

Hydrogen-Powered, Nuclear-Powered and Single-Engine Aircrafts



Willia Mcdaniel

First Edition, 2012

ISBN 978-81-323-2866-7

© All rights reserved.

Published by:

Orange Apple

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: info@wtbooks.com

Table of Contents

Chapter 1 - Hydrogen-Powered Aircraft

Chapter 2 - Avatar (Spacecraft)

Chapter 3 - Lockheed CL-400 Suntan and Reaction Engines A2

Chapter 4 - Reaction Engines Skylon

Chapter 5 - Nuclear Aircraft

Chapter 6 - Aircraft Nuclear Propulsion and Convair X-6

Chapter 7 - Convair B-36

Chapter 8 - Ace Baby Ace and Adam RA-14 Loisirs

Chapter 9 - Adamoli-Cattani Fighter and Adaridi AD3

Chapter 10 - AEG J.I, Aero A.100 and Aero A.11

Chapter 11 - Aero A.18, Aero A.23 and Aero A.32

Chapter 12 - Aero A.42, Aero Ae 270 Ibis and Aero AT3

Chapter 13 - Aero Boero AB-115, Aero Boero AB-180 and Aero Boero AB-95

Chapter- 1

Hydrogen-Powered Aircraft

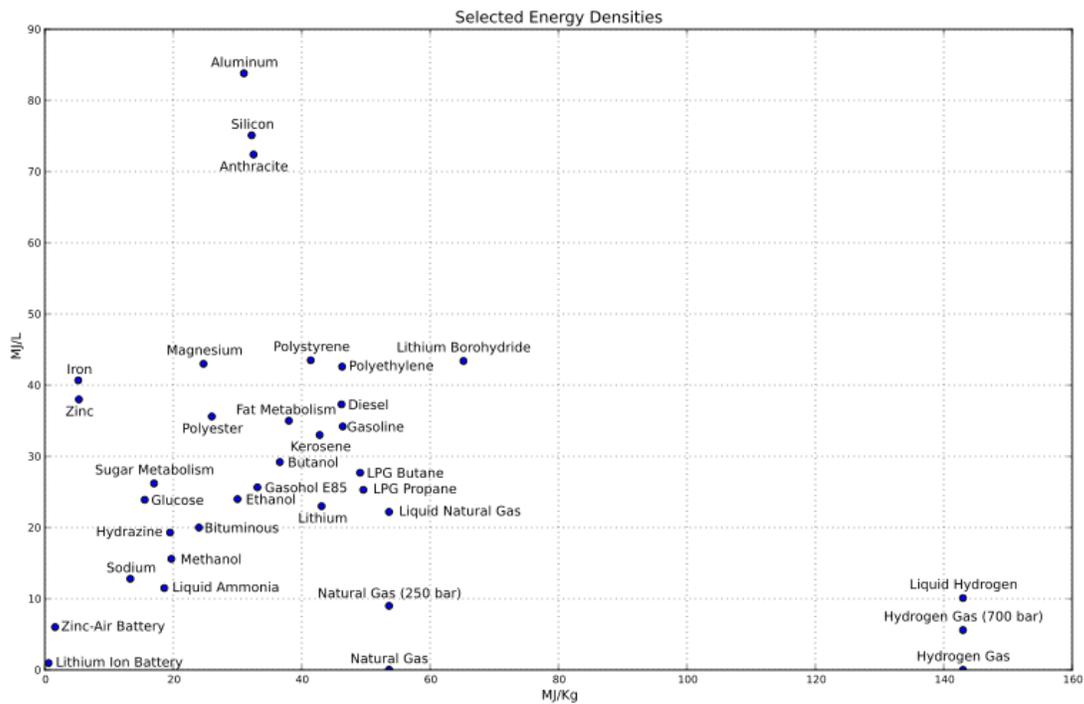


In 2008, The Boeing Fuel Cell Demonstrator achieved straight-level flight on a manned mission powered by a hydrogen fuel cell.

A **hydrogen-powered aircraft** is an airplane that uses hydrogen as a power source.

In aircraft hydrogen can either be burned in some kind of jet engine, or other kind of internal combustion engine, or can be used to power a fuel cell to generate electricity to power a propeller.

Properties of hydrogen



Energy density of fuels - horizontal per mass, vertical per volume

Being an alternative to jet fuel, hydrogen has a higher energy density per unit *mass* but a lower energy density per unit *volume*, and containing the hydrogen at high pressure would require a heavy container. In aircraft heavy containers are not an option, and therefore regular carbon fibre tanks are often used, which can only sustain a pressure of 350 bar. When compared to steel hydrogen containers (used in cars and ships), this is 500 to 700 bar. This decreases the amount of energy that can be spent on the propulsion by half. Alternatively, as with some rockets, cryogenic liquid hydrogen could be employed.

If hydrogen were available in quantity from renewable energy sources, its use in aircraft would produce fewer greenhouse gases (water vapor and a small amount of nitrogen) than current aircraft. Currently, very little hydrogen is produced using renewable energy sources, and there are several serious obstacles to the use of hydrogen in aircraft and other vehicles. According to research at the Pennsylvania State University in 2006, large commercial hydrogen aircraft could be built by 2020 but "will probably not enter service until closer to 2040."

The European Union's research project in cooperation with Airbus and 34 other partner companies dubbed CRYOPLANE assessed the technical feasibility, safety, environmental compatibility and economic viability of using liquid hydrogen as an aviation fuel. This was concluded in 2002 (with the final report published in 2003).

Liquid hydrogen is one of the best coolants used in engineering, and it has been proposed to use this property for cooling intake air for very high speed aircraft, or even for cooling the vehicle's skin itself particularly for scramjet-powered aircraft.

Properties of hydrogen aircraft

Hydrogen aircraft are usually designed with the liquid hydrogen fuel carried inside the fuselage, in order to minimize surface-area and reduce boil-off. Normal aircraft use wings for storing fuel.

Liquid hydrogen has about four times the volume for the same amount of energy of kerosene based jet-fuel. In addition, its highly volatile nature precludes storing the fuel in the wings, as with conventional transport aircraft. Therefore, most liquid hydrogen aircraft designs store the fuel in the fuselage, leading to a larger fuselage length and diameter than a conventional kerosene fueled aircraft. If that were the end of the story, the hydrogen-fueled aircraft would have lower performance than the kerosene aircraft due to the extra wetted area of the fuselage. The larger fuselage size causes more skin friction drag and wave drag. Hydrogen is about one-third of the weight of kerosene jet-fuel for the same amount of energy. This means that for the same range and performance (ignoring the effect of volume), the hydrogen aircraft would have about one-third of the fuel weight. For a Boeing 747-400 type aircraft, this would reduce the Takeoff Gross Weight from 800,000 lbs to approximately 600,000 lbs. Thus, the performance of a hydrogen-fueled aircraft is a trade-off of the larger wetted area and lower fuel weight. This trade-off depends on the size of the aircraft.

Liquid hydrogen was proposed for use on the scramjet-based National Aerospace Plane.

Hydrogen aircraft demonstrations

Several demonstrations of hydrogen-powered aircraft have been performed using purpose-build airplanes.

Boeing Research & Technology Europe (BR&TE) made a civilian aircraft from a 2-seat Dimona motor glider running on a fuel cell (called Theator Airplane)". Lange Aviation GmbH also made a hydrogen-powered airplane with its Antares DLR-H2 airplane.

These aircraft are of course configured in such fashion that the current low energy output from hydrogen propulsion (a result of the low-pressure hydrogen tanks) do not pose a problem. For example the Boeing Theator airplane only required 45 kW to take off, and 20 kW to stay airborne.

In July 2010 Boeing also unveiled its hydrogen powered Phantom Eye UAV, that uses two Ford Motor Company internal combustion engines converted to operate on hydrogen.

Current aircraft

- The Russian manufacturer Tupolev built a prototype hydrogen-powered version of the Tu-154 airliner, named the Tu-155, which made its first flight in 1989.
- Northrop Grumman has successfully tested their X-47B Unmanned Combat Air System (UCAS) for Carrier Operations during 2010. This unmanned aircraft, or drone, which is still a prototype, can be programmed to perform a particular mission totally autonomously and/or remotely controlled by a pilot. It can operate at altitudes up to 16,000 ft. The liquid hydrogen version that has been successfully tested on 2010 can fly for 5 to 7 days without refuelling.

Proposed hydrogen aircraft

- Reaction Engines Skylon orbital hydrogen fuelled jet plane
- Reaction Engines A2 antipodal hypersonic jet airliner
- DLR Smartfish
- Boeing plans to build a hydrogen-powered jet

Chapter- 2

Avatar (Spacecraft)

AVATAR RLV



A scaled down version of AVATAR undergoing aerodynamic test.

Function	Unmanned reusable spaceplane technology demonstrator
Manufacturer	DRDO/ISRO
Country of origin	 India
Size	
Diameter	N/A
Stages	1/2
Capacity	
Launch history	
Status	Under Development
Launch sites	Satish Dhawan Space Centre
Total launches	0
Maiden flight	2011, projected

AVATAR (Sanskrit: अवतार) (from "Aerobic Vehicle for Hypersonic Aerospace Transportation") is a single-stage reusable rocketplane capable of horizontal takeoff and landing, being developed by India's Defense Research and Development Organization

along with Indian Space Research Organization and other research institutions; it could be used for cheaper military and civilian satellite launches.

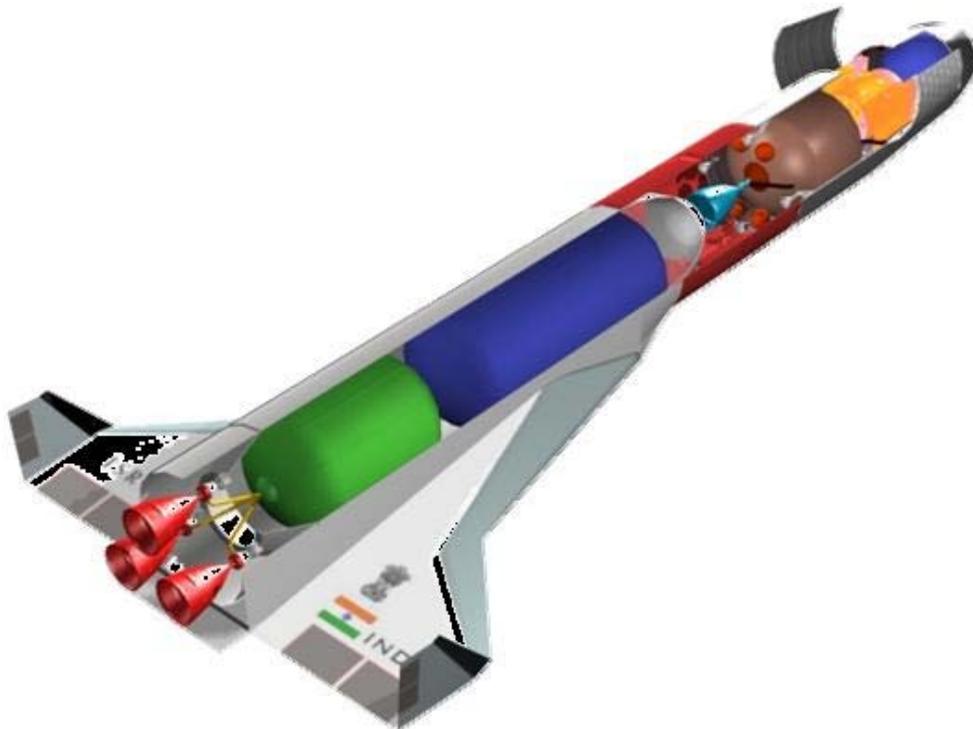
When operational, it is planned to be capable of delivering a payload weighing up to 1,000 kg to low earth orbit. It would be the cheapest way to deliver material to space at about US\$67/kg. Each craft is expected to withstand 100 launches.

Concept

The idea is to develop a hypersonic vehicle that can take off from conventional airfields, collect air in the atmosphere on the way up, liquefy it, separate oxygen and store it on board for subsequent flight beyond the atmosphere. The AVATAR RLV was first announced in May 1998 at the Aero India 98 exhibition held at Bangalore. It is planned to be the size of a MiG-25 fighter and would be capable of delivering a 500 kg to 1,000 kg payload to low earth orbit at very low cost for an estimated vehicle life of 100 launches.

AVATAR is proposed to weigh only 25 tonnes in which 60 per cent of mass will be liquid hydrogen fuel. The oxygen required by the vehicle for combustion is collected from the atmosphere, thus reducing the need to carry oxygen during launch. AVATAR is said to be capable of entering into a 100-km orbit in a single stage and launching satellites weighing up to one tonne.

Operation



AVATAR RLV-TSTO

AVATAR would take off horizontally like a conventional airplane from a conventional airstrip using turbo-ramjet engines that burn air and hydrogen. Once at a cruising altitude, the vehicle would use scramjet propulsion to accelerate from Mach 4 to Mach 8. During this cruising phase, an on-board system would collect air from the atmosphere, from which liquid oxygen would be separated and stored. The liquid oxygen collected then would be used in the final flight phase when the rocket engine burns the collected liquid oxygen and the carried hydrogen to attain orbit. The vehicle would be designed to permit at least a hundred re-entries into the atmosphere.

Dr. M R Suresh, a senior ISRO official, stated that, "The dream of making a vehicle which can take off from a runway like an aircraft, and to return to the runway after deploying the spacecraft in the desired orbit (or Single-stage-to-orbit or SSTO) can be fulfilled only by the availability of more advanced high strength but low density materials so that the structural mass of the vehicle could be reduced considerably from the present levels. The advent of nano-technology could play a deciding factor in developing such exotic materials. However, the material technology available today can realize a Two Stage To Orbit (TSTO) vehicle only and the configuration of the vehicle which is being considered. However, the before realizing the RLV-TSTO it is important to perfect many critical technologies pertaining to hypersonic reentry vehicles. Hence a technology demonstrator vehicle (RLV-TD) is being developed."

Development



A model of the RLV-TD

AVATAR is being developed by India's Defense Research and Development Organization. Air Commodore Raghavan Gopalaswami, former chief of Bharat Dynamics Ltd, Hyderabad, is heading the project. He coined the name and made the presentation on the space plane at the global conference on propulsion at Salt Lake City (USA) on July 10, 2001. Gopalaswami said the idea for AVATAR originated from the work published by the RAND Corporation of the United States in 1987.

AVATAR is currently in the prototype testing stage and an initial development budget of only \$5 million is allocated. Along with DRDO team development of critical technology

components were undertaken by as many as 23 academic institutions (Indian Institutes of Technology, Indian Institute of Science et al.) along with ISRO in India. Both the scramjet engine concept and the liquid oxygen collection process have already undergone successful tests at DRDO and at the IISC. DRDO has approved further testing of the liquid oxygen process and assigned a team to conduct a detailed review of the vehicle's design.

Currently DRDO plans to build and fly a scaled-down version of AVATAR, weighing just 3 tonnes at takeoff. The project is headed by Vikram Sarabhai Space Centre in Thiruvananthapuram. The mini AVATAR is to be built by a Hyderabad-based private company called CIM Technologies, project completion data is still not finalized. The prototype will be launched using the PSLV and will demonstrate all technologies used in AVATAR including oxygen collection. The aerodynamics characterization of the RLV-TD was done by National Aerospace Laboratories. The AVATAR design has already been patented in India and applications for registration of the design have been filed in patent offices in the United States, Germany, Russia and China.

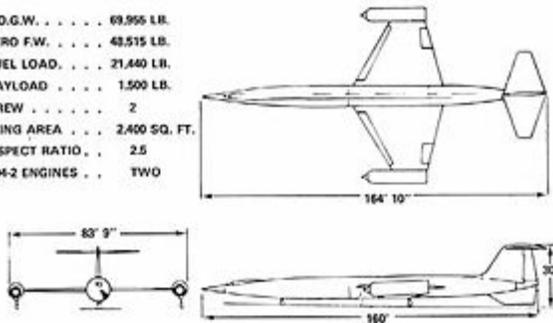
Chapter- 3

Lockheed CL-400 Suntan and Reaction Engines A2

Lockheed CL-400 Suntan

CL-400

T.O.G.W. 69,955 LB.
ZERO F.W. 48,515 LB.
FUEL LOAD. 21,440 LB.
PAYLOAD 1,500 LB.
CREW 2
WING AREA 2,400 SQ. FT.
ASPECT RATIO 2.5
304-2 ENGINES TWO



3-view of the Suntan concept aircraft

Role	Proposed reconnaissance aircraft
Manufacturer	Lockheed Aircraft Corporation
Designed by	Clarence L "Kelly" Johnson

Suntan was the code-name of a prototype reconnaissance aircraft program, with the goal of creating a much faster and higher-altitude successor to the U-2, enabled by the use of liquid hydrogen (LH2) as fuel. From 1956-1958, the United States Air Force funded a highly secretive program of research and development on the aircraft (the CL-400, designed at the Lockheed Skunk Works) and engine design, and made significant investments in large-scale LH2 production. In addition to Lockheed, Pratt and Whitney (part of United Aircraft, now United Technologies Corporation) played a major part. Program successes included the concept design of a Mach 2.5 aircraft capable of flying at

30,000 meters, and successful conversion of an existing turbojet engine to run on liquid hydrogen, as well as 25+ hours of testing on a customized LH2 engine design.

Ultimately, budgetary pressures and difficulty achieving sufficient range, plus the fact that an LH2 powered aircraft was considered too dangerous and expensive to maintain led to the project's cancellation. In addition, the unusual fuel would have meant that existing airbases would have needed extensive facilities to handle the aircraft.

However, the aircraft research was redirected to more conventionally-fueled designs and resulted in the successful SR-71.

By advancing the state of the art in LH2 propulsion, and by establishing an industrial infrastructure for high-volume hydrogen production, the groundwork was laid for successful use of liquid hydrogen as a rocket fuel for the Apollo program and the Space Shuttle.

Reaction Engines A2

A2



Artist's concept of the Reaction Engines A2

Role	Hypersonic Airliner
Manufacturer	Unknown
Designed by	Reaction Engines Limited
Status	Under design study

The **Reaction Engines Limited A2** (called the **A2**) is a design study for a hypersonic airliner. The airliner is intended to provide environmentally-friendly, long range and high capacity commercial transportation. It is being examined as part of the LAPCAT programme of the European Union. The plane has not been commercially launched yet, but Reaction Engines Limited, the British design firm, says it could probably be developed into a working aircraft within 25 years, if there is market demand for it.

Development

“ Our work shows that it is possible technically; now it's up to the world to decide if it wants it. ”

— Alan Bond, managing director of Reaction Engines Limited

The vehicle is intended to have about 20,000 kilometres (12,000 mi) range and good subsonic and supersonic fuel efficiency, thus avoiding the problems inherent in earlier supersonic aircraft. The top speed is projected to be Mach 5+. It calls for the use of liquid hydrogen as a fuel, which has twice the specific impulse of kerosene, and can be used to cool the vehicle and the air entering the engines via a precooler.

The developers say it would be able to fly from Brussels to Sydney in about 4.6 hours, compared to around a complete day of travel with normal aircraft. The cost of a ticket is intended to be roughly business class level.

Design

Capabilities



The LAPCAT A2 concept in the upper atmosphere

Alan Bond told *The Guardian* newspaper:

“ The A2 is designed to leave Brussels International Airport, fly quietly and subsonically out into the north Atlantic at Mach 0.9 before reaching Mach 5 across the North Pole and heading over the Pacific to Australia. ”

The great circle route is not used in this example because the route travels mostly over land. The sonic boom generated by travelling at supersonic speed can cause great discomfort for people on the ground, which was why Concorde was prohibited for flying supersonically over land.

Another advantage of the design is that, while the 143 metre-long A2 is much longer than conventional jets, it would be lighter than a Boeing 747 and could take off and land on current airport runways.

However, the A2 design does not have windows. The heat generated by traveling so quickly makes it difficult to install windows that are not too heavy. One solution Reaction Engines has proposed is to install flat panel displays, showing images of the scene outside.

Engines

The Scimitar engines use related technology to the company's earlier SABRE engine, which is intended for space launch, but here adapted for very long distance, very high speed travel.

Normally, as air enters a jet engine, it is compressed by the inlet, and thus heats up. This means that high speed engines need to be made of technologies and materials that can survive extremely high temperatures. In practice, this inevitably makes the engines heavier and also reduces the amount of fuel that can be burnt to avoid melting the gas turbine section of the engine, which in turn reduces thrust at high speed.

The key design feature for the Scimitar engines is the precooler, which is a heat exchanger that transfers the heat from the incoming air into the hydrogen fuel. This greatly cools the air, which allows the engines to burn more fuel even at very high speed, and allows the engines to be made of lighter, but more heat susceptible, materials such as light alloys. The engine inlet diffuser also has to slow the incoming air to subsonic speeds as if the air moved through the precooler and compressor at supersonic speeds, it would cause damage to them.

The rest of the engine is described as having high-bypass (4:1) turbofan engine features to give it good efficiency and subsonic (quiet) exhaust velocity at low speeds. Unlike SABRE the A2's Scimitar engine would not have rocket engine features.

Specifications

- **Range:** 20,000 kilometres (12,000 mi)

- **Length:** 143 metres (469 ft)
- **Fuel:** Liquid hydrogen
- **Passengers:** 300 (Single Class)
- **Cruising speed:** Mach 5
- **Specific fuel consumption:** 0.86 lbf/lb·h at Mach 5 (40,900 m/s - 4,170 seconds),
0.375 lbf/lb·h at Mach 0.9 (96,000 m/s - 9,600 seconds)
- **Lift to drag ratio:** 11.0 at 5.9 km, Mach 0.9, 5.9 at 25 km Mach 5
- **Noise:** 101 dBa at 450m lateral

Chapter- 4

Reaction Engines Skylon

Skylon



The Skylon vehicle is an aircraft designed to reach orbit.

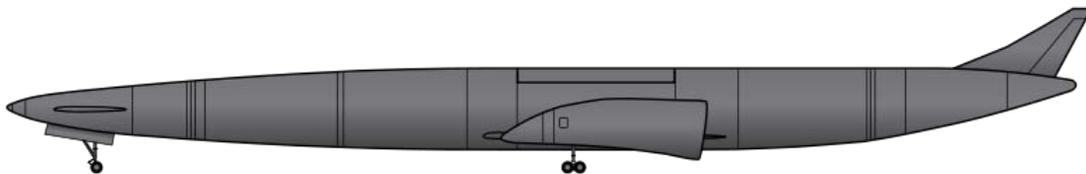
Role	Re-usable Spaceplane
National origin	UK/multinational
Designed by	Reaction Engines Limited
Status	Research and development
Program cost	Projected to be £7.1 billion (~\$12 billion est. 2004)
Unit cost	£190 million (projected)
Developed from	Horizontal Take-Off and Landing (HOTOL) project

Skylon is a design for an unpowered spaceplane by the British company, Reaction Engines Limited (REL). It uses a combined-cycle, air-breathing jet engine to reach orbit in a single stage. A fleet of vehicles is envisaged; the design is aiming for re-usability up to 200 times. In paper studies, the costs per kilogram of payload are hoped to be lowered from the current £15,000/kg to £650/kg (as of 2011), including the costs of research and development (R&D), with costs expected to fall much more over time after the initial expenditures have amortised. The cost of the program has been estimated by the developer to be about \$12 billion.

The vehicle design is for a hydrogen-powered aircraft that would take off from a conventional runway, and accelerate to Mach 5.4 at 26 km using atmospheric air before switching the engines to use the internal liquid oxygen (LOX) supply to take it to orbit. It would then release its payload, which can weigh up to 12-tonnes, and re-enter the atmosphere. The payload would be carried in a standardised payload container or passenger compartment.

During re-entry the relatively light vehicle would fly back through the atmosphere and land back at the runway, with its skin protected by a ceramic composite. It would then undergo inspection and any necessary maintenance and, if the design goal is achieved, be able to fly again within two days. As of 2010, only a small portion of the funding required to develop and build Skylon has been secured. The research and development work on the SABRE engine design is proceeding under a small European Space Agency (ESA) grant. In January 2011, REL submitted a proposal to the British Government to request additional funding for the Skylon project.

Technology and innovations



The Skylon spaceplane is designed as a two-engine, "tailless" aircraft, which is fitted with a steerable canard.

Structure of the fuselage

The fuselage of Skylon is expected to be carbon fibre space frame; a light and strong structure that supports the weight of the aluminium fuel tanks and to which the ceramic skin is attached. Multiple layers of reflective foil thermal insulation fill the spaces of the frame.

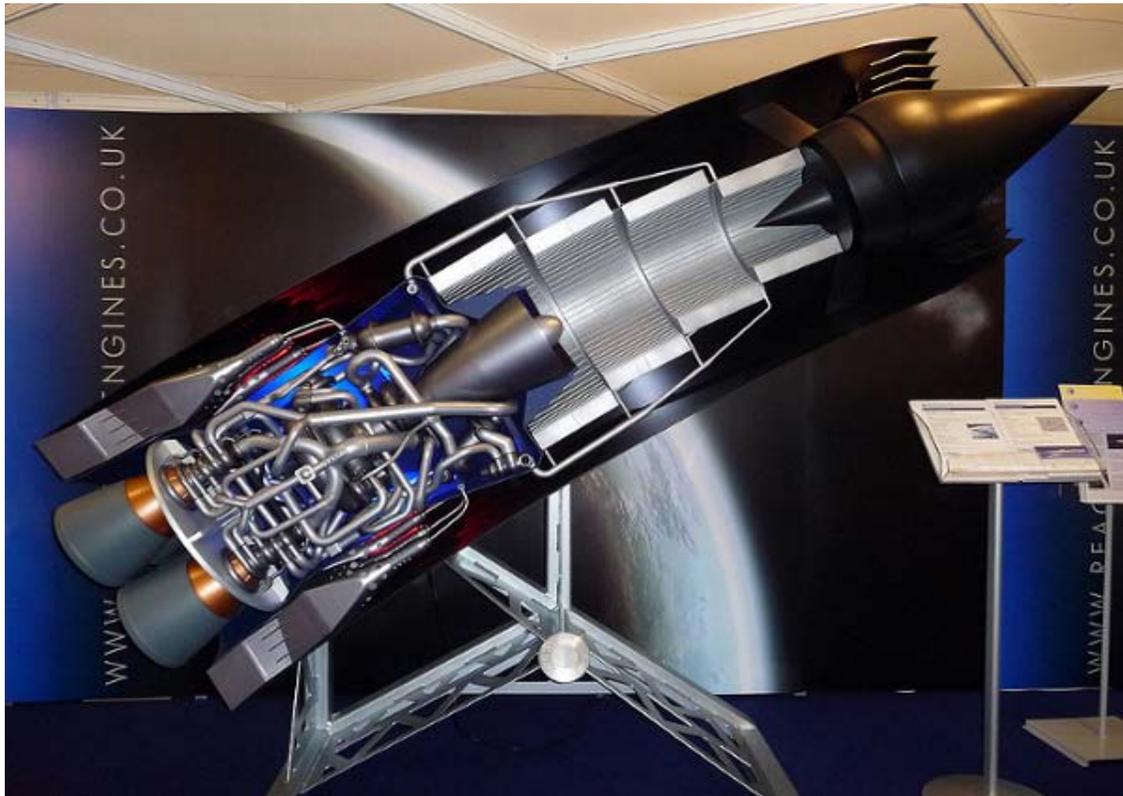
The currently proposed Skylon model C2 will be a physically large vehicle, with a length of 82 metres (269 ft) and a diameter of 6.3 metres (21 ft). Because it will use a low-density liquid hydrogen fuel, a great volume is needed to contain enough energy to reach orbit. The propellant is intended to be kept at low pressure to minimise stress; a vehicle that is both large and light has an advantage during atmospheric reentry compared to other vehicles due to a low ballistic coefficient. Because of the low ballistic coefficient, Skylon would be slowed at higher altitudes where the air is thinner. As a result, the skin of the vehicle would only reach 1100 Kelvin (K). In contrast, the smaller Space Shuttle is heated to 2000 K on its leading edge, and so employs an extremely heat-resistant but extremely fragile silica thermal protection system. The Skylon design need not use such a system, instead opting for using a far thinner yet durable reinforced ceramic skin.

However, due to turbulent flow around the wings during re-entry, some parts of Skylon would need to be actively cooled.

Skylon would employ a highly-loaded tightly spaced wheel assembly, to save weight and also interior space when the wheels are retracted into the fuselage. Because this wheel design distributes the weight of the aircraft and the force of its landing over a smaller area of the runway, it would require a specially strengthened runway. It will possess a retractable undercarriage with high pressure tires and water cooled brakes. If problems were to occur just before a take-off the brakes would be applied to stop the vehicle, the water boiling away to dissipate the heat. Upon a successful take-off, the water would be jettisoned, thus reducing the weight of the undercarriage by many tons. During landing, the empty vehicle would be far lighter, and hence the water would be unneeded. The payload fraction would be significantly greater than normal rockets and the vehicle should be fully reusable (200 times or more).

SABRE Engines

One of the significant features of the Skylon design is the engine, called SABRE. The engines are designed to operate much like a conventional jet engine at up to around Mach 5.5 (1700 m/s), 26 kilometres (16 mi) altitude, beyond which the air inlet closes and the engine operates as a highly efficient rocket to orbital speed.



The Reaction Engines Limited Synergistic Air-Breathing Rocket Engine (SABRE) engine is a key component of the Skylon spaceplane.

The proposed engine for the vehicle is not a scramjet, but a jet engine running combined cycles of a precooled jet engine, rocket engine and ramjet. Originally the key technology for this type of precooled jet engine did not exist as it required a heat exchanger that was ten times lighter than the state of the art. Research conducted since then has achieved the necessary performance.

Operating an air-breathing jet engine at up to Mach 5.5 is difficult. Several previous engines proposed by other designers have been good as jet engines but performed poorly as rockets. This engine design aims to be a good jet engine within the atmosphere, as well as being an excellent rocket engine outside. The problem with operating at Mach 5.5 has been that the air coming into the engine heats up as it is compressed into the engine, which can cause the engine to overheat. Attempts to avoid these issues typically make the engine much heavier (scramjets/ramjets) or greatly reduce the thrust (conventional turbojets/ramjets). In either case the end result is an engine that has a poor thrust to weight ratio at high speeds, resulting in an engine that is too heavy to assist much in reaching orbit.

The SABRE engine design aims to avoid this by using some of the liquid hydrogen fuel to cool the air at the inlet. The air is then used for combustion much like in a conventional jet. Because the air is cooled at all speeds, the jet can be built of light alloys and the weight is roughly halved. Additionally, more fuel can be burnt at high speed. Beyond Mach 5.5, the air would still be unusably hot despite the cooling, so the air inlet closes and the engine relies solely on on-board liquid oxygen and hydrogen fuel as in a normal rocket.

Because the engine uses the atmosphere as reaction mass at low altitude, it will have a high specific impulse (around 2,800 seconds), and burn about one fifth of the propellant that would have been required by a conventional rocket. Therefore, it would be able to take off with much less total propellant than conventional systems. This, in turn, means that it doesn't need as much lift or thrust, which permits smaller engines, and allows conventional wings to be used. While in the atmosphere, using wings to counteract gravity drag is more fuel-efficient than simply expelling propellant (as in a rocket), again reducing the total amount of propellant needed.

"Single Stage to Orbit" capability

A vehicle that can fly to orbit without staging is known as single stage to orbit (SSTO). Proponents of SSTO claim that staging causes a number of problems such as being difficult, expensive or even impossible to recover, reuse and reassemble the parts and therefore believe that SSTO designs hold the promise of reducing the cost of space-flight.

The Skylon design aims to take off from its specially strengthened runway, fly into low earth orbit, re-enter the atmosphere, and land back on its runway like a conventional aeroplane, without staging, while being fully reusable.

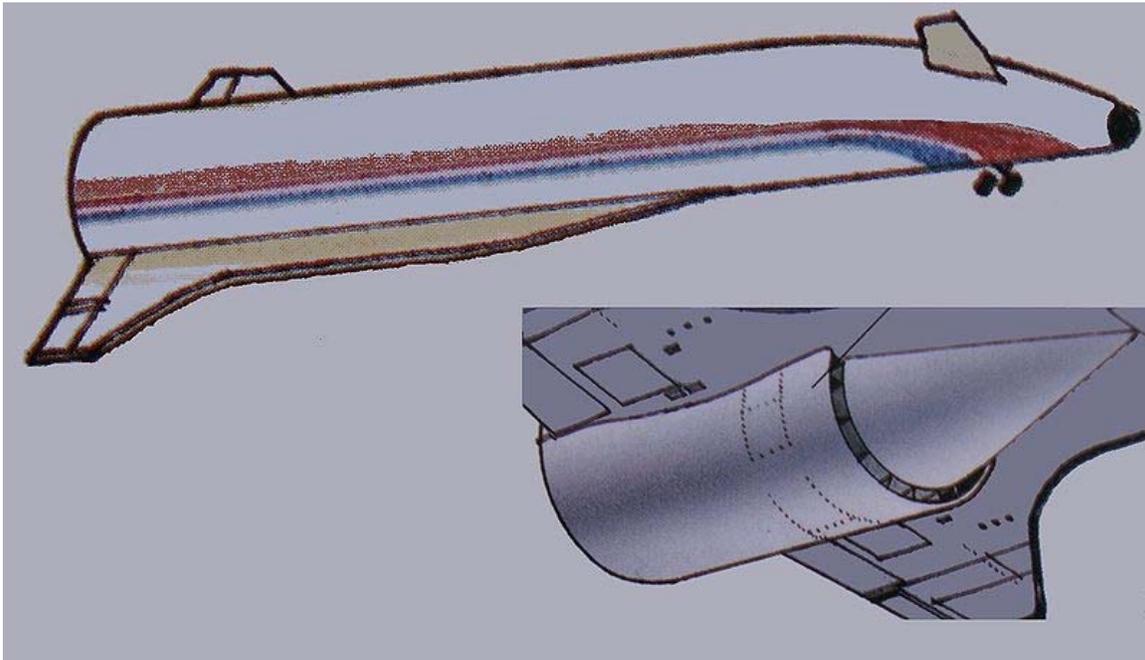
Payload bay

The payload bay of the Skylon C2 design is a cylinder 12.3 metres (40.4 ft) long and 4.6 metres (15 ft) in diameter. It is designed to be comparable with current payload dimensions, and yet able to support the containerization of payloads that Reaction Engines hopes for in the future. To an equatorial orbit, Skylon could deliver 12 tonnes (26,455 lb) to a 300 kilometres (186 mi) height or 10.5 tonnes (23,149 lb) to a 460 kilometres (286 mi) altitude. It could also launch 9.5 tonnes (20,944 lb) to the orbit of the International Space Station, when launching from the equator. Using interchangeable payload containers, Skylon could be fitted to carry satellites or fluid cargo into orbit, or, in a specialised habitation module, up to 30 astronauts in a single launch.

Current project status

As of 2010, the funding required to develop and build the entire craft has not yet been secured, and so current research and development work is focused on the engines, under an ESA grant of €1 million. In January 2011, REL submitted a proposal to the British Government requesting additional funding for the Skylon project.

Research and development programme



The Skylon was developed from the ill-fated British HOTOL project.

Skylon is based upon a previous project of Alan Bond, which was known as HOTOL. The development programme of HOTOL began in 1982, a time when space technology was moving towards reusable launch systems such as the American Space Shuttle. In conjunction with British Aerospace and Rolls Royce, a design emerged that proved

highly promising, so much so that the British Government donated £2 million to further their work. However, in 1988, the Conservative government withdrew funding, and the development programme was terminated. Following this major setback, Alan Bond decided to set up his own company, Reaction Engines Limited, with the hope of continuing development with private funding.

After having secured funding, the design of the craft was revisited, undergoing a rigorous redesign throughout much of the 1990s. In the last decade, Reaction Engines has been working with the University of Bristol to develop the engines vital to the success of Skylon. The STRICT/STERN engines produced by this programme were deemed a great success. The next stage of development is to construct a full-sized working prototype of the SABRE Engine.

The differences between Skylon and its predecessor are numerous. For example, HOTOL was to have been launched from a rocket sled (to save weight), whereas Skylon uses a conventional retractable undercarriage. Skylon also uses a different engine design; the SABRE engine is expected to offer higher performance. Another issue that the Skylon design aims to circumvent was the intrinsically poor stability of HOTOL. The weight of the rear-mounted engine tended to make the HOTOL vehicle flip over mid-flight due to the centre of mass lying behind the centre of drag. Attempts to fix this problem ended up sacrificing much of the potential payload that the HOTOL vehicle could carry, and contributed to the failure of the project. Skylon would solve this by placing the engines at the end of the wings closer to the centre of the vehicle and thus moving the centre of mass forward, ahead of the centre of drag.

The complete Skylon project has a projected R&D cost of over \$10 billion and will continue for another 7–10 years. In February 2009, the British National Space Centre (now the UK Space Agency) and ESA announced that they were partially funding work with €1 million Euros (\$1.28 million dollars) on Skylon's engine to produce a demonstration engine by 2011.

The Technology Demonstration Programme will last approximately 2.5 years and will benefit from another €1 million from the ESA. This programme will take Reaction Engines Ltd from a Technology Readiness Level (TRL) of 2/3 up to 4/5. The former UK Minister for Science and Innovation in 2009, Lord Drayson, commented on Skylon in a speech: "This is an example of a British company developing world-beating technology with exciting consequences for the future of space."

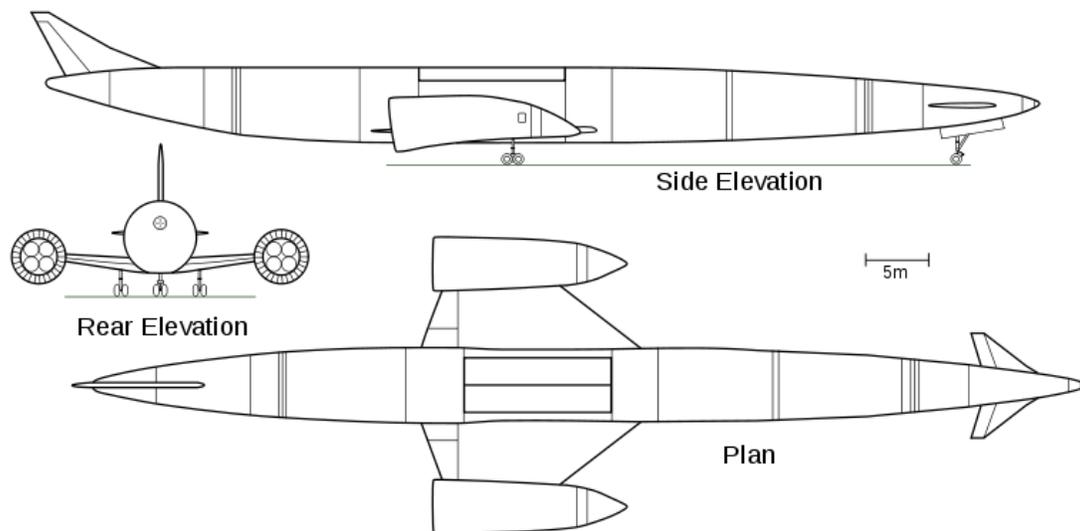
Economics and political will

Once operative, Skylon could potentially lower satellite costs from the current £15,000/kg to £650/kg, according to evidence submitted to the UK parliament by Reaction Engines Ltd. However, funding and support from the British government has not been easy to establish.

Request for funding from the British government was undertaken in 2000, with a proposal that could have offered a large potential return on investment. The request was not taken up at that time. Subsequent discussions with the British National Space Centre led to agreement in 2009 on a co-funding agreement between BNSC, ESA and REL to continue technology development for the SABRE engine. Testing of the SABRE engine will commence in June 2011 with the start of Phase 3 in the Skylon development programme. Pre-orders are expected in the 2011–2013 time frame coinciding with the formation of the manufacturing consortium. According to David Willetts, the UK Minister of State for Universities and Science:

"The European Space Agency is funding proof of concept work for Skylon from UK contributions. This work is focusing on demonstrating the viability of the advanced British engine technology that would underpin the project. Initial work will be completed in mid 2011 and if the trial is successful, we will work with industry to consider next steps."

Specifications



Skylon C2

General characteristics

- **Crew:** automated
- **Capacity:** 40
- **Length:** 83.3 m (273 ft)
- **Wingspan:** 25.4 m (82 ft)
- **Height:** ()
- **Empty weight:** 53,000 kg (120,000 lb)
- **Loaded weight:** 345,000 kg (760,000 lb)
- **Powerplant:** 2× SABRE synergistic combined cycle jet engine

- **Dry thrust:** 2,700 LT; 3,000 ST (2,700 LT; 3,000 ST) each
- **Thrust with afterburner:** 3,500 LT; 4,000 ST (3,500 LT; 4,000 ST) each

Performance

- **Maximum speed:** orbital
- **Range:** orbital ()
- **Service ceiling:** 26,000 m air breathing, >200 km exoatmospheric (85,000 ft air breathing, >124 mi exoatmospheric)
- **Thrust/weight:** ~1.2 – 3 at burnout (~0.768 atmospheric)SSTO

- Fuselage diameter: 6.75 m (22.15 ft)
- Maximum payload mass: 12,000 kg (26,000 lb)
- Specific impulse: 3560 s (35 kN·s/kg) atmospheric, 450 s (4.4 kN·s/kg) exoatmospheric
- SABRE engine thrust/weight ratio: up to 14 atmospheric

Chapter- 5

Nuclear Aircraft

A **nuclear aircraft** is an aircraft powered by nuclear energy. Research into them was pursued during the Cold War by the United States and the Soviet Union as they would presumably allow a country to keep nuclear bombers in the air for extremely long periods of time, a useful tactic for nuclear deterrence. Neither country created any nuclear aircraft in production numbers. One design problem, never adequately solved, was the need for heavy shielding to protect the crew from radiation sickness.

Unmanned missiles have been designed to use nuclear thermal rockets, but such designs were considered too dangerous for crews to actually fly.



The only US aircraft to carry a nuclear reactor was the NB-36H. The program was canceled in 1958

U.S. programs

NEPA and ANP

In May, 1946, the Nuclear Energy for the Propulsion of Aircraft (NEPA) project was started by the United States Air Force. Studies under this program were done until May, 1951 when NEPA was replaced by the Aircraft Nuclear Propulsion (ANP) program. The ANP program included provisions for studying two different types of nuclear-powered jet engines, General Electric's Direct Air Cycle and Pratt & Whitney's Indirect Air Cycle. ANP also contained plans for two B-36s to be modified by Convair under the **MX-1589** project, one of the B-36s was to be used to study shielding requirements for an airborne reactor while the other was to be the X-6. The program was cancelled before the X-6 was completed, however.

The Oak Ridge National Laboratory conducted research (Aircraft Reactor Experiment) to produce a nuclear powered aircraft. Two General Electric turbofan engines were successfully powered to nearly full thrust using two shielded reactors. The two engines complete with reactor system are currently located at the EBR-1 facility south of the Idaho National Laboratory.



Experimental HTRE reactors for nuclear aircraft, on display at Idaho National Laboratory near Arco, Idaho.

The U.S. designed these engines to be used in a new specially designed nuclear bomber, the WS-125. The WS-125 was eventually terminated by Eisenhower who cut NEPA and told Congress that there was no urgency for the program. Eisenhower did back a small scale program developing high temperature materials and high performance reactors. That program was terminated early in the Kennedy administration.

Project Pluto

In 1957, the Air Force and the U.S. Atomic Energy Commission contracted with the Lawrence Radiation Laboratory to study the feasibility of applying heat from nuclear reactors to ramjet engines. This research became known as *Project Pluto*. The engines being developed under this program were intended to power an unmanned cruise missile, called SLAM, for Supersonic Low Altitude Missile. The program succeeded in producing two test engines which were operated on the ground. On May 14, 1961, the world's first nuclear ramjet engine, "Tory-IIA," mounted on a railroad car, roared to life for just a few seconds. On July 1, 1964, seven years and six months after it was born, "Project Pluto" was cancelled.

Soviet programs

Soviet Nuclear Bomber hoax

The 1 December 1958 issue of *Aviation Week* included an article, *Soviets Flight Testing Nuclear Bomber*, that claimed that the Soviets had made great progress in their own nuclear aircraft program. This was accompanied by an editorial on the topic as well. The magazine claimed that the aircraft was real beyond a doubt, stating that "A nuclear-powered bomber is being flight tested in the Soviet Union. Completed about six months ago, this aircraft has been flying in the Moscow area for at least two months. It has been observed both in flight and on the ground by a wide variety of foreign observers from Communist and non-Communist countries." Unlike the US designs of the same era, which were purely experimental, the article noted that "The Soviet aircraft is a prototype of a design to perform a military mission as a continuous airborne alert warning system and missile launching platform."

Photographs illustrated the article, along with technical diagrams on the proposed layout. They were so widely seen that one company produced a plastic model aircraft, a surprisingly faithful rendition of the diagrams in the article.

Concerns were soon expressed in Washington that "*the Russians were from three to five years ahead of the US in the field of atomic aircraft engines and that they would move even further ahead unless the US pressed forward with its own program*". This led to continued funding of the US's own program, for a time.

In reality the entire article was a hoax. The aircraft in the photographs was later revealed to be the entirely conventional Myasishchev M-50 *Boulder*, a medium-range strategic bomber with performance similar to the USAF's B-58 Hustler. The design was considered

a failure and never entered service. The design was revealed to the public on Soviet Aviation Day in 1963 at Monino, putting the issue to rest.

Tupolev Tu-119

The Soviet program of developing nuclear aircraft resulted in the experimental Tupolev Tu-119, also known as the Tu-95LAL (LAL- Летаящая Атомная Лаборатория- Flying Nuclear Laboratory). It was based on a Tupolev Tu-95 bomber. It had 4 conventional turboprop engines and an onboard nuclear reactor. The Tu-119 completed 34 research flights. Most of these were made with the reactor shut down. The main purpose of the flight phase was examining the effectiveness of the radiation shielding which was one of the main concerns for the engineers. Massive amounts of protection used resulted in radiation levels low enough to consider continuing development. But, as in the US, development never continued past this point. The obvious potential of the ICBM made the expensive program superfluous, and around the mid 1960s it was cancelled.

Chapter- 6

Aircraft Nuclear Propulsion and Convair X-6

Aircraft Nuclear Propulsion



HTRE 3, left, and HTRE 1, right, on display at the Idaho National Laboratory near Arco, Idaho

The **Aircraft Nuclear Propulsion (ANP)** program and the preceding **Nuclear Energy for the Propulsion of Aircraft (NEPA)** project worked to develop a nuclear propulsion system for aircraft. The United States Army Air Force initiated **Project NEPA** on May 28, 1946. After funding of \$10 million in 1947, NEPA operated until May 1951, when the project was transferred to the joint Atomic Energy Commission (AEC)/USAF ANP. The USAF pursued two different systems for nuclear powered jet engines, the **Direct Air Cycle** concept which was developed by General Electric, and **Indirect Air Cycle** which was assigned to Pratt & Whitney. The program was intended to develop and test the Convair X-6, but was cancelled in 1961 before that aircraft was built.

Direct Air Cycle program



Aircraft Reactor Experiment building at ORNL

The General Electric program, which was based at Evendale, Ohio, was pursued because of its advantages in simplicity, reliability, suitability and quick start ability. Conventional jet engine compressor and turbine sections were used, with the compressed air run through the reactor itself to heat it before being exhausted through the turbine.

The US *Aircraft Reactor Experiment (ARE)* was a 2.5 MW thermal nuclear reactor experiment designed to attain a high power density for use as an engine in a nuclear powered bomber. It used the molten fluoride salt NaF-ZrF₄-UF₄ (53-41-6 mol%) as fuel, was moderated by beryllium oxide (BeO), used liquid sodium as a secondary coolant and had a peak temperature of 860 °C. It operated for a 1000-hour cycle in 1954. It was the first molten salt reactor. Work on this project in the US stopped after ICBMs made it obsolete. The designs for its engines can currently be viewed at the EBR-I memorial building at the Idaho National Laboratory.

In 1955, this program produced the successful X-39 engine, two modified General Electric J47s with heat supplied by the Heat Transfer Reactor Experiment-1 (HTRE-1). The HTRE-1 was replaced by the HTRE-2 and eventually the HTRE-3 unit powering the two J47s. The HTRE-3 used "a flight-type shield system" and would probably have gone on to power the X-6 had that program been pursued.

Indirect Air Cycle program

The Indirect Air Cycle program was assigned to Pratt & Whitney, at a facility near Middletown, Connecticut. This concept would have produced far less radioactive pollution. One or two loops of liquid metal would carry the heat from the reactor to the engine. This program involved a great deal of research and development of many light-weight systems suitable for use in aircraft, such as heat exchangers, liquid-metal turbopumps and radiators. The Indirect Cycle program never came anywhere near producing flight-ready hardware.

MX-1589 project

On September 5, 1951, the USAF awarded Consolidated-Vultee a contract to fly a nuclear reactor onboard a modified Convair B-36 under the MX-1589 project of the ANP program. The NB-36H Nuclear Test Aircraft (NTA) was to study shielding requirements for an airborne reactor, to determine whether a nuclear aircraft was feasible. This was the only known airborne reactor experiment by the U.S. with an operational nuclear reactor on board. The NTA flew a total of 47 times testing the reactor over West Texas and Southern New Mexico. The reactor, named the Aircraft Shield Test Reactor (ASTR), was operational but did not power the plane, rather the primary purpose of the flight program was shield testing.

Convair X-6

Convair X-6



Convair NB-36H flying nuclear reactor testbed

Role	Experimental aircraft
Manufacturer	Convair
First flight	Not flown
Status	Cancelled
Primary user	USAF
Number built	1 (for weight tests only)
Developed from	Convair B-36



Convair NB-36H, flying testbed for X-6 project

The **Convair X-6** was a proposed experimental aircraft project to develop and evaluate a nuclear-powered jet aircraft. The project was to use a Convair B-36 bomber as a testbed aircraft, and though one NB-36H was modified during the early stages of the project, the program was cancelled before the actual X-6 and its nuclear reactor engines were completed. The X-6 was part of a larger series of programs, costing US\$7 billion in all, that ran from 1946 through 1961. Because such an aircraft's range would not have been limited by liquid jet fuel, it was theorized that nuclear-powered strategic bombers would be able to stay airborne for weeks at a time.

History

In May, 1946, the Nuclear Energy for the Propulsion of Aircraft (NEPA) project was started by the Air Force. Studies under this program were done until May, 1951 when NEPA was replaced by the Aircraft Nuclear Propulsion (ANP) program. The ANP program contained plans for two B-36s to be modified by Convair under the **MX-1589** project. One of the B-36s was to be used to study shielding requirements for an airborne reactor while the other was to be the X-6.

Nuclear Test Aircraft

The first modified B-36 was called the Nuclear Test Aircraft (NTA), a B-36H-20-CF (Serial Number 51-5712) that had been damaged in a tornado at Carswell AFB on September 1, 1952. This plane was redesignated the XB-36H, then the NB-36H and was

modified to carry a 3 megawatt, air-cooled nuclear reactor in its bomb bay. The reactor, named the Aircraft Shield Test Reactor (ASTR), was operational but did not power the plane. Water, acting as both moderator and coolant, was pumped through the reactor core and then to water-to-air heat exchangers to dissipate the heat to the atmosphere. Its sole purpose was to investigate the effect of radiation on aircraft systems.

To shield the flight crew, the nose section of the aircraft was modified to include a 12-ton lead and rubber shield. The standard windshield was replaced with one made of 6-inch-thick acrylic glass. The amount of lead and water shielding was variable. Measurements of the resulting radiation levels were then compared with calculated levels to enhance the ability to design optimal shielding with minimum weight for nuclear-powered bombers.

The NTA completed 47 test flights and 215 hours of flight time (during 89 of which the reactor was operated) between September 17, 1955, and March 1957 over New Mexico and Texas. This was the only known airborne reactor experiment by the U.S. with an operational nuclear reactor on board. The NB-36H was scrapped at Fort Worth in 1958 when the Nuclear Aircraft Program was abandoned. After the ASTR was removed from the NB-36H, it was moved to the National Aircraft Research Facility.

Based on the results of the NTA, the X-6 and the entire nuclear aircraft program was abandoned in 1961.

Development plans



Experimental Breeder Reactor Number 1 in Idaho, the first power reactor. The reactor is in the building top right, the two structures lower left are reactors from the Aircraft Nuclear Propulsion Project

Had the program progressed, follow-on aircraft would have been based on the successor to the B-36, Convair's swept-wing B-60.

The X-6 would have been powered by General Electric X-39 engines, utilizing a P-1 reactor. In a nuclear jet engine, the reactor core was used as a heat source for the turbine's air flow, instead of burning jet fuel. One disadvantage of the design was that, since the airflow through the engine was used to cool the reactor, this airflow had to be maintained even after the aircraft had landed and parked. GE built two prototype engines, which can be seen outside the Experimental Breeder Reactor I in Arco, Idaho.

A large, 350-foot (106.7 meter-) wide hangar was built at Test Area North, part of the National Reactor Testing Station (now part of the Idaho National Laboratory), Monteview, Idaho to house the X-6 project, but the project was cancelled before the planned 15,000-foot (4,572m) runway was built. The length was necessitated by the expected weight of the nuclear-powered aircraft.

Soviet program

In the 1960s, the Soviet Union's Tupolev design bureau conducted a similar experiment using a Tupolev Tu-119, which was a Tu-95 bomber modified to carry an operational reactor.

Specifications (NB-36H)

General characteristics

- **Crew:** Five
- **Length:** 162 ft (49.38 m)
- **Wingspan:** 230 ft (70.1 m)
- **Height:** 46 ft 9 in (14.26 m)
- **Wing area:** 4,770 ft² (443.3 m²)
- **Max takeoff weight:** 360,000 lb (163,000 kg)
- **Powerplant:**
 - 4× General Electric X40 turbojets, () each
 - 6× Pratt & Whitney R-4360-53, 3,800 hp (2,830 kW) each

Performance

- **Maximum speed:** 390 mph (628 km/h)
- **Service ceiling:** 40,000 ft (12,200 m)

Chapter- 7

Convair B-36

B-36 "Peacemaker"



The B-36D used both piston and jet engines.

Role	Strategic bomber
Manufacturer	Consolidated Vultee
Designed by	Ted Hall
First flight	8 August 1946
Introduced	1949
Retired	12 February 1959
Primary user	United States Air Force
Number built	384
Unit cost	US\$4.1 million (B-36D) (\$37.8 million in today's dollars)
Variants	Convair YB-60 Convair XC-99 Convair X-6 (Unbuilt)

The **Convair B-36 "Peacemaker"** was a strategic bomber built by Convair and operated solely by the United States Air Force (USAF) from 1949 to 1959. The B-36 was the largest mass-produced piston engine aircraft ever made. It had the longest wingspan of any combat aircraft ever built (230 ft or 70 m), although there have been larger military transports. The B-36 was the first bomber capable of delivering any of the nuclear weapons in the US arsenal from inside its two bomb bays without aircraft modifications. With a range greater than 6,000 mi (9,700 km) and a maximum payload of 72,000 lb (33,000 kg), (and thereby having the ability to carry both the US's atomic fission and fusion weapons), the B-36 was the world's first manned bomber with an unrefueled intercontinental range.

Development

The genesis of the B-36 can be traced to early 1941, prior to the entry of the U.S. into World War II. At the time it appeared there was a very real chance that Britain might fall to the Nazi 'Blitz', making a strategic bombing effort by the United States Army Air Corps (USAAC) against Germany impossible with the aircraft of the time. The U.S. would need a new class of bomber that could reach Europe from bases in North America, necessitating a combat range of at least 5,700 miles (9,200 km), the length of a Gander, Newfoundland–Berlin round trip. The USAAC therefore sought a bomber of truly intercontinental range, similar to the Nazi RLM's own ultra-long-range *Amerika Bomber* program.

The USAAC opened up a design competition for the very long-range bomber on 11 April 1941, asking for a 450 mph (720 km/h) top speed, a 275 mph (443 km/h) cruising speed, a service ceiling of 45,000 ft (14,000 m), beyond the range of ground-based anti-aircraft fire, and a maximum range of 12,000 miles (19,000 km) at 25,000 ft (7,600 m). These proved too demanding—far exceeding the technology of the day—for any short-term design, so on 19 August 1941 they were reduced to a maximum range of 10,000 mi (16,000 km), an effective combat radius of 4,000 mi (6,400 km) with a 10,000 lb (4,500 kg) bombload, a cruising speed between 240 and 300 mph (390 and 480 km/h), and a service ceiling of 40,000 ft (12,000 m).

Experimentals and prototypes



The huge new XB-36 alongside the first superbomber, the B-29 Superfortress. The wings of the 'Peacemaker' were 7 feet (2.1 m) thick at the root.



The XB-36 taking off. Production aircraft had four-wheel main gear instead of the giant single tires seen on the prototype aircraft.

Consolidated Vultee Aircraft Corporation (later Convair) and Boeing Aircraft Company took part in the competition, with Consolidated winning a tender on 16 October 1941. Consolidated asked for a \$15 million contract with \$800,000 for research and development, mock-up, and tooling. Two experimental bombers were proposed, the first to be delivered in 30 months, and the second within another six months. Originally designated Model B-35, the name was changed to B-36 to avoid confusion with the Northrop YB-35.

Throughout its development, the B-36 would encounter various delays. When the United States entered World War II on 7 December 1941, Consolidated was ordered to slow down the B-36 project and increase production of the B-24 Liberator. The first mockup was inspected on 20 July 1942, following six months of refinements. A month after the mockup inspection the project was moved from San Diego, California to Fort Worth, Texas, which set back development several months. Consolidated changed the tail from a twin-tail to a single, thereby saving 3,850 pounds, but this change would delay delivery by 120 days. The tricycle landing gear system's initial main gear design, incorporating huge single wheels that would quickly be found to cause significant ground pressure problems, only allowed the B-36 to land at just three airports in the United States (Fort Worth, Eglin Field, Florida, and Fairfield-Suisun Field (now Travis AFB) in California), mandated that Consolidated design a four-wheeled truck-type wheel arrangement for the main gear instead, which distributed the weight more evenly and reduced weight by 1,500 lb. Changes in the United States Army Air Forces (USAAF) requirements would add back any weight saved in redesigns, and cost more time. A new antenna system needed to be designed to accommodate an ordered radio and radar system. The Pratt & Whitney engines were redesigned, adding another 1,000 lb.

World War II and after

Early in the war, the military refused to supply materials, tradespeople, and engineers to the project, which slowed work. As the Pacific war progressed, the United States increasingly needed a bomber capable of reaching Japan from its bases in Hawaii, and the B-36 began its development in earnest again. Secretary of War Henry L. Stimson, in discussions with high ranking officers of the AAF, decided to waive normal Army procurement procedures, and on 23 July 1943 ordered 100 B-36s before the completion and testing of the two prototypes. The first delivery was due in August 1945, and the last in October 1946, but Consolidated (now renamed Convair) delayed delivery. The aircraft was unveiled on 20 August 1945, and flew for the first time on 8 August 1946.

After the Cold War began in earnest with the 1948 Berlin Airlift and the 1949 atmospheric test of the first Soviet atomic bomb, American military planners sought bombers capable of delivering the very large and heavy first-generation atomic bombs. The B-36 was the only American aircraft with the range and payload to carry such bombs from airfields on American soil to targets in the USSR. (Storing nuclear weapons in foreign countries was, and remains, diplomatically sensitive and risky).

The B-36 was arguably obsolete from the outset, being piston-powered, particularly in a world of super-sonic jet interceptors, but its jet rival, the B-47 Stratojet, which did not become fully operational until 1953, lacked the range to attack the Soviet homeland from North America and could not carry the huge first-generation hydrogen bomb. Nor could the other American piston bombers of the day, the B-29 or B-50. Intercontinental ballistic missiles (ICBMs) did not become effective deterrents until the 1960s. Until the B-52 Stratofortress became operational in the late 1950s, the B-36, as the only truly intercontinental bomber, continued to be the primary nuclear weapons delivery vehicle of the Strategic Air Command (SAC).

Convair touted the B-36 as the "aluminum overcast", a so-called "long rifle" giving SAC truly global reach. While General Curtis LeMay headed SAC (1949–57), he turned the B-36 arm, through intense training and development, into an effective nuclear delivery force, forming the heart of the Strategic Air Command. Its maximum payload was more than four times that of the B-29, even exceeding that of the B-52. The B-36 was slow and could not refuel in midair, but could fly missions to targets 3,400 mi (5,500 km) away and stay aloft as long as 40 hours. Moreover, the B-36 was believed to have "an ace up its sleeve": a phenomenal cruising altitude for a piston-driven aircraft, made possible by its huge wing area and six 28-cylinder engines, putting it out of range of all piston fighters, early jet interceptors, and ground batteries.

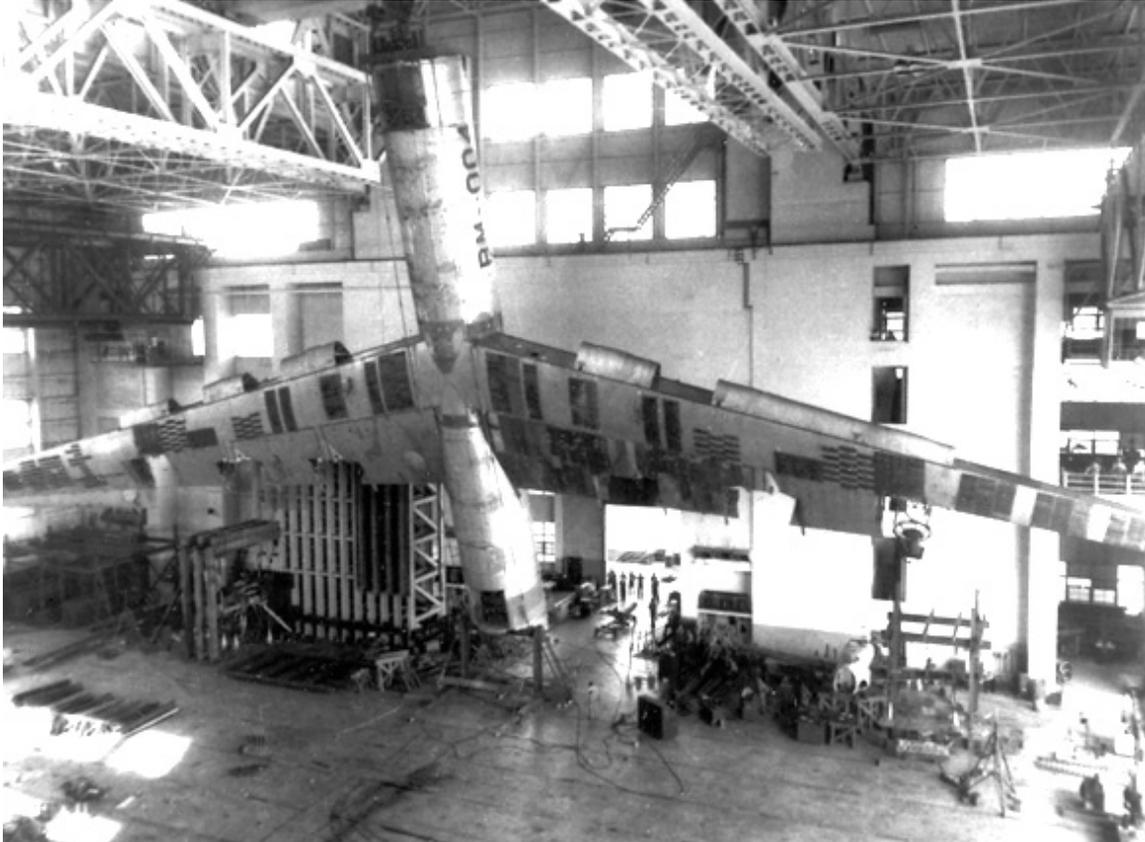
Operating and financial problems

The B-36 was difficult to operate, prone in its early service years to catastrophic engine fires, electrical failures, and other costly malfunctions. In later years, inaccessible fuel and oil leaks were problems. To its critics, these problems made it a "billion-dollar blunder". In particular, the United States Navy saw it as a costly bungle, diverting Congressional funding and interest from naval aviation and aircraft carriers in general, and carrier-based nuclear bombers in particular. In 1947, the Navy attacked Congressional funding for the B-36, alleging it failed to meet Pentagon requirements. The U.S. Navy held to the preeminence of the aircraft carrier in the Pacific during World War II, presuming carrier-based aircraft would be decisive in future wars. To this end, the Navy designed the USS *United States* (CVA-58), a "supercarrier" capable of launching huge fleets of tactical aircraft or nuclear bombers. It then pushed to have funding transferred from the B-36 to the USS *United States*. The Air Force successfully defended the B-36 project, and the *United States* was officially cancelled by Secretary of Defense Louis A. Johnson in a cost-cutting move. Several high-level Navy officials questioned the government's decision, alleging a conflict of interest because Johnson had once served on Convair's Board of Directors. The uproar following the cancellation of *United States* was nicknamed the "Revolt of the Admirals".

The furor, as well as the significant use of aircraft carriers in the Korean War, resulted in the design and procurement of the subsequent *Forrestal* class of supercarriers, which were of comparable size to the *United States* but with a design geared towards greater multirole use with composite air wings of fighter, attack, reconnaissance, electronic warfare, early warning and anti-submarine warfare aircraft. At the same time, heavy

manned bombers for the Strategic Air Command were also deemed crucial to national defense and, as a result, the two systems were never again in competition for the same budgetary resources.

Design



An B-36 airframe undergoing structural stability tests. Note for scale the three men at the extreme right of the photograph

The B-36 took shape as an aircraft of immense proportions. It was two-thirds longer than the previous "superbomber", the B-29. The wingspan and tail height of the B-36 exceeded those of the Antonov An-22, the largest ever mass-produced propeller-driven aircraft. Only with the advent of the Boeing 747 and the Lockheed C-5 Galaxy, both designed two decades later, did aircraft capable of lifting a heavier payload become commonplace.

The wings of the B-36 were large even when compared with present-day aircraft, exceeding, for example, those of the C-5 Galaxy, and enabled the B-36 to carry enough fuel to fly very long missions without refueling. The widest point around the chord of the wing was seven and a half feet thick containing a crawlspace that allowed crew access to the engines. The wing area permitted cruising altitudes well above the operating ceiling of any 1940s-era piston and jet-turbine fighters. All versions of the B-36 could cruise at over 40,000 ft (12,000 m). B-36 mission logs commonly recorded mock attacks against

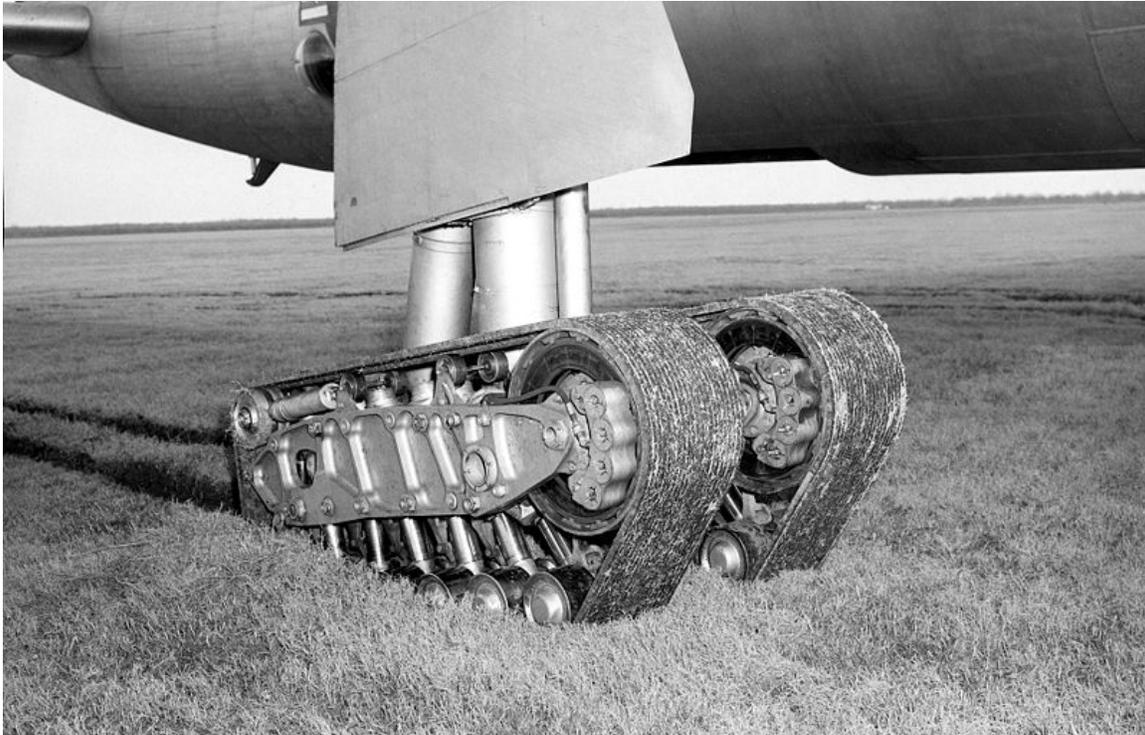
U.S. cities while flying at 49,000 ft. In 1954, the turrets and other nonessential equipment were removed, resulting in a "featherweight" configuration believed to have resulted in a top speed of 423 mph (700 km/h), and cruise at 50,000 ft (15,000 m) and dash at over 55,000 ft (16,800 m), perhaps even higher.

The large wing area and the option of starting the four jet engines gave the B-36 a wide margin between stall speed (V_S) and maximum speed (V_{max}) at these altitudes. This made the B-36 more maneuverable at high altitude than the USAF jet interceptors of the day, which either could not fly above 40,000 ft (12,000 m), or if they did, were likely to stall out when trying to maneuver or fire their guns. However, the Navy argued that their F2H Banshee fighter could intercept the B-36, thanks to its ability to operate at more than 50,000 ft (15,000 m). The Air Force declined the Navy's invitation to a fly-off between the Banshee and the B-36. Later, the new Secretary of Defense, Louis A. Johnson, who considered the U.S. Navy and Naval Aviation essentially obsolete in favor of the U.S. Air Force and Strategic Air Command, forbade putting the Navy's claim to the test.

The propulsion system alone made the B-36 a very unusual aircraft. All B-36s featured six 28-cylinder Pratt & Whitney R-4360 'Wasp Major' radial engines. Even though the prototype R-4360s delivered a total of 18,000 hp (13 MW), early B-36s were slow and required long takeoff runs. The situation improved with later versions delivering 3,800 hp (2.8 MW) apiece. Each engine drove an immense three-bladed propeller, 19 ft (5.8 m) in diameter, mounted in the pusher configuration. This unusual configuration prevented propeller turbulence from interfering with airflow over the wing, but also led to chronic engine-overheating due to insufficient airflow around the engines, resulting in numerous in-flight engine fires.

Beginning with the B-36D, Convair added a pair of General Electric J47-19 jet engines suspended near the end of each wing; these were also retrofitted to all extant B-36Bs. Thus the B-36 came to have 10 engines ("six turnin' and four burnin' ", as said by American airmen), more than any other mass-produced aircraft. The jet pods greatly improved takeoff performance and dash speed over the target. In normal cruising flight, the jet engines were shut down to conserve fuel. The two pods with four turbojets and the six piston engines combined gave the B-36 a total of 40,000 hp for short periods of time.

The B-36 had a crew of 15. As in the B-29, the pressurized flight deck and crew compartment were linked to the rear compartment by a pressurized tunnel through the bomb bay. In the B-36, one rode through the tunnel on a wheeled trolley, by pulling oneself on a rope. The rear compartment featured six bunks and a dining galley, and led to the tail turret. The B-36 also tested the experimental Boston Camera.



Closeup of experimental tracked landing gear

The XB-36 featured a single-wheel landing gear whose tires were the largest ever manufactured up to that time, 9 ft 2 in (2.7 m) tall, 3 ft (1 m) wide, and weighing 1,320 lb (600 kg), with enough rubber for 60 automobile tires. These tires placed so much weight per unit area on runways, the XB-36 was restricted to the Fort Worth airfield adjacent to the plant of manufacture, and to a mere two USAF bases beyond that. At the suggestion of General Arnold, the single-wheel gear was soon replaced by a four-wheel bogie. At one point a tank-like tracked landing gear was also tried on the XB-36, but proved heavy and noisy and was quickly abandoned.

Weaponry

The four bomb bays could carry up to 86,000 lb (39 metric tons) of bombs, more than 10 times the load carried by the World War II workhorse, the B-17 Flying Fortress, and substantially more than the entire B-17's gross weight. The B-36 was not designed with nuclear weaponry in mind, because the mere existence of such weapons was top secret during the period when the B-36 was conceived and designed (1941–46). Nevertheless, the B-36 stepped into its nuclear delivery role immediately upon becoming operational. In all respects except speed, the B-36 could match what was arguably its approximate Soviet counterpart, the Tu-95, which began production in January 1956 and at the time of this writing is still in service. Until the B-52 came on line, the B-36 was the only means of delivering the first generation Mark-17 hydrogen bomb, 25 ft (7.5 m) long, 5 ft (1.5 m) in diameter, and weighing 42,000 lb (19,000 kg), the heaviest and bulkiest American

aerial nuclear bomb ever. Carrying this massive weapon required merging two adjacent bomb bays.

The defensive armament consisted of six remote-controlled retractable gun turrets, and fixed tail and nose turrets. Each turret was fitted with two 20 mm cannons, for a total of 16 cannons, the greatest defensive gunnery ever carried by any aircraft. Recoil vibration from gunnery practice often caused the airplane's electrical wiring to jar loose or the vacuum tube electronics to malfunction, leading to failure of the aircraft controls and navigation equipment. This contributed to the crash of B-36B 44-92035 on 22 November 1950.



B-36 upper or lower gun turret with 2x 20 mm M-24A1 cannon

The Convair B-36 was the only aircraft designed to carry the T-12 Cloudmaker, a gravity bomb weighing 43,600 lb (19,800 kg) and designed to produce an earthquake bomb effect. The first prototype XB-36 flew on 8 August 1946. The speed and range of the prototype failed to meet the standards set out by the Army Air Corps in 1941. This was expected, as the engines required (Pratt & Whitney R-4360s) were not yet available, and the lack of qualified workers and materials needed to install them prevented Convair from achieving its goals.

A second aircraft, the YB-36, flew on 4 December 1947. It featured a redesigned high visibility bubble canopy, which was later adopted for production. Altogether, the YB-36 was much closer to the production aircraft. Additionally, the engines used on the YB-36 were a good deal more powerful and more efficient.



The XB-36 on its first flight.

The first of 21 B-36As were delivered in 1948. They were admittedly interim airframes, intended for crew training and later conversion. No defensive armament was fitted as none was ready. Once later models were available, all B-36As were converted to RB-36E reconnaissance models. The first B-36 variant meant for normal operation was the B-36B, delivered beginning in November 1948. This aircraft met all the 1941 requirements, but had serious problems with engine reliability and maintenance (changing the 336 spark plugs was a task dreaded by ground crews), and with the availability of armaments and spare parts. Later models featured more powerful variants of the R-4360 engine, improved radar, and redesigned crew compartments.

The four jet engines raised fuel consumption, thus reducing range. Meanwhile, the advent of air-to-air missiles rendered conventional gun turrets obsolete. In February 1954, the USAF awarded Convair a contract reducing the weight of the entire B-36 fleet by implementing a new "Featherweight" design program in three configurations:

- Featherweight I removed the six movable gun turrets and other defensive hardware.
- Featherweight II removed the rear compartment crew comfort features, and all hardware accommodating the XF-85 parasite fighter.

- Featherweight III incorporated both configurations I and II.

The six turrets eliminated by Featherweight I reduced the aircraft's crew from 15 to 9. Featherweight III enabled a longer range and an operating ceiling of at least 47,000 ft (14,000 m), features especially valuable for reconnaissance missions. The B-36J-III configuration (the last 14 made) featured a single radar-aimed tail turret, extra fuel tanks in the outer wings, and landing gear allowing the maximum gross weight to rise to 410,000 lb (190,000 kg). Production of the B-36 ceased in 1954.

Operational history



RB-36D

The B-36, including its GRB-36, RB-36, and XC-99 variants, was in service as part of the USAF Strategic Air Command from 1948 through 1959. The B-36 never dropped a bomb or fired a shot in active service.

Maintenance



Personnel and equipment required to get and keep a B-36 aircraft in the air

The B-36 was too large to fit in most hangars. Moreover, even an aircraft with the range of the B-36 needed to be stationed as close to the enemy as possible, and this meant the northern continental United States, Alaska, and the Arctic. As a result, most "normal" maintenance, such as changing the 56 spark plugs (always at risk of fouling by the leaded fuel of the day) on each of its six engines, or replacing the dozens of bomb bay light bulbs shattered after a gunnery mission, was performed outdoors, in 100 °F (38 °C) summers or -60 °F (-51 °C) winters, depending on the location. Special shelters were built so that the maintenance crews could enjoy a modicum of protection while working on the engines. Often, ground crews were at risk of slipping and falling from icy wings, or being blown off the wings by a propeller running in reverse pitch.

The wing roots were thick enough, at 7 ft (2.1 m), to enable a flight engineer to access the engines and landing gear by crawling through the wings. This was possible only at altitudes not requiring pressurization.

The Wasp Major engines also had a prodigious appetite for lubricating oil, each engine requiring its own 100 gal (380 l) tank.((cn))

Engine fires

Much more than other large aircraft powered by piston engines, the B-36 was very prone to engine fires, to the extent that some crews changed the phrase "six turning, four burning" into "two turning, two burning, two smoking, two joking, and two unaccounted for". This problem was exacerbated by the propellers' pusher configuration, which increased carburetor icing. The design of the R-4360 engine tacitly assumed that it would be mounted in the conventional tractor configuration—propeller/air intake/28 cylinders/carburetor—with air flowing in that order. In this configuration, the carburetor is bathed in warmed air flowing past the engine, and so is unlikely to ice up. However, the R-4360 engines in the B-36 were mounted backwards, in the pusher configuration—air intake/carburetor/28 cylinders/propeller. The carburetor was now in front of the engine and so could not benefit from engine heat, and also made more traditional short term carburetor heat systems unsuitable. Hence, when intake air was cold and humid, ice gradually obstructed the carburetor air intake, which in turn gradually increased the richness of the air/fuel mixture until the unburned fuel in the exhaust caught fire. Three engine fires of this nature led to the first loss of an American nuclear weapon, described below.

Crew experience

Training missions were typically in two parts; first, a 40 hour flight—followed by some time on the ground for refueling and maintenance—then a 24 hour second flight. With a sufficiently light load, the B-36 could fly at least 10,000 mi (16,000 km) nonstop, and the highest cruising speed of any version, the B-36J-III, was only 230 mph (380 km/h). Turning the jet engines on could raise the cruising speed to over 400 mph (650 km/h), but the resulting higher fuel consumption reduced the range. Hence a 40-hour mission, with the jets used only for takeoff and climbing, flew about 9,200 mi (15,000 km).

The B-36 was not a particularly enjoyable aircraft to fly. Its overall performance, in terms of speed and maneuverability, was never considered sprightly. Lieutenant General James Edmundson likened it to "...sitting on your front porch and flying your house around." Despite its immense exterior size, the pressurized crew compartments were relatively cramped, especially when occupied for 24 hours by a crew of 15 in full flight kit.

War missions would have been essentially one-way, taking off from forward bases in Alaska or Greenland, overflying the USSR, and landing in Europe, North Africa (Morocco), or the Middle East. Ironically, recollections of crew veterans reveal that while crews were confident of their ability to complete a mission if called upon to do so, they were less confident of surviving the weapon delivery itself. Their concerns were a function of the relatively low speed of the aircraft coupled with the extreme destructive power of the bombs they were carrying, resulting in the aircraft still being within blast range once the bombs detonated on target. These concerns were borne out by the 1954 Operation Castle tests, in which B-36s flew near detonations in the 15-megaton range, at distances believed typical of wartime delivery, and experienced extensive blast damage.

Experiments



NB-36H nuclear reactor testbed



GRB-36 carrying YRF-84F modified for FICON test. USAF Museum Photo Archives

The B-36 was employed in a variety of aeronautical experiments throughout its service life. Its immense size, range and payload capacity lent itself to use in research and development programs. These included nuclear propulsion studies, and "parasite" programs in which the B-36 carried smaller interceptors or reconnaissance aircraft.

In May 1946, the Air Force began the Nuclear Energy for the Propulsion of Aircraft (NEPA) project which was followed in May 1951 by the Aircraft Nuclear Propulsion (ANP) program. The ANP program required that Convair modify two B-36s under the MX-1589 project. One of the modified B-36s studied shielding requirements for an airborne reactor to determine whether a nuclear aircraft was feasible. The Nuclear Test Aircraft (NTA) was a B-36H-20-CF (serial number 51-5712) that had been damaged in a tornado at Carswell AFB on 1 September 1952. This aircraft, designated the XB-36H (and later NB-36H), was modified to carry a 1 MW, air-cooled nuclear reactor in the aft bomb bay, with a four-ton lead disc shield installed in the middle of the aircraft between the 1,000-kilowatt reactor and the cockpit. A number of large air intake and exhaust holes were installed in the sides and bottom of the aircraft's rear fuselage to cool the reactor in flight. On the ground, a crane would be utilized to remove the 35,000 pound reactor from the aircraft. To protect the crew, the highly-modified cockpit was encased in lead and rubber, with a 1-foot-thick (30 cm) leaded glass windshield. The reactor was operational but did not power the aircraft; its sole purpose was to investigate the effect of radiation on aircraft systems. Between 1955 and 1957, the NB-36H completed 47 test flights and 215 hours of flight time, during 89 of which the reactor was critical.

Other experiments involved providing the B-36 with its own fighter defense in the form of parasite aircraft carried partially or wholly in a bomb bay. One parasite aircraft was the rather miniscule McDonnell XF-85 Goblin, which docked using a trapeze system. The concept was tested successfully using a B-29 carrier, but docking proved difficult even for experienced test pilots. Moreover, the XF-85 was seen as no match for contemporary foreign powers' newly-developed interceptor aircraft in development and in service, consequently, the project was cancelled.

More successful was the FICON project, involving a modified B-36—called a GRB-36D "mothership"—and the RF-84K, a fighter modified for reconnaissance, in a bomb bay. The GRB-36D would ferry the RF-84K to the vicinity of the objective, whereupon the RF-84K would disconnect and begin its mission. Ten GRB-36Ds and 25 RF-84Ks were built and saw limited service in 1955-1956.

Projects TIP TOW and Tom-Tom involved docking F-84s to the wingtips of B-29s and B-36s. The hope was that the increased aspect ratio of the combined aircraft would result in a greater range. Project TIP TOW was canceled when the combination of two EF-84Ds and a specially modified test EB-29A crashed, killing everyone on all three aircraft. This accident was attributed to one of the EF-84Ds flipping over onto the wing of the EB-29A. Project Tom-Tom, involving RF-84Fs and a GRB-36D from the FICON project (redesignated JRB-36F), continued for a few months after this crash, but was also canceled due to the violent turbulence induced by the wingtip vortices of the B-36.

Strategic Reconnaissance



In late 1952 during the Korean War six 5th Strategic Reconnaissance Wing RB-36Ds were deployed to the 91st Strategic Reconnaissance Group. at Yokota AB, Japan. This was the first introduction of RB-36 to the Korean theater. While not employed in any combat missions over North Korea, these RB-36s conducted high altitude aerial reconnaissance over Chinese Manchurian and Soviet east Asian targets while attached to the 91st SRG.

One of the SAC's initial missions was to plan strategic aerial reconnaissance on a global scale. The first efforts were in photo-reconnaissance and mapping. Along with the photo-reconnaissance mission, a small electronic intelligence (ELINT) cadre was operating. Weather reconnaissance was part of the effort, as was Long Range Detection, the search for Soviet atomic explosions. In the late 1940s, strategic intelligence on Soviet capabilities and intentions was scarce. Before the development of the Lockheed U-2 high altitude spy plane and orbital reconnaissance satellites, technology and politics limited American reconnaissance efforts to the borders, and not the heartland, of the Soviet Union.

One of the essential criteria of the early postwar reconnaissance aircraft was the ability to cruise above 40,000 ft, a level determined by knowledge of the capability of Russian air defense radar. The main Russian air defense radar in the 1950s was the American supplied SCR-270, or locally made copies, which were only effective up to 40,000 ft – in theory, an aircraft cruising above this level would remain undetected.

The first aircraft, which put this theory to the test, was the RB-36D specialized photographic-reconnaissance version of the B-36D. It was outwardly identical to the

standard B-36D, but carried a crew of 22 rather than 15, the additional crew members being needed to operate and maintain the photographic reconnaissance equipment that was carried. The forward bomb bay in the bomber was replaced by a pressurized manned compartment that was filled with fourteen cameras. This compartment included a small darkroom where a photo technician could develop the film. The second bomb bay contained up to 80 T-86 photo flash bombs, while the third bay could carry an extra 3,000 gallon droppable fuel tank. The fourth bomb bay carried ferret ECM equipment. The defensive armament of 16 M-24A-1 20 mm cannons was retained. The extra fuel tanks increased the flight endurance to up to 50 hours. It had an operational ceiling of 50,000 ft. Later, a lightweight version of this aircraft, the RB-36-III, could even reach 58,000 ft. RB-36s were distinguished by the bright aluminium finish of the camera compartment (contrasting with the dull magnesium of the rest of the fuselage) and by a series of radar domes under the aft fuselage, varying in number and placement. When developed, it was the only American aircraft having enough range to fly over the Eurasian land mass from bases in the United States, and size enough to carry the bulky high resolution cameras of the day.

The standard RB-36D carried up to 23 cameras, primarily K-17C, K-22A, K-38, and K-40 cameras. A special 240-foot focal length camera was tested on 44-92088, the aircraft being redesignated ERB-36D. The long focal length was achieved by using a two-mirror reflection system. The camera was supposedly capable of resolving a golf ball at an altitude of 40,000 ft. This camera is now with the National Museum of the United States Air Force at Wright Patterson AFB.

The first RB-36D (44-92088) made its initial flight on 18 December 1949, only six months after the first B-36D had flown. It initially flew without the turbojets. The 28th Strategic Reconnaissance Wing based at Rapid City AFB (later renamed Ellsworth AFB), South Dakota received its first RB-36D on 3 June 1950. Due to severe materiel shortages, the new RB-36Ds did not become operationally ready until June 1951. The 24th and last RB-36D was delivered in May 1951. A total of 24 RB-36Ds were built. Some RB-36Ds were later modified to the featherweight configuration, in which all but the tail guns were removed. The crew was reduced from 22 to 19. These aircraft were redesignated as RB-36D-III. Modifications were carried out by Convair from February 1954 to November 1954.

In 1951 RB-36Ds, with a range of 9,300 miles, began probing the boundaries of the Soviet Arctic and were rather disturbed to find their on-board equipment indicating that they had been detected by Soviet radar - so much for the theory. However, detecting aircraft on ground-based radar was one thing, intercepting them was far more difficult. A number of overflights of Soviet bases in the arctic, particularly the new nuclear weapons test complex at Novaya Zemlya, were made by RB-36 aircraft operating from RAF Sculthorpe in England. RB-36s performed a number of rarely acknowledged reconnaissance missions and is suspected of having carried out numerous penetrations of Chinese (and Soviet) airspace under the direction of General Curtis LeMay.

In early 1950, Convair began conversion of the B-36As to the reconnaissance configuration. Included in the conversions was the sole YB-36 (42-13571). These converted examples were all redesignated RB-36E. The six R-4360-25 engines were replaced by six R-4360-41s. They were also equipped with the four J-47 jet engines that were fitted to the RB-36D. Its normal crew was 22, which included five gunners to man the 16 M-24A-1 20 mm cannon. The last conversion was completed in July 1951. Later, the USAF also bought 73 long-range reconnaissance versions of the B-36H under the designation RB-36H. 23 were accepted during the first six months of 1952, the last were delivered by September 1953. More than a third of all B-36 models were reconnaissance models.

Advances in Soviet air defense systems meant that the RB-36 became limited to flying outside of the borders of the Soviet Union, as well as Eastern Europe. By the mid 1950s, the jet-powered Boeing RB-47E was able to pierce Soviet airspace and conduct a variety of spectacular overflights of the Soviet Union. Some of these flights probed deep into the heart of the Soviet Union, taking a photographic and radar recording of the route attacking SAC bombers would follow to reach their targets. The risks involved in mounting these dangerous sorties over some of the most inhospitable terrain on earth speaks volumes for the courage and skill of the crews involved. Flights which involved penetrating mainland Russia were termed SENSINT (Sensitive Intelligence) missions. One RB-47 even managed to fly 450 miles inland and photograph the city of Igarka in Siberia.

As with the strategic bombardment versions of the B-36, the RB-36s were phased out of the SAC inventory beginning in 1956, the last being sent to Davis-Monthan in January 1959.

Obsolescence



YB-52 prototype at Carswell AFB, 1955 shown with a 7th Bomb Wing B-36

With the appearance of the Soviet MiG-15 in combat over North Korea in 1950, USAF propeller-driven bombers were rendered obsolete as strategic offensive weapons. Although the MiG-15 had limited range and lacked radar, the swept-wing Soviet jet carried heavy-caliber weapons and could fly faster and higher than the F-80C and F-84G, the B-29's straight-winged jet fighter escorts. During daylight, the MiG-15 could attack the propeller-driven B-29s with impunity, forcing the United States to switch the B-29 to night raids.

The B-36, along with the B-29/B-50 Superfortresses in the USAF inventory in the early 1950s, were all designed during World War II, prior to the jet age. It would take a new generation of swept-wing jet bombers, being able to fly higher and faster to effectively defeat the defense of the MiG-15 or subsequent Soviet-designed interceptors if the Cold War escalated into an armed conflict between the United States and Soviet Union.

With the end of fighting in Korea, President Eisenhower, who had taken office in January 1953, called for a "new look" at national defense. His administration chose to invest in the Air Force, especially Strategic Air Command. The Air Force retired nearly all of its B-29/B-50s to be replaced by the new Boeing B-47 Stratojet. By 1955 the Boeing B-52 Stratofortress swept-wing strategic jet bombers would be entering the inventory in substantial numbers, and the B-36s began to be replaced.

In addition to the obsolescence of the aircraft, other factors leading to the phaseout of the B-36 were:

- The Peacemaker was not designed for aerial refueling, and required intermediate refueling bases in order to reach its planned targets deep in the Soviet Union.
- Its slow speed made it vulnerable to Soviet jet interceptor aircraft, making long-range bombardment flights over Soviet territory extremely hazardous, seriously compromising its ability to reach its planned target and return.
- Radar-guided surface-to air missiles, such as the Soviet SA-2 Guideline, capable of reaching 65,600 ft (20,000 m), emerged.
- The B-36 airframe, especially the wings, proved vulnerable to metal fatigue.
- Inflight wing flexing led to fuel leakage, a common problem.

The scrapping of B-36s began in February 1956. Once replaced by B-52s, they were flown directly from operational squadrons to Davis-Monthan AFB, Arizona, where the Mar-Pak Corporation handled their reclamation and destruction. However, defense cutbacks in FY 1958 compelled the B-52 procurement process to be stretched out and the B-36 service life to be extended. The B-36s remaining in service were supported with components scavenged from planes sent to Davis-Monthan for scrapping. Further update work was undertaken by Convair at San Diego (Specialized Aircraft Maintenance, SAM-SAC) until 1957 to extend the life and capabilities of the B-36s. By December 1958, only 22 B-36s (all of them B-36Js) were still operational.

On 12 February 1959, the last B-36J (and the final J built by Convair-52-2827) left Biggs AFB, Texas, where it had been on duty with the 95th Heavy Bombardment Wing, and

was flown to Amon Carter Field in Fort Worth, where it was put on permanent display. Within two years, all but five B-36s (which had been saved for museum display) had been scrapped at Davis-Monthan AFB.

Variants

Variant Built

XB-36 1
YB-36 1
B-36A 22
XC-99 1
B-36B 62
B-36D 26
RB-36D 24
B-36F 34
RB-36F 24
B-36H 83
RB-36H 73
B-36J 33
YB-60 2

Total 385

XB-36

Prototype powered by six 3,000 hp (2,200 kW) R-4360-25 engines and unarmed, one built.

YB-36

Prototype, s/n 42-13571, with modified nose and raised cockpit roof, one built later converted to YB-36A.

YB-36A

Former YB-36 with modified four-wheel landing gear, later modified as a RB-36E.

B-36A

Production variant, unarmed, used for training, 22 built, all but one converted to RB-36E.

XC-99

A cargo/transport version of the B-36. Only one sole example was ever produced.

B-36B

Armed production variant with six 3,500 hp (2,600 kW) R-4360-41 engines, 73 built, later conversions to RB-36D and B-36D.

RB-36B

Designation for 39 B-36Bs temporary fitted with a camera installation.

YB-36C

Projected variant of the B-36B with six 4,300 hp (3,200 kW) R-4360-51 engines driving tractor propellers, not built.

B-36C

Production version of the YB-36, completed as B-36Bs.

B-36D

Same as B-36B but fitted with four J47-GE-19 engines, two each in two underwing pods, 22 built and 64 conversions from B-36B.

RB-36D

Strategic reconnaissance variant with two bomb bays fitted with camera installation, 17 built and seven conversions from B-36B.

GRB-36D

Same as RB-36D but modified to carry a GRF-84F Thunderstreak on a ventral trapeze as part of the FICON program, 10 modified.

RB-36E

The YB-36A and 21 B-36As converted to RB-36D standards.

B-36F

Same as B-36D but fitted with six 3,800 hp (2,800 kW) R-4360-53 engines and four J47-GE-19 engines, 34 built.

RB-36F

Strategic reconnaissance variant of the B-36F with additional fuels capacity, 24 built.

B-36H

Same as B-36F with improved cockpit and equipment changes, 83 built.

NB-36H

One B-36H fitted with a nuclear reactor installation for trials, had a revised cockpit and raised nose. This was intended to evolve into the Convair X-6.

RB-36H

Strategic reconnaissance variant of the B-36H, 73 built.

B-36J

High altitude variant with strengthened landing gear, increased fuel capacity, armament reduced to tail guns only and reduced crew, 33 built.

YB-60

Originally designated the YB-36G, s/n 49-2676 and 49-2684. Project for a jet-powered swept wing variant. Due to the difference from a standard B-36 it was re-designated the YB-60.

Related models

In 1951, the USAF asked Convair to build a prototype of an all-jet variant of the B-36. Convair complied by replacing the wings on a B-36F with swept wings, from which were suspended eight Pratt & Whitney XJ57-P-3 jet engines. The result was the B-36G, later renamed the Convair YB-60. The YB-60 was deemed inferior to Boeing's YB-52, and the project was terminated.

Just as the C-97 was the transport variant of the B-50, the B-36 was the basis for the Convair XC-99, a double-decked military cargo plane that was the largest piston engined, land-based aircraft ever built, and the longest practical aircraft (185 ft/56 m) of its era. The sole example built was extensively employed for nearly a decade, especially for cross-country cargo flights during the Korean War. In 2005, this XC-99 was dismantled in anticipation of its being moved from the former Kelly Air Force Base, now the Kelly

Field Annex of Lackland AFB in San Antonio, Texas, where it had been retired since 1957. The XC-99 was subsequently relocated to the National Museum of the United States Air Force at Wright-Patterson Air Force Base near Dayton, Ohio for restoration, with C-5 Galaxy transports carrying pieces of the XC-99 to Wright-Patterson as space and schedule permitted.

A commercial airliner derived from the XC-99, the Convair Model 37, never left the drawing board. It would have been the first "jumbo" airliner.

Operators



Convair RB-36H-55-CF Peacemaker 52-1383 of the 72d Strategic Reconnaissance Wing landing at RAF Burtonwood, Lancashire, England in October 1956

 United States

- United States Air Force

5th Strategic Reconnaissance Wing, January 1951–September 1958, Fairfield-Suisun AFB (later renamed Travis AFB), California (also RB-36)

6th Bombardment Wing, August 1952–August 1957, Walker AFB, New Mexico

7th Bombardment Wing, June 1948–May 1958, Carswell AFB, Texas

9th Strategic Reconnaissance Wing, May 1949–April 1950, Fairfield-Suisun AFB (later renamed Travis AFB), California (also RB-36)

11th Bombardment Wing, December 1948–December 1957, Carswell AFB, Texas

28th Strategic Reconnaissance Wing, July 1949–May 1957, Ellsworth AFB, South Dakota (also RB-36)

42d Bombardment Wing, April 1953–September 1956, Loring AFB, Maine

72d Strategic Reconnaissance Wing, October 1952–January 1959, Ramey AFB, Puerto Rico (also RB-36)

92d Bombardment Wing, July 1951–March 1956, Fairchild AFB, Washington
95th Bombardment Wing, August 1953–February 1959, Biggs AFB, Texas
99th Strategic Reconnaissance Wing, August 1951–September 1956, Fairchild AFB, Washington (also RB-36)

Survivors



B-36J AF Serial Number 52-2220 on display in the Cold War Gallery at the National Museum of the United States Air Force

Only four (and a half) B-36 type aircraft survive today, from the 384 produced.

- YB-36/RB-36E AF Serial No. 42-13571. This was the first prototype to be converted to the bubble canopy used on production B-36s. It was on display in the 1950s and 1960s at the former site of the Air Force Museum, now the National Museum of the United States Air Force, at Wright-Patterson Air Force Base near Dayton, Ohio. When the museum's current location at Wright-Patterson was being developed in the late 1950s, the cost of moving the bomber was more than simply flying a different B-36 to the new location and the aircraft was slated to be scrapped. It was cut up at the old museum site by the summer of 1972. Instead, private collector Walter Soplata bought it and transported the pieces by truck to his farm in Newbury, Ohio, where it sits today in several large pieces. The bomb bay currently contains a complete P-47N still packed in its original shipping crate.
- RB-36H-30-CF AF Serial No. 51-13730, is on display at the Castle Air Museum at the former Castle Air Force Base in Atwater, California.
- B-36J-1-CF AF Serial No. 52-2217, is on display at the Strategic Air and Space Museum, formerly located at Offutt Air Force Base, and now just off base near Ashland, Nebraska.
- B-36J-1-CF AF Serial No. 52-2220, is on display at the National Museum of the United States Air Force, (formerly The U.S. Air Force Museum) at Wright-Patterson Air Force Base near Dayton, Ohio. Its flight to the museum from Davis-Monthan Air Force Base in Arizona on 30 April 1959 was the last flight of a B-36. This B-36J replaced the former Air Force Museum's original YB-36 AF Serial Number 42-13571. This was also the first aircraft to be placed in the Museum's new display hangar, and was not moved again until relocated to the Museum's

latest addition in 2003. It is displayed alongside the only surviving example of the massive 9 ft (2.7 m) XB-36 wheel and tire.

- B-36J-10-CF, AF Serial No. 52-2827, the final B-36 built, named "The City of Fort Worth", was loaned to the city of Fort Worth, Texas on 12 February 1959. It sat on the field at the Greater Southwest International Airport until that property was redeveloped as a business park (some attempts were made to begin restoration there, during in the 1970s). It then moved to the short-lived Southwest Aero Museum, which was located between the former Carswell Air Force Base (now NAS Carswell Joint Reserve Base) and the former General Dynamics (now Lockheed Martin) assembly plant, where it was originally built; some restoration took place while at the plant. As Lockheed Martin had no place to display the finished aircraft, and local community efforts in Fort Worth to build a facility to house and maintain the massive aircraft fell short, the USAF Museum retook possession of the aircraft and it was transported to Tucson, Arizona for loan to the Pima Air & Space Museum. It is now restored and reassembled at that museum, just south of Davis-Monthan AFB, Arizona and is displayed at that location.

Also related is the sole example of the Convair XC-99 cargo version which is undergoing restoration and reassembly at the National Museum of the United States Air Force at Wright-Patterson AFB in Dayton, Ohio.

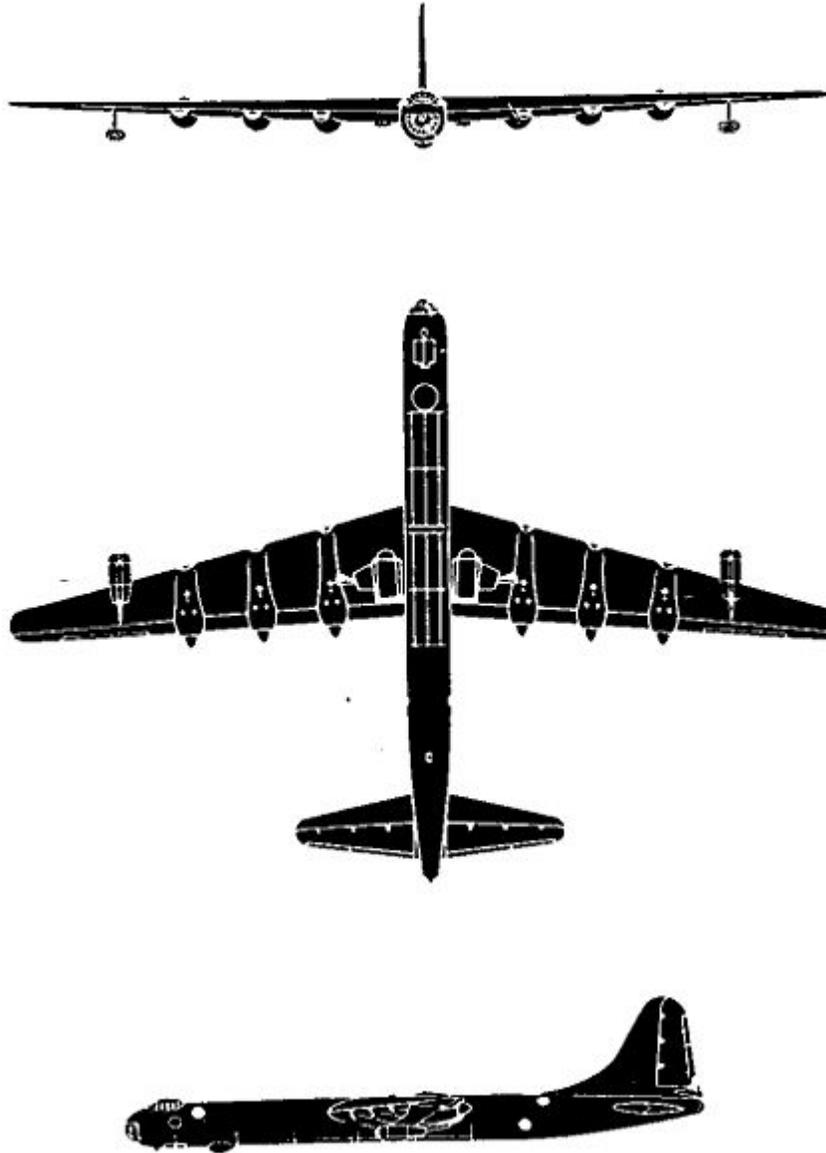
Notable incidents and accidents

Though the B-36 had a better than average overall safety record, 10 B-36s crashed between 1949 and 1954 (three B-36Bs, three B-36Ds, and four B-36Hs). Goleta Air and Space Museum maintains a web site with photographs and lengthy excerpts from the official crash reports. A total of 32 B-36s were written-off in accidents between 1949 and 1957 of 385 built. When a crash occurred, the magnesium-rich airframe burned readily.

B-36s were involved in two "Broken Arrow" incidents. On 13 February 1950, a B-36, serial number 44-92075, crashed in an unpopulated region of British Columbia, resulting in the first loss of an American atom bomb. The bomb's plutonium core was dummy lead, but it did have TNT, and it detonated over the ocean prior to the crew bailing out. Locating the crash site took some effort. Later in 1954, the airframe, stripped of sensitive material, was substantially destroyed (in situ) by a U.S. military recovery team.

On 22 May 1957, a B-36 accidentally dropped a Mark-17 hydrogen bomb on a deserted area while landing at Kirtland AFB in Albuquerque, New Mexico. Only the conventional trigger detonated, the bomb being unarmed. These incidents were classified for decades.

Specifications (B-36J-III)



General characteristics

- **Crew:** 13
- **Length:** 162 ft 1 in (49.42 m)
- **Wingspan:** 230 ft 0 in (70.12 m)
- **Height:** 46 ft 9 in (14.25 m)
- **Wing area:** 4,772 ft² (443.5 m²)
- **Airfoil:** NACA 63(420)-422 root, NACA 63(420)-517 tip
- **Empty weight:** 166,165 lb (75,530 kg)
- **Loaded weight:** 262,500 lb (119,318 kg) (combat weight)

- **Max takeoff weight:** 410,000 lb (186,000 kg)
- **Powerplant:**
 - 4× General Electric J47 turbojets, 5,200 lbf (23.2 kN) each
 - 6× Pratt & Whitney R-4360-53 "Wasp Major" radials, 3,800 hp (2,835 kW) each

Performance

- **Maximum speed:** 418 mph (363 knots, 672 km/h)
- **Cruise speed:** 230 mph (200 knots, 370 km/h)
- **Combat radius:** 3,985 mi (3,465 nmi, 6,415 km)
- **Ferry range:** 10,000 mi (8,700 nmi, 16,000 km)
- **Service ceiling:** 43,600 ft (13,300 m)
- **Rate of climb:** 1,995 ft/min (10.1m/s)

Armament

- **Guns:** 1 remotely operated tail turret with 2× 20 mm (0.787 in) M24A1 autocannons
- **Bombs:** 86,000 lb (39,000 kg) with weight restrictions, 72,000 lb (32,700 kg) normal

Notable appearances in media

In 1949, the B-36 was featured in the documentary film, *Target: Peace*, which was centered around the operations of the 7th Bombardment Wing at Carswell AFB. Other scenes included B-36 production at the Fort Worth plant.

In 1955, the film *Strategic Air Command* was released, starring James Stewart and June Allyson with Stewart playing a baseball star and his subsequent service in Strategic Air Command. The flying sequences (and sounds) of the B-36 dominate the film. This film remains as the only full-length film featuring this aircraft. As of 1 January 2011, this film is available for viewing on Netflix.

The documentary *Lost Nuke* (2004) chronicles a 2003 Canadian expedition that set out to solve the mystery of the world's first lost nuclear weapon. The team traveled to the remote mountain British Columbia crash site of 44-92075.

Lore

Throughout its time in service, the B-36 was the subject of USAF lore, some apocryphal, some containing a grain of truth.

"If all engines function normally at full power during the pre-takeoff warm-up, the lead flight engineer will sometimes say to the Aircraft Commander (AC), 'six turning and four

burning." Erratic reliability led to the wisecrack, 'two turning, two burning, two joking, and two smoking, with two engines not accounted for.'"
—Michael Daciek quoting Capt. Banda

Chapter- 8

Ace Baby Ace and Adam RA-14 Loisirs

Ace Baby Ace

Ace Baby Ace



Role	Sports aircraft
National origin	USA
Manufacturer	Acro Sport
Designed by	Orland Corben

The **Ace Baby Ace** was the world's first aircraft to be marketed as a homebuilt aircraft when its plans were offered for sale in 1929. Plans are still available and Baby Aces are still being built today. Orland Corben designed a series of aircraft for the Ace Aircraft Manufacturing Company, the Baby Ace, Junior Ace, and Super Ace. Corbin's name was associated with the aircraft, and it is commonly known as the *Corben Baby Ace*.

Design

It is a single-seat parasol wing monoplane of conventional taildragger configuration. The fuselage is of fabric-covered tubular construction and the wings are wood. A variety of powerplants may be used, typically in the 65-100 hp (50-75 kW) range.

Operational History

In the mid 1950's Paul Poberezny, founder of the Experimental Aircraft Association bought the rights to the Ace aircraft, and produced a \$500 Baby Ace that was featured in Popular Mechanics. The series of articles were in conjunction with a CAA effort to revitalize American aviation by promoting amateur built aircraft.

Specifications (Typical Baby Ace D)

General characteristics

- **Crew:** one, pilot
- **Length:** 17 ft 11 in (5.46 m)
- **Wingspan:** 26 ft 6 in (8.08 m)
- **Height:** 6 ft 7 in ()
- **Wing area:** 110 ft² (10.22 m²)
- **Airfoil:** Clark Y
- **Empty weight:** 600 lb (270 kg)
- **Loaded weight:** 950 lb (430 kg)
- **Powerplant:** 1× Salmson, Szekely, Continental, or Anzani engine choices., 65-100 hp (50-75 kW)

Performance

- **Maximum speed:** 95 knots (110 mph, 176 km/h)
- **Service ceiling:** 10,500 ft (3,200 m)
- **Rate of climb:** 1,200 ft/min (370 m/min)

Adam RA-14 Loisirs

Adam RA-14 Loisirs



RA-14 Loisirs at Mery-sur-Oise airfield near Paris
in May 1957

Role	light sporting high-wing cabin monoplane
National origin	France
Manufacturer	Roger Adam
Designed by	Roger Adam
Status	Rights sold to Maranda Aircraft Company LTD in 1957
Primary user	private owners and aero clubs

The **RA-14 Loisirs** was a French two-seat high-wing light touring aircraft designed by Roger Adam shortly after World War II.

Design and production

The Loisirs ("Leisure") was designed in May 1945 by Etablissements Aeronautiques R. Adam. It was a tube, wood and fabric two-seater suitable for amateur construction. It was a high-wing braced monoplane of with fixed tail-wheel undercarriage. The seats were positioned side-by-side.

The company sold plans and manufactured parts for the aircraft which could be fitted with a range of engines of between 65 h.p and 80 h.p. These included the Regnier 4D and Continental A65, A75 and C90 engines.

The design rights were sold in 1957 to the Maranda Aircraft Company of Canada who sold plans for amateur construction of the Loisirs RA14BM1. More than 30 examples were built in North America.

Survivors

Of the French production of 40 Loisirs, 17 were active in 1965 and five were still flying in the country in 2001.

Specification

General characteristics

- **Crew:** 2
- **Length:** 6.99 m (22 ft 11 in)
- **Wingspan:** 10.90 m (35 ft 9 in)
- **Height:** 2.21 m (7 ft 3 in)

- **Wing area:** 16.0 m² (172 sq ft)
- **Empty weight:** 279 kg (616 lb)
- **Gross weight:** 479 kg (1,056 lb)
- **Powerplant:** 1 × Continental A65 air-cooled flat-four, 48 kW (65 hp)

Performance

- **Maximum speed:** 140 km/h; 76 kn (87 mph)
- **Cruise speed:** 121 km/h; 65 kn (75 mph)
- **Range:** 451 km; 243 nmi (280 mi)
- **Service ceiling:** 4,000 m (13,123 ft)

Chapter- 9

Adamoli-Cattani Fighter and Adaridi AD3

Adamoli-Cattani fighter

The so-called **Adamoli-Cattani fighter** was a prototype fighter aircraft designed as a private venture by two Italian aircraft builders in 1918. They intended to build the smallest practical biplane around the most powerful engine available to them, a 149 kW (200 hp) Le Rhône. The result was a reasonably conventional design, other than the fact that the wings featured hinged leading edges in place of conventional ailerons. The Farina Coach Building factory in Turin began construction of the prototype; the Officine Moncenisio in Condove completed it.

Upon completion, ground testing revealed that the engine as installed could only deliver some 80% of its rated power, thus leaving the aircraft significantly underpowered. Limited tests continued until the end of World War I, when the Armistice made further development superfluous.

Specifications (Adamoli-Cattani fighter)

General characteristics

- **Crew:** one, pilot
- **Length:** 6.10 m (20 ft)
- **Wingspan:** 8.6 m (28 ft 2 in)
- **Height:** m (ft in)
- **Wing area:** m² (ft²)
- **Empty:** 470 kg (1,036 lb)
- **Loaded:** 675 kg (1,488 kg)
- **Maximum takeoff:** kg (lb)
- **Powerplant:** 1x Le Rhône, 149 kW (200 hp)

Performance

- **Maximum speed:** 300 km/h (186 mph)
- **Endurance:** 2.5 hours
- **Range:** 750 km (469 miles)
- **Service ceiling:** m (ft)
- **Rate of climb:** m/min (ft/min)
- **Wing loading:** kg/m² (lb/ft²)
- **Power/Mass:** 220 W/kg (0.13 hp/lb)

Armament

- 2x .303-in (7.7-mm) machine guns

Adaridi AD 3

AD 3



The Adaridi at the Finnish Aviation Museum.

Role	Experimental aircraft
Designed by	Adaridi
First flight	April 17, 1924
Introduced	1924
Retired	1931
Primary user	Finnish Air Force
Number built	1

Adaridi AD 3 was a wooden aircraft designed by the Russian engineer Boris Adaridin, who lived in Finland. It was a high wing aircraft with a low-powered engine. In 1923, the

Finnish Air Force ordered one Adaridi aircraft. The aircraft was not given any official designation code. The maiden flight was on April 17, 1924.

The German ace, Leutnant Emil Thuy (32 victories in World War I) described the aircraft as having mediocre flying qualities, and that the 12 hp engine was inadequate. The aircraft was never meant to become a military aircraft, it was merely an exercise in building an aircraft.

The aircraft was stationed at the fighter squadron at Utti air force base from the summer of 1924 until 1931. It was very rarely flown, as unexperienced pilots couldn't get the aircraft off the ground.

Operators

 Finland

- Finnish Air Force

Museum aircraft

The sole manufactured Adaridi is displayed at the Finnish Aviation Museum.

Specifications (Adaridi)

General characteristics

- **Crew:** One, pilot
- **Length:** 5.30 m (17 ft 5 in)
- **Wingspan:** 11.60 m (38 ft ½ in)
- **Height:** m (ft in)
- **Wing area:** m² (ft²)
- **Empty weight:** kg (lb)
- **Loaded weight:** kg (lb)
- **Useful load:** kg (kg)
- **Max takeoff weight:** 260 kg (572 lb)
- **Powerplant:** 1× Salmson AD.3 3-cylinder radial engine, 9 kW (12 hp)

Performance

- **Never exceed speed:** km/h (knots, mph)
- **Maximum speed:** 106 km/h (57 knots, 65 mph)
- **Cruise speed:** km/h (knots, mph)
- **Stall speed:** km/h (knots, mph)
- **Range:** km (nm, mi)
- **Service ceiling:** m (ft)
- **Rate of climb:** m/s (ft/min)

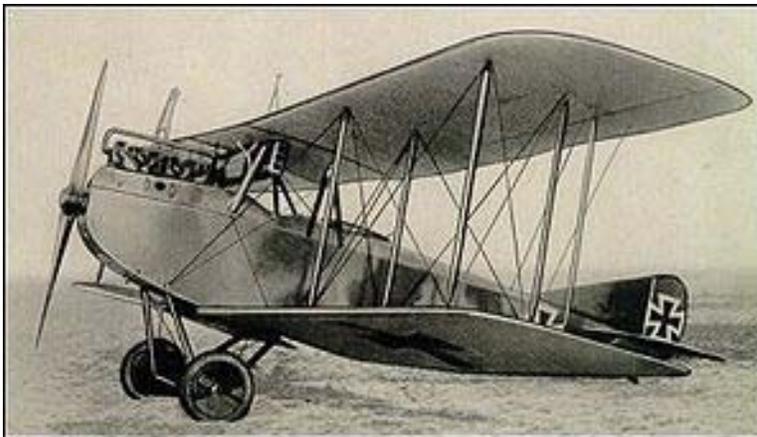
- **Wing loading:** kg/m^2 (lb/ft^2)
- **Power/mass:** W/kg (hp/lb)

Chapter- 10

AEG J.I, Aero A.100 and Aero A.11

AEG J.I

AEG J.I



Role	Ground attack aircraft
Manufacturer	Allgemeine Elektrizitäts-Gesellschaft
Introduced	1917
Primary user	<i>Luftstreitkräfte</i>

The **AEG J.I** was a biplane ground attack aircraft of 1917, an armored and more powerful version of the AEG C.IV reconnaissance aircraft.

Design and development

AEG J.I featured armour protection for the pilot and for the more powerful engine that was fitted to the heavier aircraft. Two 7.92 mm (.312 in) LMG 08/15 machine guns were fitted to the floor of the observer's cockpit for ground targets. One 7.92 mm (.312 in)

Parabellum MG14 machine gun was provided in the typical rear-facing defensive position. Finally, armor plating was added around the engine and cockpits.

The **J.Ia** version featured aileron controls on the lower wings, in addition to the upper.

Operators

 German Empire

- *Luftstreitkräfte*

Specifications (AEG J.I)

General characteristics

- **Crew:** Two
- **Length:** 7.20 m (23 ft 7½ in)
- **Wingspan:** 13.46 m (44 ft 2 in)
- **Height:** 3.35 m (10 ft 11⅞ in)
- **Wing area:** 33.2 m² (358 ft²)
- **Empty weight:** 1,455 kg (3,201 lb)
- **Loaded weight:** 1,740 kg (3,828 lb)
- **Powerplant:** 1× Benz Bz.IV 6 cylinder water-cooled inline engine, 149 kW (200 hp)

Performance

- **Maximum speed:** 150 km/h (82 kn, 93 mph)
- **Range:** 375 km (203 nm, 234 mi)
- **Service ceiling:** 4,500 m (14,760 ft)
- **Rate of climb:** 0.854 m/s (551 ft/min)
- **Wing loading:** 52.4 kg/m² (10.7 lb/ft²)
- **Power/mass:** 0.171 kW/kg (0.104 hp/lb)
- **Endurance:** 2.5 hrs

Armament

- 2 × 7.92 mm (.312 in) fixed, downwards firing LMG 08/15 machine guns
- 1 × 7.92 mm (.312 in) Parabellum MG14 in rear cockpit

Aero A.100

Aero A.100

Role	Light bomber Reconnaissance aircraft
National origin	Czechoslovakia
Manufacturer	Aero Vodochody
First flight	1933
Retired	late 1940s
Primary user	Czech Air Force
Produced	1930s
Number built	44

The **Aero A.100** was a biplane light bomber and reconnaissance aircraft built in Czechoslovakia during the 1930s. It was the final step in a design lineage that extended back to the Aero A.11 a decade earlier. A.100s remained in service throughout World War II and for a few years post-war. A number were also supplied to Nationalist Spanish forces during the Spanish Civil War.

Development

Development of the A.100 was in response to a Czech Air Force requirement of 1932 for a uniform replacement for the A.11s, Aero Ap.32s, and Letov Š.16s then in service. Work began with a revision of the Aero A.430 that quickly became quite a different aircraft. Of standard biplane configuration, the A.100 was a somewhat ungainly-looking aircraft and somewhat obsolescent by the time of its first flight in 1933, a member of the final generation of biplane military aircraft to be designed in Europe. Nevertheless, since the only other competitor for the air force contract, the Praga E.36 had not flown by the close of tenders, the A.100 was ordered for production. A total of 44 were built, in two batches.

Specifications (A.100)

General characteristics

- **Crew:** 2
- **Length:** 11.08 m (36 ft 4 in)
- **Wingspan:** 14.70 m (48 ft 3 in)
- **Height:** 3.60 m (11 ft 10 in)
- **Wing area:** 44.3 m² (476 ft²)
- **Empty weight:** 2,040 kg (4,490 lb)
- **Loaded weight:** 3,220 kg (7,080 lb)
- **Powerplant:** 1× Avia-built Hispano-Suiza Vr-36, 552 kW (740 hp)

Performance

- **Maximum speed:** 270 km/h (150 knots, 170 mph)
- **Range:** 900 km (490 nm, 560 mi)
- **Service ceiling:** 6,500 m (21,000 ft)
- **Rate of climb:** 4.2 m/s (820 ft/min)
- **Wing loading:** 73 kg/m² (9.4 lb/ft²)
- **Power/mass:** 170 W/kg (0.10 hp/lb)

Armament

- **Guns:**
 - 2× forward-firing 7.92 mm (0.312 in) wz.29 machine guns
 - 2× 7.92 mm wz.30 machine guns in ring mount for observer
- **Bombs:** 600 kg (1,300 lb)

Operators

-  Czechoslovakia
-  Germany
 - *Luftwaffe* (small numbers)
-  Spain

Aero A.11

Aero A.11



Role	Light bomber Reconnaissance aircraft
Manufacturer	Aero Vodochody
First flight	1925

Introduced	1920s
Retired	1940s
Primary users	Czech Air Force Finnish Air Force
Number built	~250

The **Aero A.11** was a biplane light bomber and reconnaissance aircraft built in Czechoslovakia between the First and Second World Wars. It formed the basis for a large number of other Czechoslovakian military aircraft of the inter-war period. Around 250 were built, with some remaining in service at the outbreak of World War II.

Designed by Antonin Husnik, it was a development of the Aero A.12 (despite what the numbering of the designs might suggest). A Hispano-Suiza 8Fb-powered version, the **A.11H-s** was built for the Finnish Air Force, the only foreign operator of the type. The Finns had eight aircraft of this type and used them between 1927-39.

Variants

- **A.11** : Two-seat light bomber, reconnaissance biplane.
- **A.11HS** : Export version for Finland.
- **A.11N** : Night bomber version.
- **Ab.11** : Light bomber version.

Operators

 Czechoslovakia
 Finland

- Finnish Air Force

Specifications (A.11)

General characteristics

- **Crew:** 2
- **Length:** 8.2 m (27 ft)
- **Wingspan:** 12.8 m (43 ft 0 in)
- **Height:** 3.1 m (10 ft)
- **Wing area:** 36.5 m² (393 ft²)
- **Empty weight:** 1,080 kg (2,380 lb)
- **Loaded weight:** 1,537 kg (3,381 lb)
- **Powerplant:** 1× Walter W IV, 180 kW (240 hp)

Performance

- **Maximum speed:** 240 km/h (130 knots, 150 mph)

- **Range:** 750 km (400 nm, 470 mi)
- **Service ceiling:** 7,600 m (25,000 ft)
- **Rate of climb:** 3.82 m/s (751 ft/min)
- **Wing loading:** 42 kg/m² (8.6 lb/ft²)
- **Power/mass:** 120 W/kg (0.071 hp/lb)

Armament

- **Guns:**
 - 1× forward firing .303 in (7.7 mm) Vickers machine gun
 - 2× .303 in (7.7 mm) Lewis machine gun in flexible mount for observer
- **Bombs:** 200 kg (441 lb)

Operators

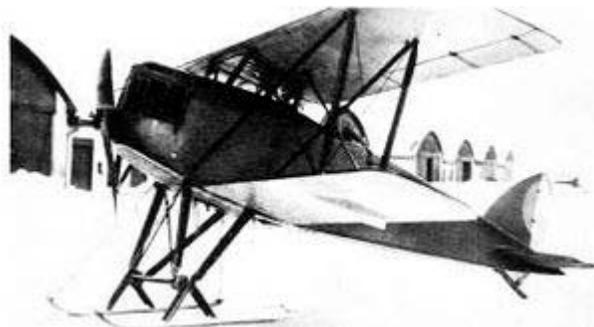
- Czechoslovakia
- Finland

Chapter- 11

Aero A.18, Aero A.23 and Aero A.32

Aero A.18

Aero A.18



Role	Fighter aircraft
National origin	Czechoslovakia
Manufacturer	Aero Vodochody
Designed by	Antonin Vlasák Antonin Husník
First flight	March 1923
Retired	1939 (due to German invasion)
Status	1 preserved at the Letecké Muzeum
Primary users	Czech Air Force Czech Aero Club
Produced	1920s
Number built	20

The **Aero A.18** was a biplane fighter aircraft built in Czechoslovakia in the 1920s. It was a development of the Ae 02 and Ae 04 fighters Aero had designed during World War I, but also borrowed from the more recent A.11 reconnaissance-bomber design.

The aircraft was designed by Antonin Vlasák and Antonin Husník and first flew in March 1923. It was only one of three prototype fighters that Aero flew that year, but this one was selected for production over the A.19 and A.20 that competed with it. Twenty machines saw service with the Czech air force in the period between the wars.

The **A.18B** and **A.18C** were specially modified racing variants that competed in the Czech Aero Club's first two annual air races, in 1923 and 1924 respectively. Both aircraft won their races, and the A.18C is preserved at the Letecké Muzeum in Kbely along with a replica of a standard A.18 fighter.

Specifications (A.18)

General characteristics

- **Crew:** 1
- **Length:** 5.90 m (19 ft 4 in)
- **Wingspan:** 7.60 m (25 ft 0 in)
- **Height:** 2.86 m (9 ft 5 in)
- **Wing area:** 15.9 m² (171 ft²)
- **Empty weight:** 637 kg (1,401 lb)
- **Max takeoff weight:** 826 kg (1,817 lb)
- **Powerplant:** 1× BMW IIIa, 138 kW (185 hp)

Performance

- **Maximum speed:** 229 km/h (124 knots, 143 mph) **Range:** 400 km (220 nm, 250 mi)
- **Service ceiling:** 9,000 m (30,000 ft)
- **Rate of climb:** 9.8 m/s (1,930 ft)

Armament

- **Guns:** 2× .303 in (7.70 mm) Vickers machine guns

Operators

- Czechoslovakia

Aero A.23

Aero A.23



Role	Airliner
Manufacturer	Aero Vodochody
Introduced	1926
Retired	1936
Primary user	Czech Airlines
Produced	1920s
Number built	7

The **Aero A.23** was a Czechoslovakian biplane airliner of the 1920s. Aero's previous airliner design, the A.10 had been a relatively crude machine drawing heavily on World War I military aircraft. The A.23, designed in 1925 was relatively modern, although it still seated its pilot in an open cockpit above the passenger cabin. Seven A.23s flew CSA's Prague-Marienbad (Mariánské Lázně) and Prague-Uzhhorod routes between 1926 and 1936.

Specifications (A.23)

General characteristics

- **Crew:** 1
- **Capacity:** 8 passengers
- **Length:** 12.6 m (41 ft 4 in)
- **Wingspan:** 16.7 m (54 ft 10 in)
- **Height:** m (ft in)
- **Wing area:** 67 m² (721 ft²)
- **Empty weight:** 1,860 kg (4,100 lb)
- **Max takeoff weight:** 3,150 kg (6,950 lb)
- **Powerplant:** 1× Walter-built Bristol Jupiter IV radial engine, 450 hp (340 kW)

Performance

- **Maximum speed:** 185 km/h (100 knots, 115 mph)
- **Range:** km (nm, mi)
- **Service ceiling:** 5,500 m (18,000 ft)
- **Rate of climb:** m/s (ft/min)

Aero A.32

Aero A.32



Incomplete A.32 in the Finnish museum

Role	Reconnaissance - bomber
Manufacturer	Aero
First flight	1927
Introduced	1928
Retired	1944
Primary user	Czechoslovak Air Force Finnish Air Force
Number built	116

The **Aero A.32** was a biplane built in Czechoslovakia in the late 1920s for army co-operation duties including reconnaissance and tactical bombing. While the design took the Aero A.11 as its starting point (and was originally designated **A.11J**), the aircraft incorporated significant changes to make it suited for its new low-level role.

Like the A.11 before it, the A.32 provided Aero with an export customer in the Finnish Air Force, which purchased 16 aircraft in 1929 as the **A.321F** and **A.32GR** (which spent most of their service lives as trainers). They were assigned numbers AEj-49 - AEj-64 and

were used until 1944. At least one fuselage has survived, preserved at the Finnish Air Force Museum (in storage as of 2003).

A total of 116 of all variants were built.

Variants

- **A.321F** : Attack version for Finland, powered by a 450-hp (336-kW) Isotta Fraschini Asso Cassia piston engine.
- **A.32GR** : Attack version for Finland, powered by a 450-hp (336-kW) Gnome-Rhone built Bristol Jupiter radial piston engine.
- **Ap.32** : Improved version for the Czech Air Force. Also known as the **Apb.32**.

Operators

 Czechoslovakia

 Finland

Finnish Air Force

Specifications (A.32)

General characteristics

- **Crew:** two, pilot and observer
- **Length:** 8.20 m (26 ft 11 in)
- **Wingspan:** 12.40 m (40 ft 8 in)
- **Height:** 3.10 m (10 ft 2 in)
- **Wing area:** 36.5 m² (393 ft²)
- **Empty weight:** 1,046 kg (2,301 lb)
- **Loaded weight:** 1,917 kg (4,217 lb)
- **Powerplant:** 1× Gnome-Rhone built Bristol Jupiter radial engines, 313 kW (420 hp)

Performance

- **Maximum speed:** 226 km/h (141 mph)
- **Range:** 420 km (262 miles)
- **Service ceiling:** 5,500 m (18,040 ft)
- **Rate of climb:** 171 m/min (561 ft/min)
- **Wing loading:** 53 kg/m² (10.7 lb/ft²)
- **Power/mass:** 160 W/kg (0.10 hp/lb)

Armament

- 2 × forward-firing .303 in (7.7 mm) Vickers machine guns
- 2 × .303 in (7.7 mm) Lewis machine guns in flexible mount for observer

- Up to 12 × 10 kg (22 lb) bombs



Airplane Aero A.32 in Kbely aviation museum in Prague, Czech Republic.





Chapter- 12

Aero A.42, Aero Ae 270 Ibis and Aero AT3

Aero A.42

Aero A.42



Role	Bomber
Manufacturer	Aero
First flight	1929
Introduced	1930
Retired	1940
Status	Prototype
Primary user	Czechoslovak Air Force
Number built	2

The **Aero A.42** was a Czechoslovakian bomber aircraft of 1929 that was only ever produced in prototype form. For its day, it was an advanced design, with a sleek monoplaner configuration. However, the Czech Air Force was not satisfied with it for a number of reasons, in particular, the aircraft's take-off and landing rolls were felt to be excessively long, and crew complained about the cramped cabin. The air force suggested a set of modifications to Aero, including replacing the wooden wing with a metal one, but Aero discontinued development.

On September 20, 1930, one of the two prototypes set international speed records of 253.428 km/h over a 1,000 km (621 mile) closed circuit, carrying payloads of 500 kg (1,100 lb) and 1000 kg (2,200 lb).

One prototype was used by the Czechoslovak Air Force until 1938, then by the Slovak Air Force. Probably it was scrapped in 1940.

The A.42 was a single-engined high-wing cantilever monoplane, with a fixed landing gear.

Specifications (A.42)

General characteristics

- **Crew:** three, pilot, observer/bombardier, radio operator/gunner
- **Length:** 13.8 m (45 ft 3 in)
- **Wingspan:** 20.8 m (68 ft 3 in)
- **Height:** 3.4 m (11 ft 2 in)
- **Wing area:** 54 m² (580 ft²)
- **Empty weight:** 2,940 kg (6,480 lb) ()
- **Loaded weight:** 4,740 kg (10,450 lb) ()
- **Powerplant:** 1× Isotta-Fraschini Asso, 597 kW (800 hp)

Performance

- **Maximum speed:** 270 km/h (170 mph)
- **Service ceiling:** 7,000 m (23,000 ft)
- **Rate of climb:** 100 m/min (330 ft/min)
- **Wing loading:** 88 kg/m² (18 lb/ft²)
- **Power/mass:** 80 W/kg (0.08 hp/lb)

Armament

- 1 × 7.9 mm machine gun in ventral position
- 1 × 7.9 mm machine gun in dorsal turret
- 400 kg of small bombs

Aero Ae 270 Ibis



Ae 270 Ibis

The **Aero Ae 270 Ibis** is a turboprop-powered civil utility aircraft currently under development. Design work by Aero commenced in the early 1990s, with the aircraft's configuration finalised by 1993. In 1997, Aero signed an agreement with AIDC of Taiwan to jointly manufacture and market the aircraft as Ibis Aerospace.

Airworthiness has been certified by the Czech Civil Aviation Authority permitting training and aerial work, including commencement of commercial use.

Project was canceled and 3 fuselages were located in museum Air Park Zruč u Plzně.

Specifications (Ae 270HP)

General characteristics

- **Crew:** One or two
- **Capacity:** Up to 8 passengers or 1,200 kg (2,645 lb) cargo
- **Length:** 12.23 m (40 ft 1½ in)
- **Wingspan:** 13.82 m (45 ft 4 in)
- **Height:** 4.78 m (15 ft 8¼ in)
- **Wing area:** 21.00 m² (226.0 ft²)
- **Airfoil:** NASA MS(1)-0316.7 (root), NASA MS(1)-0312 (tip)
- **Empty weight:** 2,300 kg (5,071 lb)
- **Max takeoff weight:** 36,700 kg (8,157 lb)
- **Powerplant:** 1× Pratt & Whitney Canada PT6A-66A-42A turboprop engine, 634 kW (850 shp)

Performance

- **Maximum speed:** 500 km/h (270 knots, 311 mph) at FL 200
- **Stall speed:** 123 km/h (66 knots, 76 mph) with flaps down
- **Range:** 2,981 km (1,610 nmi, 1,852 mi) at 30,000 ft with 30-minute VFR reserve
- **Service ceiling:** 9,140 m (30,000 ft)
- **Rate of climb:** 8.7 m/s (1,710 ft/m)

Aero AT-3

AT-3



Role	Utility aircraft
National origin	Poland
Manufacturer	Aero Ltd
First flight	1997
Introduction	2002
Status	In production

The **Aero AT-3** is a two-seat, low wing, utility aircraft manufactured in Poland in ready-to-fly certificated form and as a kitplane. The aircraft is of conventional configuration and features fixed tricycle undercarriage. The structure is largely of all-metal construction. It first flew in 1997 and deliveries to customers commenced in 2002. It is certified under European Very Light Aircraft regulation.

Design and development

The AT-3 R-100 is a single-engined low-wing cantilever monoplane of all-metal construction and a fixed tricycle landing gear. It is powered by a nose-mounted

Bombardier-Rotax 912 with either a two-bladed wooden or three-bladed composite propeller.

Operational history

As of 2008, some dozen aircraft are used in Poland, among others by the Polish Aero Club, several are used in the United Kingdom, among others by Brooklands Flying Club at Sywell Aerodrome and Old Sarum Flying School, France and some other countries. Deliveries are in progress. Aeroclub Air France ordered 6 aircraft in 2008.



Aero AT-3 R100 at Cotswold Airport, Gloucestershire, England. (2010).

Variants

AT-3 SK

Special Kit, homebuilt variant.

AT-3 R100

Factory-built variant to JAR-VLA standards.

Specifications (AT-3)

General characteristics

- **Crew:** 1
- **Capacity:** 1 passenger

- **Length:** 6.25 m (20 ft 6 in)
- **Wingspan:** 7.55 m (24 ft 9 in)
- **Height:** 2.23 m (7 ft 4 in)
- **Wing area:** 9.3 m² (100.6 ft²)
- **Empty weight:** 350 kg (771 lb)
- **Useful load:** 232 kg (511 lb)
- **Max takeoff weight:** 582 kg (1,282 lb)
- **Powerplant:** 1× Rotax 912S, 100 hp (75 kW)

Performance

- **Never exceed speed:** 236 km/h (127 kts)
- **Maximum speed:** 220 km/h (119 kts)
- **Cruise speed:** 200 km/h (108 kts)
- **Stall speed:** 82 km/h (44 kts)
- **Range:** 717 km (387 nm)
- **Service ceiling:** 4000 m (13,123 ft)
- **Rate of climb:** 3.7 m/s, 222 m/min (730 ft/min)
- **Wing loading:** +3.8g -1.5 g ()
- **Power/mass:** 5.82kg/hp (12.82 lb/hp)
- Take-off distance = 160 m (525 ft)
-
- Landing distance = 150 m (492 ft)

Chapter- 13

Aero Boero AB-115, Aero Boero AB-180 and Aero Boero AB-95

Aero Boero AB-115

AB-115



Role	Light aircraft
National origin	Argentina
Manufacturer	Aero Boero
First flight	1973
Developed from	Aero Boero AB-95

The **Aero Boero AB-115** is an Argentine civil utility aircraft developed from the AB-95-115, a refined AB-95 with a more powerful engine and improved aerodynamics. Specific differences included wheel spats, a redesigned engine cowling, and swept tail surfaces.

The type was successfully exported to Brazil, where 450 have been ordered for use as trainers by aero clubs since the 1980s.

Design

The AB-115 is a high-wing monoplane, with strut-braced rectangular wings (NACA 23012 profile). The wing and nacelle are made of aluminum alloy, with fiberglass wingtips, while the rest of the fuselage and the empennage are made of welded steel tubes covered by fabric.

The trainer version, the most common variant, contains two seats in tandem configuration, with the pilot-flying/student pilot in the front seat, and the instructor/pilot-not-flying seating in the rear. Behind the rear seat there is a cargo hold, with capacity of up to 25 kg (55 Lb). The front seat has a three point seatbelt, while the rear one has a simple, abdominal belt. Both occupants enter and exit the aircraft through one single, large door in the right side of the cockpit.

The flight commands are duplicated, with the front seat's center stick, throttle lever, rudder pedals and brake pedals mechanically connected to the rear seat's. The rear stick and the throttle lever can be disassembled when carrying passenger(s).

The primary flight commands are actuated by cables and pulleys. The ailerons are made of aluminum alloy, while the rudder and elevators are made of steel tubes and fabric. The flaps have four positions (neutral, 15°, 30° and 45°), and are actuated manually, by a lever in the upper left part of the cockpit. The pitch trim tab is located in the trailing edge of the left elevator, and is actuated by a handle in the left side of the cockpit. The rudder and the left aileron also have trim tabs, but these can only be adjusted on the ground.

A Lycoming O-235-C2A air-cooled engine, rated at 115 hp (87.5 kW), drives a Sensenich model 72 CK-050, metallic fixed-pitch twin-bladed propeller. The fuel injection system uses a FACET MA 3PA carburetor, equipped with carburetor heat. The engine is also equipped with one Prestolite alternator, two Bendix Scintilla S5LN magnetos and one Prestolite starter motor. The lubricant is stored within the engine's crankcase. The lubricant system also includes an oil radiator in the front of the engine's air intake, which is triggered by a bi-metallic thermostatic valve.

The maximum fuel capacity is 115 liters, while the actual useful load is 110 liters. The engine can be fed with either 80/87 octanes, 100LL or 100/130 octanes Avgas. There are two aluminum fuel tanks, fixed by metallic belts in the roots of each wing. The fuel load is displayed by two separate sight glasses, in both sides of the cockpit. There are two separate fuel selectors, for each tank, which can be independently opened and closed.

The aircraft features a conventional undercarriage. Each of the two main gears is fixed to the fuselage in three points - two articulated joints, plus one shock absorber. The wheels are made of aluminum alloy and magnesium, and are equipped with independent hydraulic-actuated brakes. The aircraft, however, doesn't have parking brakes - when parked, it must be necessarily secured by chocks. The tailwheel is connected to the rudder by two springs, but it can also rotate freely when "unlocked".

The instrument panel is relatively simple, since the AB-115 is mostly used for basic flight training. The included flight instruments are an airspeed indicator, altimeter, VSI and a turn coordinator. The engine's instruments are a tachometer, two gauges for oil pressure and oil temperature, and an ammeter for the alternator. For navigation, there is a magnetic compass. The panel also includes one Bendix/King VHF radio, and one Bendix/King transponder. The cabin is equipped with a flood light, which is turned on by the navigation lights' switch, and the luminosity can be adjusted by a potentiometer. The aircraft is also equipped with two landing lights, both on the right wing's leading edge, but these can not be used continuously for more than five minutes.

Variants

Aero Boero AB-115BS

Civil utility/Ambulance version.

Aero Boero AB-115 Trainer

Trainer version.

Aero Boero AB-115/150

Version with more powerful 150 hp Lycoming O-320 engine. Can be used for crop spraying.

Specifications (AB-115BS)

General characteristics

- **Crew:** 1
- **Capacity:** 2 passengers
- **Length:** 7.27 m (23 ft 10¼ in)
- **Wingspan:** 10.72 m (35 ft 2 in)
- **Height:** 2.10 m (6 ft 10½ in)
- **Wing area:** 16.5 m² (177 ft²)
- **Empty weight:** 530 kg (1,168 lb)
- **Max takeoff weight:** 770 kg (1,697 lb)
- **Powerplant:** 1× Textron Lycoming O-235-C2A four cylinder, air-cooled, horizontally-opposed, 85.5 kW (115 hp) at 2400 RPM

Performance

- **Maximum speed:** 220 km/h (119 knots, 137 mph) at sea level
- **Cruise speed:** 145 km/h (75 knots, 90 mph) (normal cruise)
- **Stall speed:** 68 km/h (36 knots, 42 mph) (with full flaps - 45°)
- **Range:** 648 km (349 NM, 400 SM)
- **Service ceiling:** 2440 m (8000 ft)
- **Rate of climb:** 2.44 m/s (480 ft/min) (at maximum rate of climb and angle of climb speed of 70 mph)

Aero Boero AB-180

AB-180



Role	Civil utility aircraft
Manufacturer	Aero Boero
First flight	1967

The **Aero Boero AB-180** is an Argentine civil utility aircraft, a substantially improved development of the AB-95. It featured a more powerful engine and incorporated the aerodynamic changes made on the AB-115 and improved on them. The first example flew in 1967 and it was still in production as of 1997.

Variants

- **AB-180RV** - long-range version
- **AB-180RVR** - glider tug
- **AB-180 Condor** - high altitude version of 1971 with optional turbocharger (4 built)
- **AB-180Ag** - agricultural aircraft with 270 l (66 US gal) belly tank for chemicals
 - **AB-180SP** - 180Ag with an additional set of short wings to make a sesquiplane
- **AB-180PSA** - two seat preselection aircraft

Specifications (AB-180RVR)

General characteristics

- **Crew:** 1
- **Capacity:** 2
- **Length:** 7.08 m (23 ft 2¾ in)
- **Wingspan:** 10.78 m (35 ft 4½ in)
- **Height:** 2.05 m (6 ft 8¾ in)

- **Wing area:** 17.41 m² (187.4 sq ft)
- **Airfoil:** Modified NACA 23012
- **Aspect ratio:** 6.67
- **Empty weight:** 602 kg (1,327 lb)
- **Max takeoff weight:** 890 kg (1,962 lb)
- **Powerplant:** 1× Textron Lycoming O-360-A1A air-cooled flat-four, 134 kW (180 hp)

Performance

- **Never exceed speed:** 245 km/h (132 knots, 152 mph)
- **Maximum speed:** 225 km/h (122 knots, 140 mph) at sea level
- **Cruise speed:** 201 km/h (108 knots, 125 mph)
- **Stall speed:** 73 km/h (40 knots, 45 mph) (flaps down)
- **Range:** 1,180 km (636 nmi, 733 mi)
- **Service ceiling:** 7,000 m+ (23,000 ft)
- **Rate of climb:** 5.2 m/s (1,025 ft/min)

Aero Boero AB-95

AB-95



1961-built Aero Boero 95 at Buenos Aires - San Justo airfield in 1975

Role	Light utility aircraft
National origin	Argentina
Manufacturer	Aero Boero S.A.
First flight	March 12, 1959
Introduction	1961
Primary user	Aero Clubs
Produced	1961-1969

The **Aero Boero AB-95** is a small Argentine civil utility aircraft that first flew on March 12, 1959. It was built by Aero Boero S.A. of Cordoba. The AB-95 is a high-wing monoplane with fixed tailwheel undercarriage built of fabric-covered metal structure.

Variants

- **AB-95** - basic production version. 95 h.p. Continental C-90-12F
 - **AB-95A de Lujo** - 75 kW (100 hp) Continental O-200-A engine.
 - **AB-95A Fumigador** - crop duster with O-200A engine.
- **AB-95B** - 1963 version with 112 kW (150 hp) engine.
 - **AB-115BS** - air ambulance version (25 built).
- **AB-95-115** - 86 kW (115 hp) Textron Lycoming O-235 engine, and aerodynamic improvements, developed into AB-115. (45 built)

Specifications (AB-95)

General characteristics

- **Crew:** One, pilot
- **Capacity:** 2 passengers
- **Length:** 6.90 m (22 ft 7½ in)
- **Wingspan:** 10.42 m (34 ft 2 in)
- **Height:** 2.19 m (7 ft 2½ in)
- **Wing area:** 16.36 m² (176.1 ft²)
- **Airfoil:** NACA 23012
- **Aspect ratio:** 6.5
- **Empty weight:** 422 kg (930 lb)
- **Loaded weight:** 700 kg (1,543 lb)
- **Powerplant:** 1× Continental C90-8F air-cooled 4-cylinder horizontally-opposed engine, 70 kW (95 hp)

Performance

- **Maximum speed:** 205 km/h (111 knots, 127 mph)
- **Cruise speed:** 160 km/h (87 knots, 100 mph) (economy cruise)
- **Stall speed:** 48 km/h (26 knots, 30 mph) flaps down
- **Range:** 959 km (518 nmi, 600 mi)
- **Service ceiling:** 5,200 m (17,000 ft)
- **Rate of climb:** 5.0 m/s (1000 ft/min)
- **Wing loading:** 42 kg/m² (8.6 lb/ft²)
- **Power/mass:** 0.10 kW/kg (0.062 hp/lb)