (25)
- Air Transport International (17)
- Astar Air Cargo (8)
- Meridian Airways (5)
- BETA Cargo (4)
- Expo Aviation (1)
- National Airlines (4)

The DC-8 is no longer used by military organizations as of 2008. The DC-8 is in use by NASA as an Airborne Laboratory.

Accidents and incidents

As of August 2008, the DC-8 had been involved in 139 incidents, including 83 hull-loss accidents, with 2,256 fatalities.

Notable accidents

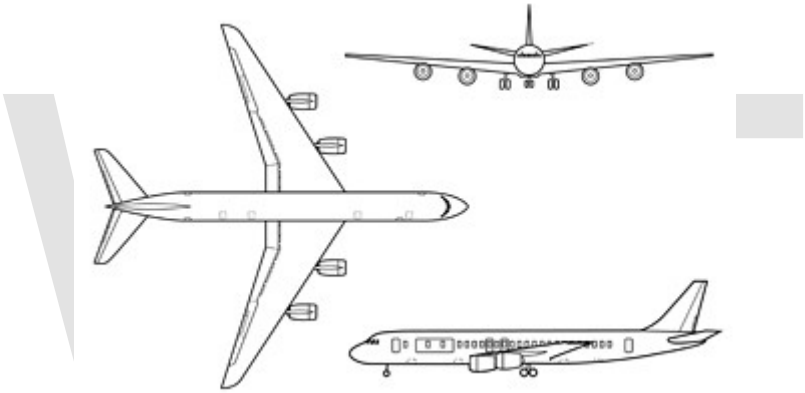
- On December 16, 1960, United Airlines Flight 826, a DC-8, collided with a TWA Lockheed Constellation (as Flight 266) in mid-air over Staten Island, New York City, New York, United States, resulting in a total of 134 fatalities.
- On May 30, 1961, Viasa Flight 897, a DC-8, crashed into the Atlantic Ocean shortly after takeoff from Lisbon Portela Airport. All 61 passengers and crew on board were killed.
- On August 20, 1962, a Panair do Brasil DC-8-33, registration PP-PDT flying from Rio de Janeiro - Galeão to Lisbon, overran the runway into the ocean during an aborted take-off. Of the 105 passengers and crew aboard, 15 died.
- On November 29, 1963, Trans-Canada Air Lines Flight 831, a DC-8, crashed shortly after takeoff from Montréal/Dorval Airport, killing all 118 people on board.
- On February 25, 1964, Eastern Air Lines Flight 304, a DC-8 flying from New Orleans International Airport to Washington National Airport crashed into Lake Pontchartrain killing all 51 passengers and 7 crew aboard. The cause was determined to be related to an abnormal trim setting resulting in aircraft instability.
- On March 4, 1966, Canadian Pacific Airlines Flight 402 (CP402), a DC-8-43 crashed on landing at Tokyo International Airport in Japan, killing 64 passengers and crew; 8 passengers survived.
- On March 5, 1967, Varig Airlines Flight 837, a DC-8-33 hit buildings while on the approach to Monrovia Airport, Liberia. Of the 71 passengers and 19 crew on

board, 66 passengers and one crew member (the flight engineer) were killed. The DC-8-33 was on a scheduled flight from Beirut to Rio de Janeiro via Rome and Monrovia. Five persons on the ground were also killed.

- On July 1, 1968, Seaboard World Airlines Flight 253, a DC-8, was forced to land in the Soviet Union. Onboard were over 200 American troops bound for Vietnam.
- On January 13, 1969, Scandinavian Airlines Flight 933, a DC-8, crashed into the Pacific Ocean west of Los Angeles International Airport. Of the 36 passengers and 9 crew aboard, 15 were killed in the crash.
- On July 5, 1970, Air Canada Flight 621, a DC-8-63, exploded near Toronto Pearson International Airport, with 109 fatalities, when premature deployment of the wing spoilers caused an engine to detach, igniting onboard fuel during the subsequent go around.
- On May 5, 1972 Alitalia Flight 112, a DC-8-43, crashed into a mountain in the outskirts of Palermo and disintegrated, killing all 115 people on board (108 passengers and 7 crew).
- On November 27, 1972, Japan Airlines Flight 446, a DC-8-62, crashed while in an initial climb on a route from Sheremetyevo International Airport of Moscow to Haneda Airport. 9 of 14 crew members and 52 of 62 passengers died, with a total of 61 of 76 occupants dead.
- On 4 December 1974, Martinair Flight 138, flew into the side of a mountain while on landing approach in Colombo, Sri Lanka. All 191 passengers and crew on board were killed.
- On 24 December 1972, Japan Airlines Flight 472, operated Douglas DC-8-53 landed at Juhu Aerodrome instead of Santacruz Airport. The aircraft overran the end of the runway and was damaged beyond economic repair.
- On October 6, 1976, Cubana Flight 455, a DC-8, was bombed by anti-Castro terrorists and crashed near Bridgetown, Barbados, killing all 73 people on board.
- On September 27, 1977, Japan Airlines Flight 715, a DC-8, crashed into a hill as the aircraft was on approach into Sultan Abdul Aziz Shah Airport, Malaysia. The accident killed 34 out of 79 passengers and crew on board.
- On September 28, 1977, Japan Airlines Flight 472, a DC-8, was hijacked after taking off from Mumbai, India by Japanese Red Army (JRA) terrorists. The terrorists forced the airplane to land in Dhaka, Bangladesh, where they demanded US$6 million and the release of nine imprisoned JRA members being held in Japan. The Japanese government complied and all of the hostages were eventually released.
- On November 15, 1978, Icelandic Airlines Flight LL 001, a DC-8 on a charter flight, crashed into a coconut plantation while on approach to Katunayake, Sri Lanka for a refueling stop. 184 out of 264 people on board were killed.
- On December 28, 1978, United Airlines Flight 173, a DC-8, ran out of fuel while circling near Portland, Oregon, United States while the crew investigated a light indicating a problem with the landing gear. The airplane crashed in a wooded area, killing 10 and injuring 24 of the 181 on board.
- On February 9, 1982, Japan Airlines Flight 350, a DC-8-61, crashed on approach to Tokyo International Airport (Haneda). Among the 166 passengers and 8 crew, 24 passengers were killed.

- On December 12, 1985 Arrow Air Flight 1285, a DC-8, crashed after takeoff in Gander, Newfoundland, killing all 256 passengers and crew on board, making it the worst air disaster to occur in Canada; the cause was determined to be a stall most likely due to wing icing.
- On June 7, 1989, Surinam Airways Flight PY764, a DC-8, crashed while attempting to land in heavy fog at Paramaribo, Suriname. The plane hit trees and flipped upside down, killing 176 of 187 people on board.
- On July 11, 1991, Nigeria Airways Flight 2120, a Nationair DC-8-61 chartered by Nigeria Airways to transport Nigerian pilgrims to Mecca, crashed shortly after takeoff from Jeddah, Saudi Arabia, due to a fire caused by tire failure. All 261 on board died, including 14 Canadian crew members.

Specifications



	DC-8-32	DC-8-63CF
Crew	Three	
Passengers	176 (economy) 124 (mixed)	259 (economy) 180 (mixed)
Overall length	150 ft 6 in (45.87 m)	187 ft 4 in (57.10 m)
Wingspan	142 ft 5 in (43.41 m)	148 ft 5 in (45.24 m)
Overall height	43 ft 4 in (13.21 m)	43 ft 0 in (13.11 m)
Fuselage width	12 ft 3 in (3.73 m)	
Wing Area	2,771 ft² (257.4 m²)	2,927 ft² (271.9 m²)
Operating empty weight	134,000 lb (60,800 kg)	146,300 lb (66,360 kg)
Maximum Takeoff Weight	310,000 lb (140,600 kg)	355,000 lb (161,000 kg)
Powerplants (4x)	Pratt & Whitney JT4A-9 turbojets, 16,800 lbf (74.7 kN) each	Pratt & Whitney JT3D-7 turbofans, 19,000 lbf, (84.5 kN) each
Maximum Cruise Speed	588 mph (946 km/h)	596 mph (959 km/h)

Range with Max. Payload	4,605 mi (7,410 km)	2,140 mi (3,445 km)
Wing Loading	111.9 lb/ft² (546.2 kg/m²)	121.3 lb/ft² (592.2 kg/m²)
Thrust/Weight Ratio	0.217	0.21 (derived)

Chapter- 10

Hawker Siddeley P.1127

P.1127 / Kestrel

Prototype Hawker P.1127 *XP831* in 1962

Role	Experimental V/STOL aircraft
National origin	United Kingdom
Manufacturer	Hawker Aviation Hawker Siddeley
Designed by	Sydney Camm
First flight	19 November 1960 (P.1127) 7 March 1964 (Kestrel)
Primary users	Royal Air Force DOD/NASA Luftwaffe
Number built	6 P.1127s 9 Kestrels
Variants	Hawker Siddeley Harrier

The **Hawker P.1127** and the **Hawker Siddeley Kestrel FGA.1** were the development aircraft that led to the Hawker Siddeley Harrier, the first V/STOL jet fighter-bomber.

Development began in 1957, taking advantage of the Bristol Engine Company's choice to invest in the creation of the Pegasus engine. Testing began in July 1960, which included achieving vertical take off and vertical flight that same year. The test program also explored the possibility of usage upon aircraft carriers, landing on HMS *Ark Royal* in 1963. The first three aircraft crashed during testing, one at the 1963 Paris Air Show.

Improvements to future development aircraft, such as swept wings and more powerful Pegasus engines, led to the development of the Kestrel. The Kestrel which was evaluated by the *Tri-partite Evaluation Squadron*, made up of military pilots from both Britain, the United States, and West Germany. Later flights were conducted at the Edwards Air Force Base and by NASA.

Further development into a supersonic aircraft, the Hawker Siddeley P.1154, was cancelled in 1965. As a result, a variant more closely based upon the Kestrel was ordered that same year, which was named *Harrier* in 1967.

Design and development

Background

In 1957, the Bristol Engine Company informed Sydney Camm of Hawker that they had a project to combine their Olympus and Orpheus jet engines to produce a directable fan jet, an idea brought to them via NATO's Mutual Weapons Development Project (MWDP) Team from the French engineer Michel Wibault. Hawker took the planned engine, which became known as the Pegasus, as a basis for a plane that could meet the current NATO specification for a Light Tactical Support Fighter. This was a time of deep UK defence cuts, laid out in the 1957 Defence White Paper; as a result, Hawker's had to seek commercial funding and significant engine development funding came from the USA. Much model testing was done by NASA at Langley Field for the project. Hawker test pilot Hugh Merewether went to the US at NASA's request to fly the Bell X-14. In March 1959, the company's board of directors (now Hawker Siddeley) decided to fund two P.1127 prototypes. In late 1959 the British Ministry of Supply contracted for two P.1127 prototypes.

P.1127

Third prototype P.1127 *XP972* at Farnborough 1962, showing the unswept trailing edges.

The first prototype P.1127, serial *XP831* was delivered in July 1960 for static engine testing, and in October the Pegasus flight engine was made available. The first tethered flight took place the same month and free flight hover achieved on 19 November, after which the first publicity photos were released. The second prototype made its first take off conventionally on 7 July 1961. The two aircraft proceeded to "close the gap" between vertical take off and flight, achieved by 8 September.

Four more prototypes were ordered. Throughout this period improved Pegasus engines were being developed, with the Pegasus 3 being capable of 15,000 lbf (67 kN) of thrust. Apart from this, the first four aircraft were quite similar, but the fifth, *XP980* introduced

the taller fin and tailplane anhedral seen on the Harrier. The fourth machine was used, in part to give the Hawker production test pilots P.1127 familiarisation. The first carrier vertical landing was performed by the first prototype on HMS *Ark Royal* in 1963. The last P.1127, *XP984*, introduced the swept wing. It was eventually fitted with the 15,000 lbf (66.7 kN) Pegasus 5 and functioned as the prototype Kestrel.

The first three P.1127 crashed, the second and third during development. The first prototype (XP831) crashed at the Paris Air Show in 1963 but was fully repaired and resumed development flying. All the pilots involved survived.

Kestrel FGA.1

Hawker Siddeley XV-6A Kestrel in USAF livery

Nine evaluation aircraft were ordered as the **Kestrel FGA.1**, an improved version of the P.1127, the first flying on 7 March 1964. The Kestrel had fully swept wings and a larger tail than the early P.1127s, and the fuselage was modified to take the larger 15,000 lbf (85 kN) Pegasus 5 engine as in the P.1127/Kestrel prototype *XP984*.

Due to interest from the US and Germany, the Tri-partite Evaluation Squadron (TES) was formed on 15 October 1964 at RAF West Raynham, staffed by military test pilots from Britain, the US and West Germany. During testing one aircraft was lost; and evaluations finalised in November 1965.

Six of the eight surviving evaluation aircraft (the three allocated to US plus those allocated to Germany) were transferred to the USA for evaluation by the Army, Air Force, and Navy (but not the US Marine Corp) as the **XV-6A Kestrel**. After Tri-Service evaluation they were passed to the USAF for further evaluation at Edwards Air Force Base, except for two that were assigned to NASA.

One of the two remaining British based Kestrels was attached to the *Blind Landing Experimental Unit* (BLEU) at RAE Bedford and the other, *XS693*, went to Blackburn's for modification to take the uprated Pegasus 6 engine. In addition to some strengthening, there were alterations to the air intake, which had throughout the P.1127 and Kestrel series featured an inflatable lip to smooth the intake airflow when the aircraft was almost stationary. There were concerns about the Service life of these devices, so they were replaced with conventional suction relief doors. This aircraft became the prototype for pre-production Harriers.

P.1127 (RAF)

NATO requirement NBMR-3 specified for a VTOL aircraft, but one that was expected to have the performance of an aircraft like the F-4 Phantom along with the VTOL capability. Hawker drafted the P.1150, a supersonic P.1127 and the P.1154 which would meet NBMR-3. The latter was a winner of the NATO competition and development continued until cancelled at the point of prototype construction in 1965. The RAF then began looking at a simple upgrade of the Kestrel as the P.1127 (RAF).

In late 1965, six pre-production P.1127 (RAF) aircraft were ordered by the RAF (actually the remaining number from Kestrel order). The first pre-production aircraft flew on 31 August 1966. The aircraft was named Harrier in 1967.

Variants

The last of the six P.1127 prototypes (XP984) and the only one with a swept wing, later converted to the first Kestrel prototype with Pegasus 5 engine.

P.1127
: Experimental V/STOL fighter, two prototypes and four development aircraft.

Kestrel FGA.1
: Aircraft for the tripartite evaluation squadron, nine built, six eventually becoming designated XV-6A.

P.1127 (RAF)
: Development V/STOL ground attack and reconnaissance fighter, six built ordered into production as the **Harrier GR1**.

XV-6A
: United States military designation for the Kestrel FGA.1.

VZ-12
: United States Army designation for two P.1127 development aircraft, not delivered.

Operators

West Germany

- Luftwaffe (participated in the Tri-partite Evaluation Squadron, allocated aircraft not delivered and passed to United States)

United Kingdom

- Royal Air Force

United States

- United States Army (participated in both the Tri-partite Evaluation Squadron and as part of the American XV-6A Tri-service evaluation team)
- United States Air Force
- United States Navy (participated in both the Tri-partite Evaluation Squadron and as part of the American XV-6A Tri-service evaluation team)
- NASA

Aircraft on display

XV-6A Kestrel on display at the Virginia Air and Space Center

- P.1127 *XP831* on display at The Science Museum, London, England.
- P.1127 *XP980* (fitted with a Harrier GR.1 wing) is on display at the Fleet Air Arm Museum, Yeovilton, England.

- P.1127 *XP984* (temporarily fitted with an earlier P.1127 wing) is on display at the Brooklands Museum, Surrey, England.
- Kestrel FGA.1 *XS695* is currently under restoration by the Royal Air Force Museum Cosford England.
- P.1127(RAF) *XV277* on display at the National Museum of Flight, Scotland.
- P.1127(RAF) *XV278* on display at the Luftwaffenmuseum, Germany.
- XV-6A Kestrel *64-18262* on display at the National Museum of the United States Air Force at Wright Patterson AFB, Ohio, United States.
- XV-6A Kestrel *64-18263* with NASA livery on display at the Virginia Air and Space Center, Hampton, Virginia, United States
- XV-6A Kestrel *64-18264* held in storage by the United States Army Aviation Museum, Alabama, United States
- XV-6A Kestrel *64-18266* with NASA livery on display at Air Power Park, Hampton, Virginia, United States.

TV Appearance

Both a P.1127 and a Kestrel appeared as a single aircraft (XP984), in the 1966 *Flight Plan* episode of the Roger Moore TV series *The Saint*, involving a P.1127/Kestrel (referred to as the *Osprey*) being stolen and flown behind the Iron Curtain by an RAF pilot.

Specifications (Kestrel FGA.1)

Data from Mason

General characteristics

- **Crew:** 1
- **Length:** 42 ft 6 in (12.95 m)
- **Wingspan:** 22 ft 11 in (6.99 m)
- **Height:** 10 ft 9 in (3.28 m)
- **Empty weight:** approximately 9,800 lb (4,445 kg)
- **Loaded weight:** for VTO 14,500 lb (6,580 kg)
- **Max takeoff weight:** for STO, approximately 17,000 lb (7,700 kg)
- **Powerplant:** 1× Bristol Siddeley Pegasus 5 vectored-thrust turbofan, 15,000 lbf (67 kN)

Performance

- **Maximum speed:** 710 mph, Mach 0.92 (1,142 km/h) at sea level
- **Service ceiling:** (service) approximately 55,000 ft (16,750 m)
- **Rate of climb:** approximately 30,000 ft/min (150 m/s)
- **Thrust/weight:** 1.04

Chapter- 11

NASA ERAST Program

NASA's Altus II UAV developed under ERAST

The **Environmental Research Aircraft and Sensor Technology**, or **ERAST** program was a NASA program to develop cost-effective, slow-flying unmanned aerial vehicles (UAVs) that can perform long-duration science missions at altitudes above 60,000 feet. The project included a number of different technology development programs which were conducted by the joint NASA-industry ERAST Alliance. The project was formally terminated in 2003.

Program overview

According to NASA, "ERAST is a multiyear effort to develop the aeronautical and sensor technologies for a new family of remotely piloted aircraft intended for upper atmospheric science missions. Designed to cruise at slow speeds for long durations at altitudes of 60,000 to 100,000 ft, such aircraft could be used to collect, identify, and monitor environmental data to assess global climate change and assist in weather monitoring and forecasting. They also could serve as airborne telecommunications platforms, performing functions similar to communications satellites at a fraction of the cost of lofting a satellite into space."

"The ERAST program is sponsored by the Office of Aeronautics and Space Transportation Technology at NASA Headquarters, and is managed by NASA Dryden Flight Research Center. The NASA Ames Research Center, Moffett Field, California, heads the sensor technology development. The NASA Lewis Research Center, Cleveland, Ohio, and NASA Langley Research Center, Hampton, Virginia, are contributing expertise in the areas of propulsion, structures, and systems analysis. Several small high-technology aeronautical development firms, including ALTUS developer General Atomics Aeronautical Systems, Inc., are teamed with NASA in the ERAST Alliance to work towards common goals of the program." Industry partners in the ERAST Alliance included Aurora Flight Systems, AeroVironment, General Atomics, Scaled Composites, Thermo-Mechanical Systems, Hyperspectral Sciences, and Longitude 122 West.

The types of science mission which ERAST prepares for can include remote sensing for Earth sciences studies, hyperspectral imaging for agriculture monitoring, tracking of severe storms, and serving as telecommunications relay platforms.

A parallel effort headed by Ames developed lightweight, microminiaturized sensors that can be carried by these aircraft for environmental research and Earth monitoring.

Additional technologies considered by the ERAST Alliance include lightweight materials, avionics, aerodynamics, and other forms of propulsion suitable for extreme altitudes and duration.

Although ERAST Alliance members were responsible for aircraft development and operation, NASA had primary responsibility for overall program leadership, major funding, individual project management, development and coordination of payloads. NASA also worked on long-term issues with the Federal Aviation Administration and developed technology to make operation of these remotely operated aircraft in national airspace practical.

History

In 1987 and 1988, NASA conducted atmospheric ozone-layer depletion studies using two piloted NASA aircraft, a modified Douglas DC-8 jetliner and a Lockheed ER-2, a civilian version of the U-2 spy plane. However, operating the ER-2 over Antarctica, where ozone depletion took place, was regarded as risky, since if the pilot had to bail out, survival was unlikely. In addition, the ER-2 had a ceiling of 20 kilometers (65,000 feet), while ozone depletion takes place at 30 kilometers (100,000 feet), and the ER-2 could not stay aloft long enough to study ozone changes during a full day-night cycle.

In 1988, NASA decided to obtain a HALE UAV named "Perseus" to deal with these problems, designating the effort the Small High-Altitude Science Aircraft (SHASA) program. Perseus was designed by a startup company named Aurora Flight Sciences of Manassas, Virginia. The Perseus design effort struggled along on skimpy funds until 1991, when NASA was conducting a "High Speed Research Program" to evaluate designs for a future supersonic transport, and needed to learn more about the possible environmental impact of such an aircraft on the upper atmosphere. Funds became available to procure a few aircraft.

Other government agencies were also interested in HALE UAVs, and so the ERAST effort was born in September 1994 as a high-profile item in NASA'a agenda. ERAST was formally intended to promote the use of UAVs in commercial science applications, particularly high-altitude atmospheric research. ERAST also has focused on development of new miniaturized sensor and avionics systems for the UAVs and for NASA's Lockheed ER-2.

Project components and programs

Aircraft

ALTUS

The General Atomics ALTUS II is a civilian variant of the MQ-1 Predator UAV designed for scientific research missions. One of the two ALTUS aircraft, ALTUS II, was built under the ERAST program and has participated in a number of the related research missions.

The ALTUS II made its first flight on May 1, 1996. With its engine at first augmented by a single-stage turbocharger, the ALTUS II reached an altitude of 37,000 ft during its first series of development flights at Dryden in August, 1996. In October of that year, the ALTUS II was flown in an Atmospheric Radiation Measurement (ARM-UAV) study in Oklahoma conducted by Sandia National Laboratories for the Department of Energy. During the course of those flights, the ALTUS II set a single-flight endurance record for remotely operated aircraft of more than 26 hours. In October 1996, ALTUS II set an endurance record for UAVs carrying science payloads. The vehicle spent more than 24 hours at the required altitude during an ARM-UAV.

After major modifications and upgrades, including installation of a two-stage turbocharger in place of its original single-stage unit, a larger fuel tank and additional intercooling capacity, the ALTUS II returned to flight status in the summer of 1998. The goal of its development test flights was to reach one of the major ERAST Level 2 performance milestones, to fly a gasoline-fueled, piston-engine remotely piloted aircraft for several hours at an altitude at or near 60,000 feet. On March 5, 1999, The ALTUS II maintained flight at or above 55,000 feet for three hours, reaching a maximum density altitude of 57,300 feet during the mission.

Pathfinder and Helios

Helios UAV in flight

The NASA Pathfinder and Helios aircraft were a series of solar- and fuel cell system-powered UAVs which AeroVironment, Inc. developed the vehicle under the ERAST program.

Pathfinder, which was designed and built by AeroVironment, is essentially a flying wing with a 99 foot span. Solar photovoltaic cells mounted on the top of the wing produce up to 7,200 watts, powering the aircraft's six electric-driven propellers, as well as the suite of scientific instruments. Backup batteries store solar energy to power the aircraft at night.

Sensors and instruments

ARTIS camera

A small Airborne Real-Time Imaging System (ARTIS) camera, developed by HyperSpectral Sciences, Inc., under ERAST project, was flight demonstrated during the summer of 1999 on board the Scaled Composites Proteus aircraft when it took visual and near-infrared photos from Proteus while it was flying high over the Experimental Aircraft Association's AirVenture 99 Airshow at Oshkosh, Wisconsin. The images were displayed on a computer monitor at the show only moments after they were taken.

DASI

The Digital Array Scanned Interferometer (DASI) was operated from the Pathfinder in the summer of 1997, acquiring imaging interferometric data of the Hawaiian Islands. The DASI, which originated at Washington University and was jointly developed with Ames Research Center, had to meet the stringent engineering and operating requirements of the Pathfinder with respect to remote operation, very light weight, and low volume, power and bandwidth.

DSA

In March 2002, NASA Dryden, in cooperation with New Mexico State University's Technical Analysis and Applications Center (TAAC), the FAA and several other entities, conducted flight demonstrations of an active detect, see and avoid (**DSA**) system for potential application to UAVs at Las Cruces, New Mexico. The Scaled Composites Proteus aircraft was flown as a surrogate UAV controlled remotely from the ground, although safety pilots were aboard to handle takeoff and landing and any potential emergencies. Three other aircraft, ranging from general aviation aircraft to a NASA F/A-18, served as "cooperative" target aircraft with an operating transponder. In each of 18 different scenarios, a Goodrich Skywatch HP Traffic Advisory System (TAS) on the Proteus detected approaching air traffic on potential collision courses, including several scenarios with two aircraft approaching from different directions. The remote pilot then directed Proteus to turn, climb or descend as needed to avoid the potential threat.

In April 2003, a second series of flight demonstrations focusing on "non-cooperative" aircraft (those without operating transponders), was conducted in restricted airspace near Mojave, California., again using the Proteus as a surrogate UAV. Proteus was equipped with a small Amphitech OASys 35 GHz primary radar system to detect potential intruder aircraft on simulated collision courses. The radar data was telemetered directly to the ground station as well as via an Inmarsat satellite system installed on Proteus. A mix of seven intruder aircraft, ranging from a sailplane to a high-speed jet, flew 20 scenarios over a four-day period, one or two aircraft at a time. In each case, the radar picked up the intruding aircraft at ranges from 2.5 to 6.5 miles, depending on the intruder's radar signature. Proteus' remote pilot on the ground was able to direct Proteus to take evasive action if needed.

Chapter- 12

NASA 515 & Balls 8

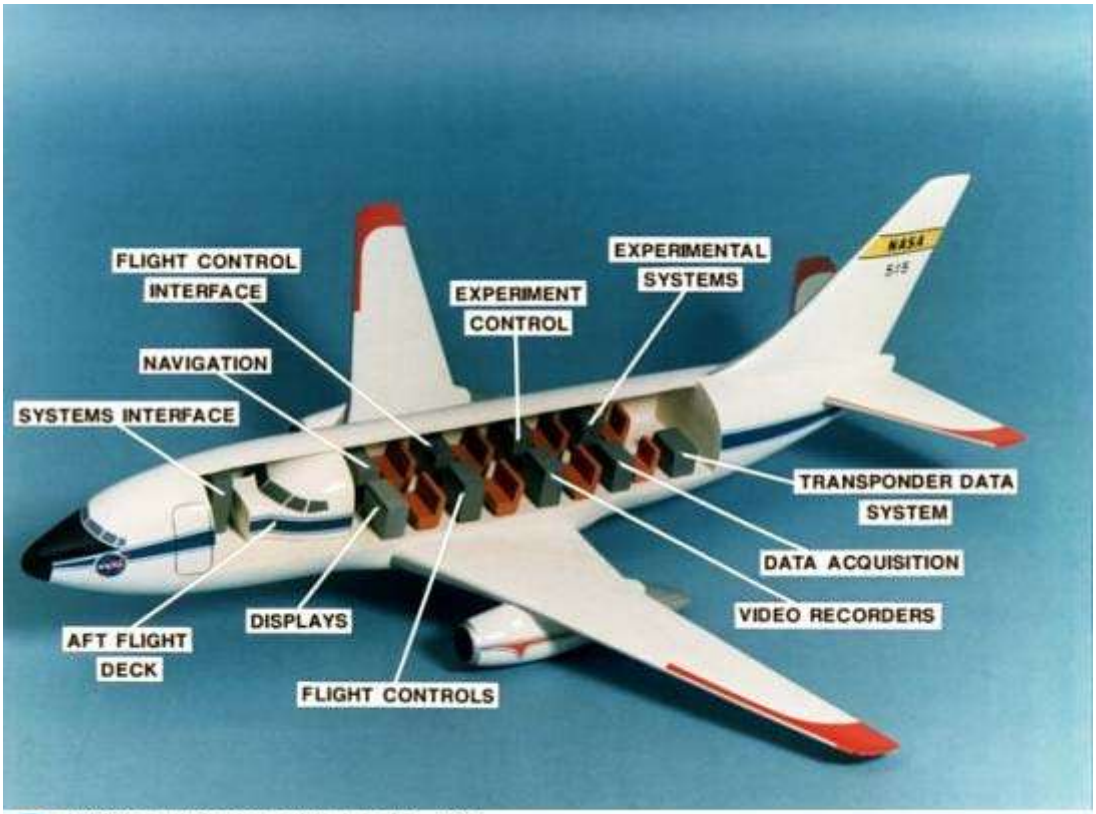
NASA 515

NASA 515

NASA 515 in flight

Role	Experimental aircraft
Manufacturer	Boeing
First flight	April 6, 1967
Introduced	1974 (NASA use)
Status	On display
Primary user	NASA
Developed from	Boeing 737

Research Aircraft: NASA 515 Boeing B-737-130
NASA Langley Research Center 11/29/1989 Image # EL-1996-00005



NASA 515 Cutaway Model of B-737
NASA Langley Research Center 9/16/1985 Image # EL-1996-00182

NASA 515 was a Boeing 737 heavily modified for NASA use as a continuing research. The aircraft was the first 737 built and was used by Boeing to qualify the 737 design. NASA 515 was maintained and flown by Langley Research Center as part of the Terminal Area Productivity (TAP) program.

The aircraft is on public display at the Museum of Flight, near Seattle, Washington.

Balls 8

Balls 8

A NASA TF-104G flies chase on the NB-52B *Balls 8* in September 1979.

Type	Boeing RB-52B/NB-52B Stratofortress
Manufacturer	Boeing Aircraft Company
Serial	52-008
Owners and operators	United States Air Force NASA
Preserved at	Edwards Air Force Base, California

Balls 8 was a NASA Boeing NB-52B mothership. It derives its nickname from its NASA tail number 52-008: leading zeroes plus the number 8. It was retired from active service with NASA on December 17, 2004 after almost 50 years flying service. *Balls 8* was famous for dropping aerospace research vehicles for 106 flights of the X-15. Like its NB-52A predecessor, a pylon was fitted under the right wing between the fuselage and the inboard engines with a 6-by-8-foot (1.8 × 2.4 m) section removed from the right wing flap in order to accommodate the X-15's tail. It flew a total of 159 captive-carry and launch missions in support of the X-15 program, from June 1959 until October 1968. It also flew missions supporting the X-24, HiMAT, Lifting Body vehicles, X-43, early launches of the OSC Pegasus rocket and numerous others.

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC93-01211-2 Date: 1993 Photo by: NASA

B-52 Flight Mission Symbology on Side of Craft

A close-up of NASA's NB-52B *Balls 8* showing mission markings

Edwards AFB 2003 Airshow

Edwards AFB 2003 Airshow

Edwards AFB 2003 Airshow

Balls 8 (bottom) with its successor aircraft (top). The cutout on the right wing flap is visible.

Balls 8 was originally an RB-52B that was first flown on June 11, 1955; and entering service with NASA on June 8, 1959. It was the oldest active B-52 still in service at the time of its retirement. It was modified at North American Aviation's Palmdale facility in order to allow it to carry the X-15. The modified bomber first was used to launch the X-15 on its fifth flight, on January 23, 1960. *Balls 8* was the last B-52 in service of any type other than the H model. It also had the lowest total air time of any operational B-52. It is on permanent public display near the north gate of Edwards Air Force Base.