AEROTECHNEWS

JOURNAL OF AEROSPACE, DEFENSE INDUSTRY AND VETERANS NEWS

AN AEROTECH NEWS AND REVIEW PUBLICATION • WWW.AEROTECHNEWS.COM • JULY 2022

X Planes Part 2

Aerotech News and Review
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The Luke Air Force Base Thunderbolt
"We train the world's greatest fighter pilots and combat ready Airmen"

X = Experimental, to the highest power

by Stuart Ibberson
editor

When people hear the term “X-Planes” they often think of cutting edge aircraft used to test technology.

Some of the most famous X-Planes that come to mind are the Bell X-1 in which Chuck Yeager broke the sound barrier, the X-15 in which multiple pilots earned their astronaut wings, and the X-35 that later became the F-35 Lightning II fighter, in service with the U.S. Air Force, the U.S. Navy, the U.S. Marine Corps, and many allies around the world.

However, not all X-Planes are aircraft (some are rockets and missiles), and not all aircraft that have the ‘X’ in their name are officially designated as X-Planes — the X-91, X-92 and XB-70 come to mind.

Beginning in 1946, two XS-1 experimental research aircraft (later redesignated X-1s) conducted pioneering tests at Muroc Army Air Field (now Edwards Air Force Base) in California, to obtain flight data on conditions in the transonic speed range. These early tests resulted in the first piloted flight faster than Mach 1.0, the speed of sound, on Oct. 14, 1947.

The XS-1 was the first high-speed aircraft built purely for aviation research purposes. The model was never intended for production. The XS-1 was designed largely in accordance with specifications provided by the National Advisory Committee for Aeronautics (NACA) [now National Aeronautics and Space Administration], paid for by the Army Air Forces, and built by Bell Aircraft Inc. The XS-1 #2 (serial number 46-063) was flight tested by NACA to provide design data for later production high-performance aircraft.

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

X-Planes have since accomplished many aviation “firsts” including breaking speed and altitude barriers, varying wing sweep in flight, implementing exotic alloys and propulsion innovations, and many more.

As a result of the X-1’s initial supersonic flight, the National Aviation Association voted its 1948 Collier Trophy to be shared by the three main participants in the program. Those honored at the White House by President Harry S. Truman included Lawrence “Larry” Bell for Bell Aircraft, Capt. Charles E. “Chuck” Yeager for piloting the flights, and John Stack of NACA for the NACA contributions.

The U.S. X-Plane Program has evolved from being the first rocket-powered airplane to break the sound barrier, to testing over 30 different major research designs — although not all were developed into flying prototypes.

As the program progressed, other non-rocket-powered experimental aircraft were built and tested. These aircraft included: a range of vertical takeoff and horizontal landing vehicles; smaller, propeller-driven reconnaissance vehicles; and a series of unmanned missile testbeds of both single and multistage designs. Although the program grew to include conventional propeller-driven aircraft, all designs had in common the aspect of being highly valuable research tools for advancement of aerodynamics and astronautics.

Accomplishments of the X-Plane family have been many. The program included: the first aircraft to break the sound barrier; the first aircraft to use a variable-sweep-wing in flight; the first to fly at altitudes in excess of 100,000, 200,000 and 300,000 feet; the first to use exotic alloy metals for primary structure; the first to test gimbaled jet and rocket engines; the first to use jet-thrust for launch and landing; the first to fly three, four, five, and six times the speed of sound; the first to test boundary-layer-airflow control theories over an entire wing at transonic speeds; the first to successfully complete a 180-degree turn using a post-stall maneuver; and the first missile to reach an intercontinental flight range.

The majority of testing for the X-Plane family has occurred at Edwards Air Force Base (formerly known as Muroc Army Airfield). Hosts within Edwards include the Air Force Test Center and Armstrong Flight Research Center (formerly known as the Air Force Flight Test Center and Dryden Flight Research Center, respectively.)

Other sites which have served as X-Plane testing sites include: Langley Research Center, Va.; Ames Research Center, Calif.; various U.S. government-owned ships; White Sands Missile Range, N.M.; Wright-Patterson Air Force Base, Ohio; Cape Canaveral Air Station, Fla.; Pinecastle Air Force Base, Fla.; Buffalo, N.Y.; and the National Aviation Facilities Experimental Center in Atlantic City, N.J. However, Edwards has seen more X-Plane programs and test flights than any other similar facility in the United States

As with every research program testing prototype equipment, the X-Plane Program has not been without technical glitches and equipment failures. Since the beginning of the program’s manned flight operations in 1946, approximately 15 major accidents and four pilot fatalities have been associated with manned vehicle tests.

So who determines whether an X-Plane is an “X-Plane?” The U.S. Department of Defense has specific guidelines and detailed protocols that identify all aircraft, helicopters, rockets, missiles, spacecraft and other aerial vehicles in military use. These guidelines are what give us F for fighter, C for cargo, A for attack, and X for experimental, among other designations.

In July 2021, Aerotech News and Review took a look at some of the more well-known X-Planes. In this special issue of Aerotech News and Review – X-Planes Part 2, we take a look at some of the less well known X-Planes, and two of the newest X-Planes

You can view X-Planes Part 1 at https://online.flipbuilder.com/vzwd/zasn/

X-57 project creates paths toward electric aviation

NASA’s X-57 Maxwell all-electric aircraft project will conclude aircraft operational activities by the end of September 2023, with documentation and close-out activities continuing for several months afterwards.

The research from the X-57 provides aviation researchers with hundreds of lessons learned, as well as revolutionary development in areas ranging from battery technology to cruise motor control design.

“NASA’s goal is to drive innovation through groundbreaking research and technology development. The X-57 project team has done just that by providing foundational information to industry through lessons learned, and we’re seeing the benefits borne out by American commercial aviation companies that are aiming to change the way we fly,” said Brad Flick, director of NASA’s Armstrong Flight Research Center in Edwards, Calif., where the X-57 aircraft was developed, during a project update on June 23. “I’m incredibly proud of their tenacity and ingenuity as they led the way in advancing electrified propulsion. The future of electrified propulsion is possible because of their contributions.”

Finalizing aircraft operations by September 2023 will not incorporate first flight of the X-57 aircraft. The project encountered several challenges to safe flight, including mechanical issues late into its lifecycle and a lack of availability of critical components required to develop experimental hardware. Given the approaching planned end of aircraft operations, the timeline would not allow the team to reach acceptable flight conditions.

Although most of the X-57’s development will complete by September 2023, the team will officially conclude its work several months afterward with additional technical publications.

The primary goal of the X-57 project was to provide knowledge about the aircraft’s electric-propulsion-focused design and airworthiness process with regulators. This information has already impacted and will continue to impact the development of advanced certification approaches for electric propulsion in emerging electric aircraft markets. The objective was not to develop a prototype, but to develop a test platform for technologies and design methods. And the team did just that, documenting and publishing the technology gaps and their solutions as they were discovered so that industry stakeholders could take advantage of those lessons as soon as possible.

NASA photograph by Lauren Hughes

NASAís X-57 Maxwell all-electric aircraft after completing high-voltage ground testing at the agency’s Armstrong Flight Research Center at Edward, Calif., in 2021.

“They did things that had never been done before, and that’s never easy,” Flick said. “While we prepare to finish this project later this year, I see a long list of achievements to celebrate and an industry that’s better today because of their work.”

The X-57 is part of NASA’s commitment to supporting the U.S. climate goal of achieving net-zero greenhouse gas emissions from the aviation sector by 2050. Since 2016, the project has shared lessons learned about battery technology, electromagnetic interference, motor controller design, and so much more. NASA will continue its research into electric aircraft through other projects, including its†Electrified Powertrain Flight Demonstration.

The aircraft was built by modifying an Italian Tecnam P2006T to be powered by an electric propulsion system. Using an existing aircraft design allowed the team to compare their data to that of a baseline model powered by traditional combustion engines.

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Aerotech News and Review is published the first Friday of the month, serving the aerospace and defense industry of Southern California, Nevada and Arizona.

News and ad copy deadline is noon on the Tuesday prior to publication. The publisher assumes no responsibility for error in ads other than space used. Your comments are welcomed and encouraged. Write to the address below.

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Type	Manufacturer	Agency	Year	Role	Notes
X-1	Bell	USAF/ NACA	1946	High-speed and high altitude flight	First aircraft to break the sound barrier in level flight. Proved aerodynamic viability of thin wing sections.
X-1A, X-1B, X-1C, X-1D	Bell	USAF/NACA	1951	High-speed and high-altitude flight	
X-1E	Bell	USAF/NACA	1955	High-speed and high-altitude flight	
X-2	Bell	USAF	1952	High-speed and high-altitude flight	First aircraft to exceed Mach 3
X-3 Stiletto	Douglas	USAF, NACA	1952	Highly loaded trapezoidal wing	Titanium alloy construction; Underpowered, but provided insights into inertia coupling
X-4 Bantam	Northrop	USAF, NACA	1948	Transonic tailless aircraft	
X-5	Bell	USAF, NACA	1951	Variable geometry	First aircraft to fly with variable wing sweep
X-6	Convair	USAF, AEC	1957	Nuclear propulsion	Not built. The Convair NB-36H was a B-36 modified to carry a nuclear reactor and flew from 1955 to 1957.
X-7	Lockheed	USAF, USA, USN	1951	Ramjet engines	
X-8 Aerobee	Aerojet	NACA, USAF, USN	1949	Upper air research	Later models used as sounding rockets
X-9 Shrike	Bell	USAF	1949	Guidance and propulsion technology	Assisted development of GAM-63 Rascal missile
X-10	North American	USAF	1953	SM-64 Navajo missile testbed	
X-11	Convair	USAF	1957	SM-65 Atlas missile testbed	
X-12	Convair	USAF	1957	SM-65 Atlas missile testbed	
X-13 Vertijet	Ryan	USAF, USN	1955	Vertical takeoff and landing (VTOL)	Tailsitting VTOL flight
X-14	Bell	USAF, NASA	1957	VTOL	Vectored thrust configuration for VTOL flight
X-15	North American	USAF, NASA	1959	Hypersonic, high-altitude flight	First manned hypersonic aircraft; capable of suborbital spaceflight
X-15A-2	North American	USAF, NASA	1964	Hypersonic, high-altitude flight	Maj. Pete Knight flew the X-15A-2 to Mach 6.70, making it the fastest piloted flight of the X-plane program
X-16	Bell	USAF	1954	High-altitude reconnaissance	"X-16" designation used to hide true purpose as a reconnaissance aircraft. Canceled
X-17	Lockheed	USAF, USN	1956	High Mach number reentry	
X-18	Hiller	USAF, USN	1959	Vertical and/or short take-off and landing	Evaluated the tiltwing concept for VTOL flight
X-19	Curtiss-Wright	Tri-service	1963	Tandem tiltrotor VTOL	XC-143 designation proposed
X-20 Dyna-Soar	Boeing	USAF	1963	Reusable spaceplane	Military spaceplane prototype. Canceled and never built.
X-21A	Northrop	USAF	1963	Boundary layer control	
X-22	Bell	Tri-service	1966	Quad ducted fan tiltrotor STOVL	
X-23 PRIME (Precision Reentry Including Maneuvering reEntry)	Martin Marietta	USAF	1966	Maneuvering atmospheric reentry	Designation never officially assigned
X-24A	Martin Marietta	USAF, NASA	1969	Low-speed lifting body	
X-24B	Martin Marietta	USAF, NASA	1973	Low-speed lifting body	
X-25	Bensen	USAF	1955	Commercial light autogyro for downed pilots	
X-26 Frigate	Schweizer	DARPA, US Army, USN	1967	Training glider for yaw-roll coupling	Quiet observation aircraft
X-27	Lockheed	None	1971	High-performance fighter	Canceled and never flew.
X-28 Sea Skimmer	Osprey	USN	1970	Low-cost aerial policing seaplane	
X-29	Grumman	DARPA, USAF, NASA	1984	Forward-swept wing	
X-30 NASP	Rockwell	NASA, DARPA, USAF	1993	Single stage to orbit spaceplane	Canceled and never built
X-31	Rockwell-MBB	DARPA, USAF, BdV	1990	Thrust vectoring supermaneuverability	
X-32A	Boeing	USAF, USN, USMC, RAF	2000	Joint Strike Fighter	
X-32B	Boeing	USAF, USN, RAF	2001	Joint Strike Fighter	
X-33	Lockheed Martin	NASA	2001	Half-scale reusable launch	Prototype never completed vehicle prototype

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Bell X-2 Starbuster

The Bell X-2 was a rocket-powered, swept-wing research aircraft designed to investigate the structural effects of aerodynamic heating as well as stability and control effectiveness at high speeds and altitudes.

The program was developed jointly in 1945 by Bell Aircraft Corporation, the U.S. Air Force, and the National Advisory Committee for Aeronautics to explore aerodynamic problems of supersonic flight and to expand the speed and altitude regimes obtained with the earlier X-1 series of research aircraft.

In 1946, the NACA Pilotless Aircraft Research Division (PARD) began testing rocket-launched X-2 models at Wallops Island, Va., to gather stability and control data. Additional tests helped NACA and Bell engineers design a pilot escape system for the X-2. The NACA made its spin tunnel and supersonic wind-tunnels at the Langley Memorial Aeronautical Laboratory, Hampton, Va., available to evaluate various aspects of the X-2 design. The NACA was also responsible for scientific instrumentation of the X-2.

Two X-2 airframes, nicknamed "Starbuster," were built at Bell's plant in Wheatfield, N.Y., using stainless steel and K-monel (a copper-nickel alloy). The vehicles were designed to employ a two-chamber Curtiss-Wright XLR25 throttleable liquid-fueled rocket engine. It had a variable thrust rating from 2,500 to 15,000 pounds.

The X-2 was equipped with an escape capsule for the pilot. In an emergency, the entire nose assembly would jettison and deploy a stabilizing parachute. Once at a safe altitude, the pilot would then manually open the canopy and bail out. Although the Air Force approved the final escape system design, NACA representatives were concerned that it might prove dangerous to use.

A Boeing B-50A bomber was modified to carry the X-2 to launch altitudes around 30,000 feet. The pilot then climbed into the X-2, dropped away from the bomber, and ignited the engines if it was a planned powered flight. After engine burnout, the pilot guided the X-2 to an unpowered landing on the surface of Rogers Dry Lake at Edwards Air Force Base, Calif.

Because of a decision to install the first available engine in airframe 46-674, airframe 46-675 was delivered to Edwards first for glide tests. It arrived at Edwards on April 22, 1952. After two captive flights, Bell test pilot Jean L. "Skip" Ziegler made the first glide flight on June 27. A rough landing caused some damage to the aircraft and the second glide flight was delayed until Oct. 8. Two days later, Air Force test pilot Maj. Frank K. "Pete" Everest successfully completed the third glide flight of the X-2.

NASA photograph

This 1952 photograph shows the X-2 #2 aircraft mounted on a special transportation dolly at Edwards Air Force Base, Calif.

Following the unpowered tests, the X-2 was returned to Bell's plant in New York. The engine had not yet been installed in the first X-2, 46-674, so it was installed in the second shortly after it returned to Wheatfield. Captive flights with the new engine were carried out over Lake Ontario.

During a flight to check the liquid oxygen system, an explosion resulted in the loss of the X-2 and severe damage to the B-50. Skip Ziegler and B-50 crew member Frank Wolko were both killed. The X-2 fell into Lake Ontario and was not recovered. The B-50A was damaged beyond economic repair and was subsequently replaced with a modified B-50D.

The following day, it began its journey to Edwards beneath the B-50D. The aircraft arrived on July 15 and technicians at the NACA High Speed Flight Station began to install instrumentation to gather handling qualities data. On the advice on the NACA, the Air Force purchased a Goodyear Electronic Digital Analyzer analog computer. Richard E. Day, NACA project engineer for the X-2, programmed the GEDA and turned it into a rudimentary flight simulator for the aircraft.

On Aug. 5, 1954, the X-2 was carried aloft for another captive flight beneath the B-50. Later that day, the X-2 was carried aloft for a second time and released. Pete Everest, now a lieutenant colonel, made a successful glide flight that ended in a rough landing on the lakebed. The vehicle sustained minor damage and was returned to Wheatfield for repair.

The X-2 returned to Edwards on Jan. 16, 1955, and captive flights resumed on Feb. 5 for propellant system checks. After several captive missions, two more glide flights were accomplished in March and April. Damage to the aircraft during landing required the X-2 to return to New York once again.

The first attempt at a powered flight took place on Oct. 25, 1955, but a nitrogen leak resulted in a decision to change the flight plan. Everest completed the mission as a glide flight. An aborted second attempt ended as a captive flight. Everest finally made the first powered X-2 flight on Nov. 18, igniting only the 5,000-pound-thrust chamber. His maximum speed during the mission was Mach 0.95. Following several aborted attempts, Everest completed a second powered flight on March 24, 1956, this time only igniting the 10,000-pound-thrust rocket chamber.

Both chambers were used for the first supersonic X-2 flight on April 25. The airplane reached a speed of Mach 1.40 and a maximum altitude of 50,000 feet. Everest completed three flights in May that pushed the airplane's speed envelope to Mach 2.53. On May 25, 1956, a new pilot was checked out in the X-2, Capt. Iven C. Kincheloe. He made a successful supersonic flight but had to shut the engine down prematurely due to a malfunction.

In June, the airplane was grounded for installation of engine nozzle extensions to improve performance. Everest made a supersonic checkout of the modified X-2 on July 12. Everest's final X-2 flight,

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STARBUSTER, FROM 4

on July 23, 1956, earned him the title "Fastest Man Alive." While gathering data on aerodynamic heating, Everest achieved a speed of Mach 2.87 at 68,000 feet.

Kincheloe now assumed the role of X-2 project pilot for a series of high-altitude missions. After two aborted flight attempts, he successfully accomplished a climb to 87,750 feet while gathering stability data on Aug. 3, 1956. That same day, NACA director Hugh L. Dryden requested that the Air Force loan the X-2 to the NACA for research purposes. The Air Force continued to fly the airplane while attempting to achieve its maximum altitude capability.


NASA photograph

This 1952 photograph shows the X-2 with a collapsed nose landing gear, after landing on the first glide flight at Edwards Air Force Base.


NASA photograph

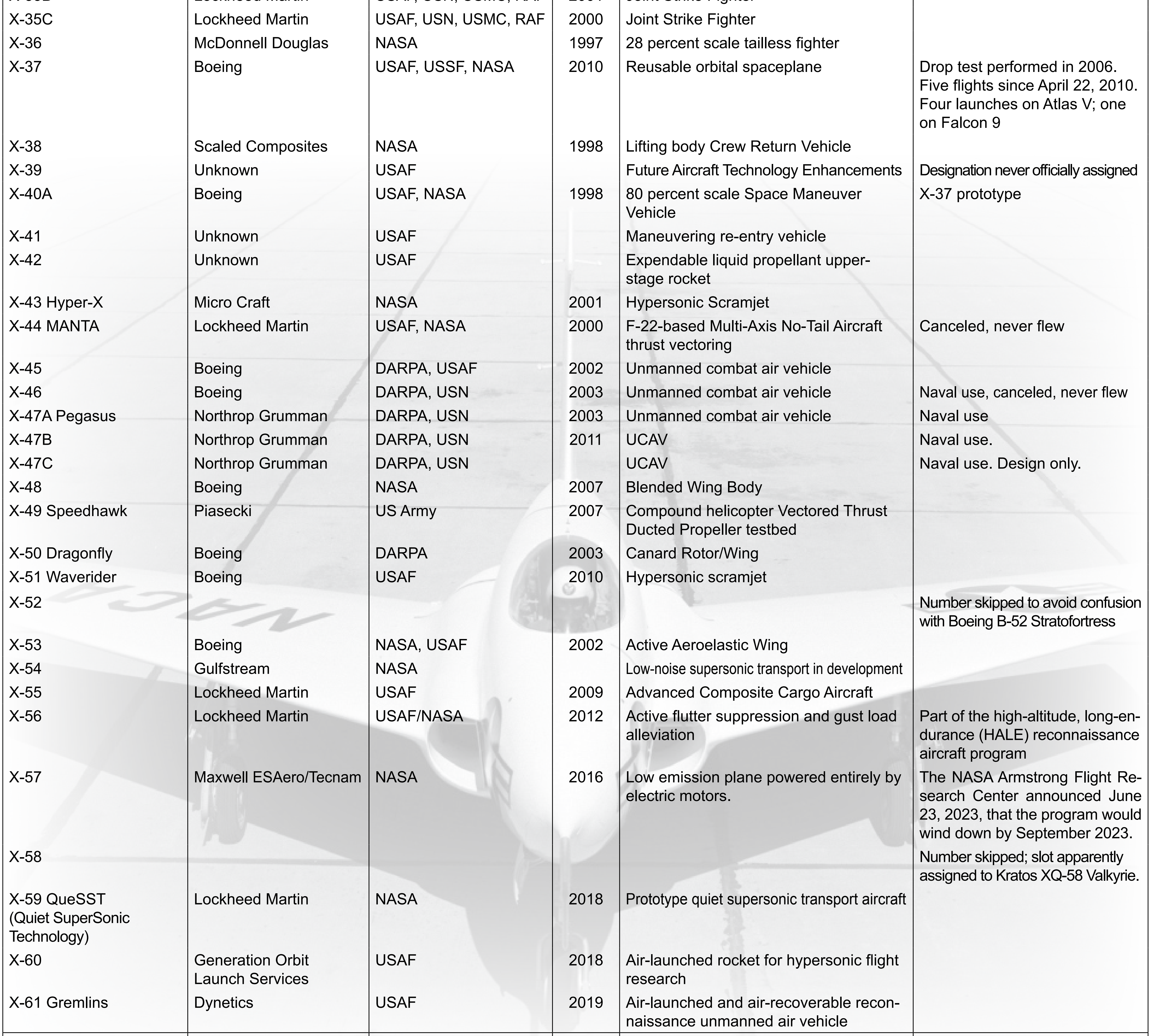
The X-2 (46-674) drops away from its Boeing B-50 mothership. Lt. Col. Frank "Pete" Everest piloted 674 on its first unpowered flight on Aug. 5, 1954.

While a flight on Aug. 8, failed to exceed 70,000 feet, another attempt on Sept. 7 reached an altitude of 126,200 feet. This earned Kincheloe the title "First of the Spacemen" and a record that stood until the advent of the X-15 program. Kincheloe made three additional flight attempts, but each ended in an abort.

The Air Force was due to transfer the X-2 to the NACA in mid-September and preparations were underway. Researchers at the NACA High Speed Flight Station were anxious to use the X-2 for heating investigations in the Mach 2 to Mach 3 range and study handling characteristics at extreme altitudes and speeds. The Air Force, however, asked for an extension of their program so that another pilot could be checked out. As Capt. Milburn G. "Mel" Apt practiced simulated missions on the GEDA, representatives from the Air Force, the NACA, and Bell agreed on a flight plan.

On Sept. 27, 1956, Apt became the first person to fly faster than three times the speed of sound. The engine burned slightly longer than expected and Apt flew a near perfect flight profile, allowing him to reach a speed of 2,094 mph (Mach 3.196). Elation was short-lived. For some reason, Apt initiated a sharp turn back toward Edwards. This resulted in a control divergence known as inertial coupling. The X-2 began to tumble uncontrollably. Apt jettisoned the escape capsule but was unable to extract himself before it struck the ground. Apt's death cast a shadow over the most spectacular achievement of the program.

FROM 3



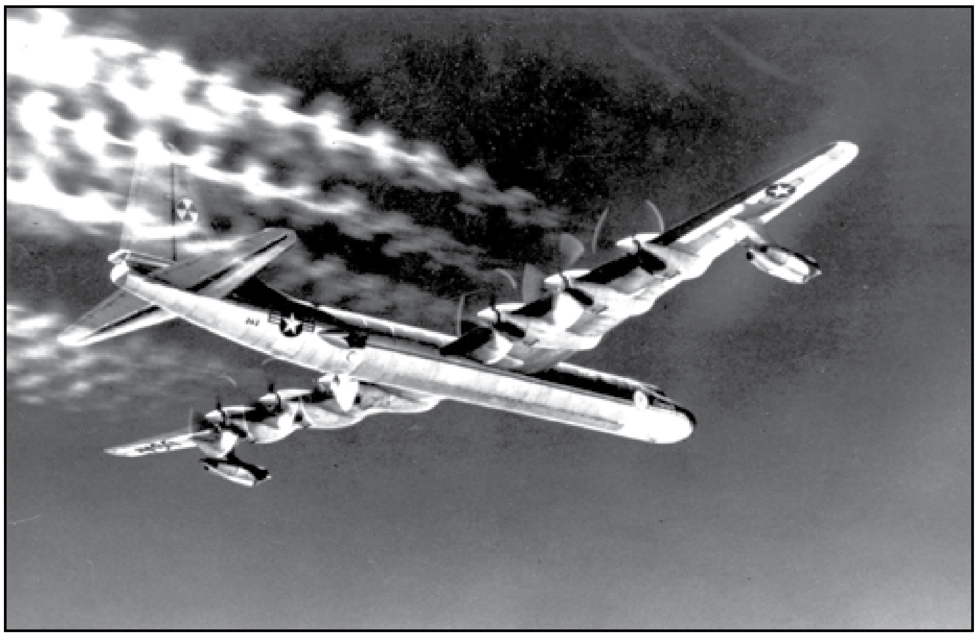
Type	Manufacturer	Agency	Year	Role	Notes
X-34	Orbital Sciences	NASA	2001	Reusable unmanned spaceplane	Never flew
X-35A	Lockheed Martin	USAF, USN, USMC, RAF	2000	Joint Strike Fighter	
X-35B	Lockheed Martin	USAF, USN, USMC, RAF	2001	Joint Strike Fighter	
X-35C	Lockheed Martin	USAF, USN, USMC, RAF	2000	Joint Strike Fighter	
X-36	McDonnell Douglas	NASA	1997	28 percent scale tailless fighter	
X-37	Boeing	USAF, USSF, NASA	2010	Reusable orbital spaceplane	Drop test performed in 2006. Five flights since April 22, 2010. Four launches on Atlas V; one on Falcon 9
X-38	Scaled Composites	NASA	1998	Lifting body Crew Return Vehicle	
X-39	Unknown	USAF		Future Aircraft Technology Enhancements	Designation never officially assigned
X-40A	Boeing	USAF, NASA	1998	80 percent scale Space Maneuver Vehicle	X-37 prototype
X-41	Unknown	USAF		Maneuvering re-entry vehicle	
X-42	Unknown	USAF		Expendable liquid propellant upper-stage rocket	
X-43 Hyper-X	Micro Craft	NASA	2001	Hypersonic Scramjet	
X-44 MANTA	Lockheed Martin	USAF, NASA	2000	F-22-based Multi-Axis No-Tail Aircraft thrust vectoring	Canceled, never flew
X-45	Boeing	DARPA, USAF	2002	Unmanned combat air vehicle	
X-46	Boeing	DARPA, USN	2003	Unmanned combat air vehicle	Naval use, canceled, never flew
X-47A Pegasus	Northrop Grumman	DARPA, USN	2003	Unmanned combat air vehicle	Naval use
X-47B	Northrop Grumman	DARPA, USN	2011	UCAV	Naval use.
X-47C	Northrop Grumman	DARPA, USN		UCAV	Naval use. Design only.
X-48	Boeing	NASA	2007	Blended Wing Body	
X-49 Speedhawk	Piasecki	US Army	2007	Compound helicopter Vectored Thrust Ducted Propeller testbed	
X-50 Dragonfly	Boeing	DARPA	2003	Canard Rotor/Wing	
X-51 Waverider	Boeing	USAF	2010	Hypersonic scramjet	
X-52					Number skipped to avoid confusion with Boeing B-52 Stratofortress
X-53	Boeing	NASA, USAF	2002	Active Aeroelastic Wing	
X-54	Gulfstream	NASA		Low-noise supersonic transport in development	
X-55	Lockheed Martin	USAF	2009	Advanced Composite Cargo Aircraft	
X-56	Lockheed Martin	USAF/NASA	2012	Active flutter suppression and gust load alleviation	Part of the high-altitude, long-endurance (HALE) reconnaissance aircraft program
X-57	Maxwell ESAero/Tecnam	NASA	2016	Low emission plane powered entirely by electric motors.	The NASA Armstrong Flight Research Center announced June 23, 2023, that the program would wind down by September 2023.
X-58					Number skipped; slot apparently assigned to Kratos XQ-58 Valkyrie.
X-59 QueSST (Quiet SuperSonic Technology)	Lockheed Martin	NASA	2018	Prototype quiet supersonic transport aircraft	
X-60	Generation Orbit Launch Services	USAF	2018	Air-launched rocket for hypersonic flight research	
X-61 Gremlins	Dynetics	USAF	2019	Air-launched and air-recoverable reconnaissance unmanned air vehicle	
X-62 VISTA	Lockheed Martin/Calspan	USAF	2021	Variable In-flight Simulator Test Aircraft	First flew in 1993 as the NF-16D (for the MATV program). Designated the X-62A during a major research system upgrade in 2021. Assigned to the USAF Test Pilot School.
X-63/X-64 – Not Assigned					
X-65 CRANE	Aurora Flight Sciences	DARPA 2023		Control of Revolutionary Aircraft with Novel Effectors	
X-66	Boeing	NASA	2023	Transonic Truss-Braced Wing	

Convair X-6 was a proposed nuclear-powered bomber

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 canceled before the actual X-6 and its nuclear reactor engines were completed. The X-6 was part of a larger series of programs, costing $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.

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



Air Force photograph

Nuclear test aircraft

The first modified B-36 was called the Nuclear Test Aircraft), a B-36H-20-CF (Serial Number 51-5712) that had been damaged in a tornado at Carswell AFB, Texas, on Sept. 1, 1952. This plane was redesignated the XB-36H, then the NB-36H and was modified to carry a three megawatt, air-cooled nuclear reactor in its bomb bay. The reactor, named the Aircraft Shield Test Reactor, 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 six-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 Sept. 17, 1955, and March 1957, over New Mexico and Texas. This was the only known airborne reactor experiment by the United States 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.

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 (J47 engines modified to use nuclear energy as fuel), 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 feet wide hangar was built at Test Area North, part of the National Reactor Testing Station (now part of the Idaho National Laboratory; Monteview) to house the X-6 project, but the project was cancelled before the planned 15,000 feet runway was built, necessitated by the expected weight of the nuclear-powered aircraft.

Soviet program

In the 1960s, the Soviet Union's Tupolev design bureau had its own design for an experimental nuclear-powered aircraft, the Tupolev Tu-119, which was a Tu-95 bomber with two of its conventional turboprops replaced by nuclear-powered turboprops.

SM-65A Atlas

In October 1945, the U.S. Army issued supersonic missile requirements to the industries which received military missiles technical papers from Nazi Germany. In 1946, Convair submitted several proposals and received funding for the MX-774 rocket study. In 1949, Soviet detonated its first nuclear weapon, U.S. Air Force gave highest priority to Convair to develop a more conventional long-range nuclear armed missile. Convair suggested a series of test articles, 16 single-stage test-beds that designated X-11 (later changed to Atlas A), and 13 one-and-one-half stage prototypes which designated X-12 (later changed to Atlas B, then XB-65 as a bomber category, and then XSM-16 as the strategic missile).

The first launch of the Atlas A was in 1957, five failures from eight launches. The first launch of the Atlas B was in 1958, four failures from 10 launches. In 1959, Atlas D (CGM-16D) ICBM was officially declared operational and taken over by the Strategic Air Command. It entered the U.S. Air Force first ICBM squadron and was used as space launcher until 1967.

The Convair SM-65A Atlas, or Atlas A was the first full-scale prototype of the Atlas missile, which first flew on June 11, 1957. Unlike later versions of the Atlas missile, the Atlas A did not feature the stage and a half design. Instead, the booster engines were fixed in place, and the sustainer engine was omitted. The propulsion system used on the initial Atlas As was an early version of the Rocketdyne MA-1 engines with conical thrust chambers that produced a mere 135,000 pounds of thrust, compared with the 360,000 pounds of the fully operational Atlas D.

Several pieces of hardware found on the operational Atlas were either missing on the A-series or only partially implemented. Powered flight on the A-series would last about two minutes and compared to later Atlases, long pad hold-down times, with up to 11 seconds between engine start and launcher release.

The first three Atlases built were used merely for static firing tests with Missile 4A being the first flight article. It was delivered to Cape Canaveral in December 1956 and erected on LC-14 in March 1957, where it sat until the following summer.

Test history

On June 11, 1957, the Atlas made its maiden voyage. The engine start proceeded normally, and the launcher release system also functioned properly. All went well until T+26 seconds when the B-2 engine lost thrust, followed two seconds later by the B-1 engine. The Atlas reached a peak altitude of 9,800 feet and tumbled end-over-end through its own exhaust trail until T+50 seconds when the range safety officer sent the destruct command.

During 4A’s launch, thousands of spectators lined the beaches around Cape Canaveral to watch, although the Air Force did not confirm that the new missile was in fact an Atlas. The sensational press reports of the missile cartwheeling and exploding in mid-air belied the fact that program officials did not really consider the test a failure, and that all things considered, the Atlas had performed far better than expected.

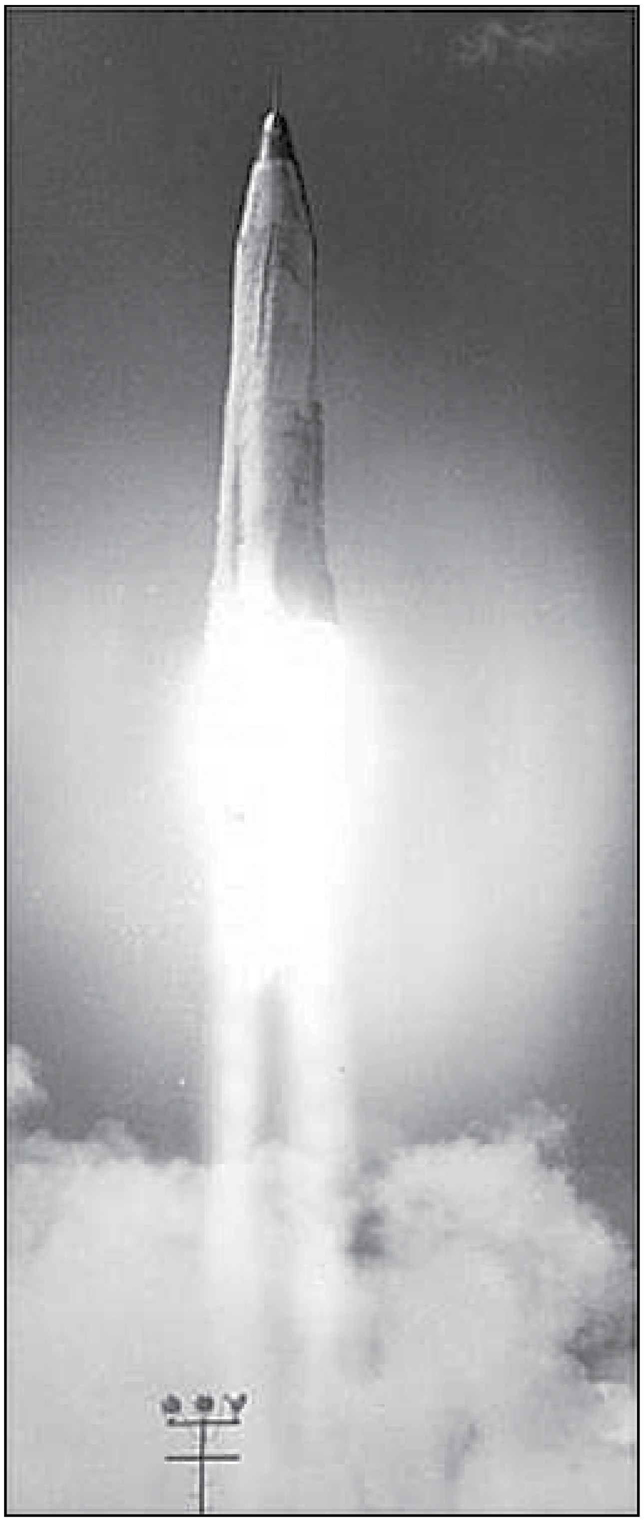
Analysis of telemetry data confirmed that the Atlas had malfunctioned due to hot exhaust gases being recirculated into the thrust section, which apparently caused failure of propellant ducting and engine shutdown due to LOX starvation. The pneumatic system also malfunctioned as tank pressure never properly transitioned to in-flight levels and along with propellant flow and pressure steadily decreased during ascent.

The flight was considered a partial success because the missile had otherwise performed well. In particular, the Atlas’s inflated balloon structure, which engineers doubted would even fly at all, had held together as the missile tumbled. The flight control system also worked well as it tried in vain to correct the missile’s flight path.

Convair engineers decided that the Atlas needed a heat shield in the thrust section more substantial than the thin fiberglass one included on the missile. They proposed a modified heat sink made from steel and fiberglass, but the Air Force rejected that idea as the shield would be extremely heavy and complicate ther booster section staging on operational Atlases. As one small modification, the pneumatic system was modified to vent inert helium gas down into the thrust section to reduce the risk of fire.

On Sept. 25, Missile 6A was launched. Aside from more instrumentation in the thrust section and the above-mentioned helium vent modification, it was identical to 4A and predictably met the same fate as once again, the thrust section overheated. Thrust levels in both engines dropped to only 35% at T+32 seconds and two seconds later, the propulsion system completely shut down.

The Range Safety destruct command was sent at T+63 seconds. This time, overheating and high vibration levels had caused a LOX regulator to fail, resulting in gas generator flameout. After this debacle, the Air Force relented and accepted the need for an improved heat shield. Other modifications were made as well, including removal of the long skirt covering the boattail and engine nozzles.



The Convair XSM-16A (later X-11) was the first testbed for what became the Atlas missile. Later the Convair X-12 became a second, more advanced testbed. A total of 12 X-11’s were built and tested. The first three were involved in static tests only. X-11 Number 4 and 6, were destroyed in launch accidents. All others performed successful test flights. The test series began on June 11, 1957 and ended on June 3, 1958.

The gas generator vent pipe was changed to point outward and away from the missile instead of directly underneath it. The engine nozzles were covered with fiberglass insulation boots and aluminum plumbing in the Atlas changed to steel plumbing which had a greater heat tolerance. The autopilot received additional filters to dampen vibration levels.

The overheating problems had not shown up on the static firing tests of Missiles 1A-3A, but it was later revealed that the engineering crews at the Sycamore test stand had had the plumbing changed to steel because it reduced the risk of overheating compared with the aluminum plumbing on flight article missiles. The PFRF (Pre Flight Readiness Firing) tests conducted on 4A and 6A also would have caused exhaust gases to go up into the boattail, and thus they probably already had internal damage at launch.

On Dec. 17, Missile 12A lifted from LC-14. The modified boattail worked; the Atlas performed well on its first successful launch, an event that raised morale after the devastating blow of two Soviet space launches and the failure of Vanguard a week earlier. This was the first Atlas with a functional guidance system (although open loop — the guidance system was included merely for evaluation purposes and not actually added to the flight program until the B-series tests), as Missiles 4A and 6A merely had a dummy guidance receiver that test patterns were transmitted to.

At T+75 seconds, the guidance system tracking beacon shorted, which caused a momentary large drain on the batteries but did not otherwise affect missile performance. The missile’s flight trajectory in the yaw axis by the time of Booster Engine Cutoff deviated by about 10,000 feet (3050 meters) from the planned program, studies of trajectory data showed this anomaly to be nearly constant during powered flight.

It was concluded that there had been an incorrect offset in the yaw axis, either from a misaligned engine, yaw gyro, or some combination of both. After the success of the launch, the Air Force acknowledged for the first time that the missile was in fact an Atlas.

The fourth Atlas test involved Missile 10A, which was erected on LC-12 in September and would have been the third Atlas launched, but there were considerable difficulties getting it ready for flight. After the post flight findings from 6A, it was taken down for modifications and a PFRF firing on Dec. 10 resulted in the B-1 thrust chamber rupturing from rough combustion.

The thrust chamber was replaced, and a launch attempt was made on Dec. 16, but had to be aborted following a leak in the B-1 main fuel valve. A second launch attempt on Jan. 7, 1958, failed due to another fuel valve leak, and finally on January 10, the missile was launched. 10A performed an almost perfect flight, with no abnormalities of note occurring. This was also the first Atlas with functioning vernier engines, although they were not attached to the autopilot loop.

On Feb. 7, Missile 13A was launched from LC-14. The engines switched to an improved variant of the MA-1 system with bell-shaped thrust chambers and 150,000 pounds of thrust, also the verniers were added to the autopilot loop for the first time. The APS (Auxiliary Power System) ceased operating at liftoff due to improper disconnect of a pad umbilical. At T+108 seconds, the engines started oscillating in all three axes and the propulsion system quickly shut down due to propellant starvation caused by missile tumbling. The Atlas broke up at T+163 seconds.

The failure was attributed to a short in the vernier engine feedback transducer which caused the unexpected engine oscillation. Flight data also confirmed that the B-2 turbopump had disintegrated due to loss of lubricant oil pressure. The lube oil manifold pressure had dropped rapidly at T+16 seconds and remained steady at 460 psi until a pressure surge and then drop off at T+106 seconds. The turbopump broke apart at T+116 seconds due to a bearing failure, but the propulsion system already shut down due to missile tumbling so it ultimately had no effect on the outcome of the flight.

Missile 11A was launched from LC-12 on Feb. 20. This was the first flight where a roll program was added to the autopilot. Once again, the vernier feedback transducer shorted, leading to complete loss of control at T+103 seconds. The booster engines shut down due to missile tumbling and breakup of the Atlas occurred at T+126 seconds. The V-2 vernier shut down at T+109 seconds due to an apparent LOX duct rupture, while the V-1 vernier operated until final missile destruction.

Missile 15A was launched on April 5, following two aborted launch attempts on March 28 and April 1, the latter being called off when the V-2 vernier exploded at ignition. Because aerodynamic heating was believed to have caused the electrical malfunctions on 13A and 11A, more insulation and resistors were added around the vernier wiring and the fairing around the engine nozzles extended.

The flight was uneventful until T+96 seconds when a momentary drop in B-1 thrust occurred. Total engine shutdown occurred at T+105 seconds and the Atlas fell into the Atlantic Ocean, remaining structurally intact until impact. Postflight analysis concluded that a bearing in the LOX turbopump gearbox had come loose, resulting in shutdown of the pump and loss of thrust.

The Atlas A program concluded with the flight of 16A on June 3, which mostly completed its mission objectives, although several hardware malfunctions occurred. An improperly adjusted LOX regulator resulted in slightly below normal booster engine thrust.

The pneumatic system experienced difficulties and helium bottle pressure was nearly down to zero at BECO. This was thought to be caused by a valve sticking open that allowed helium to enter the LOX tank uncontrollably, although the boil-off valve operated correctly and opened to vent the tank and prevent excessive pressure buildup.

The V-1 vernier failed to start due to a leak resulting in loss of the start tank fuel supply. Telemetry data for the propellant utilization system was erratic or nonexistent for most of the flight, and the guidance tracking beacon failed at T+69 seconds; it was thought to have been torn off the missile. The pressure level in the turbopump gearbox was also modified slightly to prevent a recurrence of the malfunctions on 13A and 15A.

The Atlas A conducted eight test flights, of which four were successful. All launches were conducted from Cape Canaveral Air Force Station, at either Launch Complex 12 or Launch Complex 14.

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Bell X-14: Experimental VTOL aircraft

The Bell X-14 (Bell Type 68) was an experimental VTOL aircraft flown n the United States in the 1950s. The main objective of the project was to demonstrate vectored thrust horizontal and vertical takeoff, hover, transition to forward flight, and vertical landing.

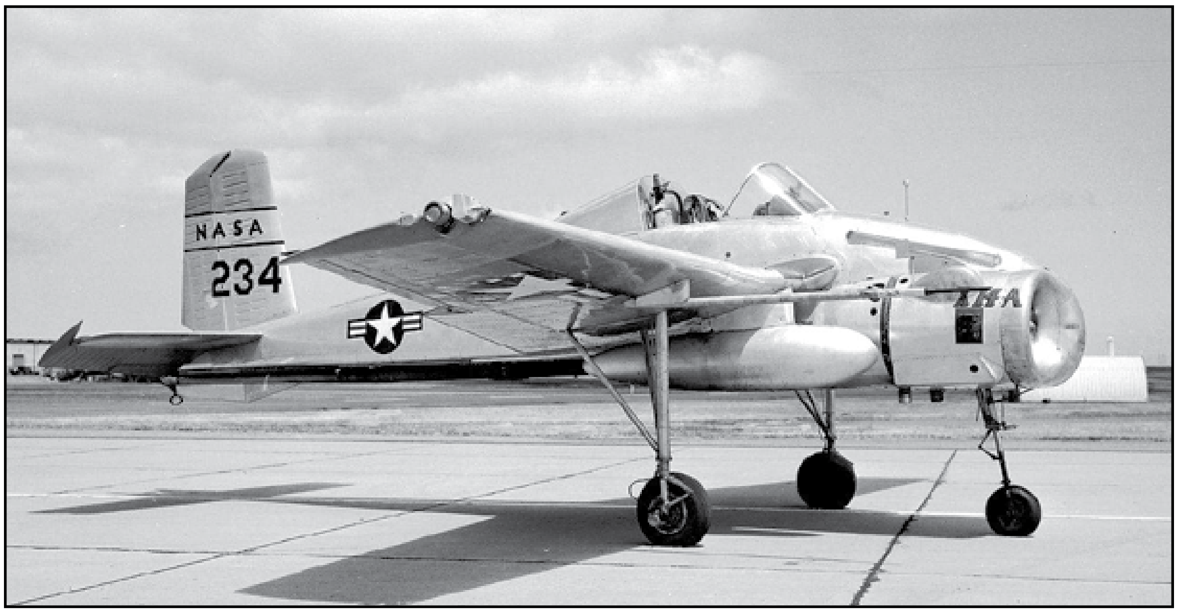
Bell constructed the X-14 as an open-cockpit, all-metal (duralumin) monoplane for the U.S. Air Force. It was powered by two Armstrong Siddeley Viper turbojet engines equipped with thrust deflectors sited at the aircraft's center of gravity. The engines are fixed in position; transition from vertical to horizontal flight is achieved with a system of movable vanes that control the direction of engine thrust.

Top speed was 180 miles per hour with a service ceiling of 20,000 feet. The X-14 was designed using existing parts from two Beechcraft aircraft: wings, ailerons, and landing gear of a Beech Bonanza and the tailcone and empennage of a Beech T-34 Mentor.

The X-14 first flew on Feb. 19, 1957, as a vertical takeoff, hover, then vertical landing. The first transition from hover to horizontal flight occurred on May 24, 1958. In 1959, its Viper engines were replaced with General Electric J85 engines. That year the aircraft was delivered to the NASA Ames Research Center as the X-14A. During the development of the P.1127, Hawker test pilots Bill Bedford and Hugh Merewether visited NASA Ames to fly the X-14 and acquaint themselves with jet V/STOL aircraft handling prior to the first flights of the prototype P.1127. It served as a test aircraft with NASA until 1981.

The X-14 project provided a great deal of data on VTOL (Vertical Take-Off and Landing) type aircraft and flight control systems.

In 1971, the X-14A was fitted with new engines (General Electric J85-GE-19) and redesignated the X-14B. An onboard computer and digital fly-by-wire control system were also installed to enable emulation of landing characteristics of other VTOL aircraft.



The X-14B was used in this test role until it was damaged beyond repair in a landing accident on May 29, 1981. At the time, there were plans to develop an X-14C with an enclosed cockpit. There were also plans for an X-14T trainer. None of these further versions got beyond the planning stage.

During all its years of service, the X-14 was flown by more than 25 pilots with no serious incidents or injuries.

Northrop X-21: Testing laminar flow control

The Northrop X-21A was an experimental aircraft designed to test wings with laminar flow control. It was based on the Douglas WB-66D airframe, with the wing-mounted engines moved to the rear fuselage and making space for air compressors.

The aircraft first flew on April 18, 1963, with NASA test pilot Jack Wells at the controls. Although useful testing was accomplished, the extensive maintenance of the intricate laminar-flow system caused the end of the program.

Laminar-flow control is a technology that offers the potential for significant improvement in drag coefficient which would provide improvements in aircraft fuel usage, range or endurance that far exceed any known single aeronautical technology. In principle, if 80 percent of wing is laminar, then overall drag could be reduced by 25 percent.

The frictional force between the air and the aircraft surface, known as viscous drag, is much larger in a turbulent boundary layer than in a laminar one. The principal type of active laminar-flow control is removal of a small amount of the boundary-layer air by suction through porous materials, multiple narrow surface slots, or small perforations (boundary layer suction).

Two major modifications were required, the first involving the standard underwing podded Allison J71 engines being removed and replaced by a pair of 9,490 lbf static thrust General Electric XJ79-GE-13 non-afterburning turbojets mounted in pods attached to the rear of the fuselage sides. Bleed air from the J79 engines was fed into a pair of underwing fairings, each of which housed a "bleed-burn" turbine which sucked the boundary layer air out through the wing slots.

The X-21A test vehicles (55-0408 and 55-0410) also incorporated sophisticated laminar flow control systems built into a completely new wing of increased span and area, with a sweep reduced from 35 to 30 degrees. The wing had multiple series of span-wise slots (800,000 in total) through which turbulent boundary-layer was "sucked in", resulting in a smoother laminar flow. Theoretically, reduced drag, better fuel economy, and longer range could be achieved.

The forward cockpit carried a pilot and two flight engineers while two additional flight test engineers were housed in a central fuselage bay underneath the wing.

In initial testing there were significant problems with the porous materials and surface slots getting plugged with debris, bugs, and even rain. In certain conditions, ice crystals would form due to the rapid cooling of air over the laminar surfaces. This would abruptly disrupt laminar flow, causing rapid melting and rapid transition back to turbulent flow. Maximum achievement of 95 percent laminar flow over those areas was desired. However, the design effort was canceled due to the plugging problems.

Pioneering data was obtained in the X-21 flight program, including the effects of surface irregularities, boundary-layer turbulence induced by three-dimensional span-wise flow effects in the boundary layer (referred to as span-wise contamination), and degrading environmental effects such as ice crystals in the atmosphere.

Bell X-22: Researching dual tandem-ducted propeller

The X-22A was intended to evaluate a unique dual tandem-ducted propeller configuration for a V/STOL transport aircraft. It was also, from the beginning, designed to provide a highly versatile platform capable of general research on V/STOL handling qualities using a unique variable stability control system.

Takeoff was to selectively occur either with the propellers tilted vertically upwards, or on a short runway with the nacelles tilted forward at approximately 45 degrees.

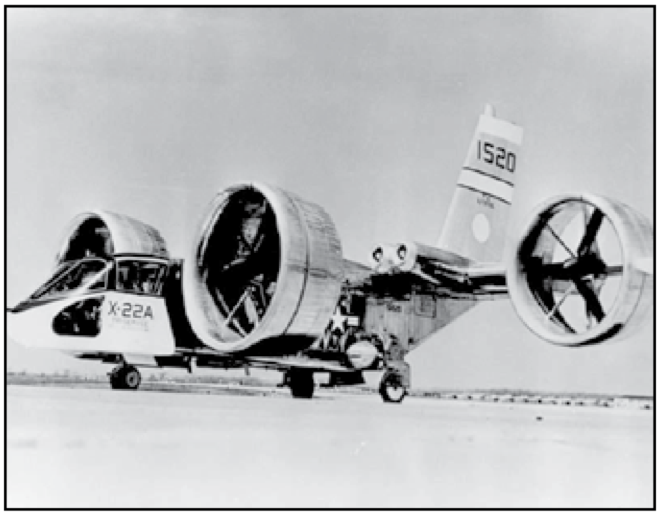
Additionally, the X-22 was to provide more insight into the tactical application of vertical takeoff troop transporters such as the preceding Hiller X-18 and the X-22's successor, the Bell XV-15. Another program requirement was a true airspeed in level flight of at least 326 mph.

The maiden flight of the prototype occurred on March 17, 1966. In contrast to other tilt-rotor craft (such as the Bell XV-3), transitions between hovering and horizontal flight succeeded nearly immediately. However, interest increased more towards VTOL and V/STOL properties, not the specific design of the prototype.

Due to failure of a propeller control, described by test pilot Stanley Kakol as the only non-redundant component in the power chain, the prototype crashed on Aug. 8, 1966, and technicians stripped it for components to make the second prototype flight capable. The fuselage was still used as a simulator for some time afterwards.

The second X-22 first flew on Aug. 26, 1967. Early that year, it was equipped with a variable flight control and stabilizer system from Cornell Aeronautical Laboratory, which improved flight performance.

Although the X-22 was considered the best aircraft of its type at the time, the program was canceled. The required maximum speed of 525 km/h was never reached. The second prototype was moved to Cornell Aeronautical Laboratory for further testing; the last flight occurred in 1988. Although the ducted fan propellers were considered usable, they were not used again on a U.S. military aircraft until the F-35B.



X-28 Sea Skimmer: A single-seat flying boat

The Osprey GP2 Osprey, also known as the Air Skimmer, Sea Skimmer, or Pereira GP2 Osprey, was a single-seat flying boat designed by Eut Tileston under contract to George Pereira, a private builder.

After the release of Pereira’s amphibious Osprey II some years later, this aircraft became known retrospectively as the Osprey I.

The original plane was designed to be water launched only. Initial test flights were performed in the Sacramento Delta. A single example was evaluated by the U.S. Navy as the X-28. Pereira formed Osprey Aircraft to market the plans to homebuilders, including plans for a trailer that allows the pilot to launch and recover the aircraft single-handed.1

The Navy became interested in the project through a Naval Air Development Center study into patrol missions in Southeast Asia. The study required that the aircraft be capable of flight under visual flight rules, be lightweight, cost less than $5,000 dollars, and be able to be manufactured in Southeast Asia.

After examining Pereira’s Osprey in 1971, the Navy purchased the aircraft and commenced testing it as the X-28A in the fall of that year. Although the Osprey met most of the requirements of the program, the program itself was cancelled without any further military examples produced.

Lockheed Martin X-33 Venturestar

The Lockheed Martin X-33 was a proposed uncrewed, sub-scale technology demonstrator suborbital spaceplane that was developed for a period in the 1990s.

The X-33 was a technology demonstrator for the VentureStar orbital spaceplane, which was planned to be a next-generation, commercially operated reusable launch vehicle.

The X-33 would flight-test a range of technologies that NASA believed it needed for single-stage-to-orbit reusable launch vehicles, such as metallic thermal protection systems, composite cryogenic fuel tanks for liquid hydrogen, the aerospike engine, autonomous (uncrewed) flight control, rapid flight turn-around times through streamlined operations, and its lifting body aerodynamics.

Failures of its 21-meter wingspan and multi-lobed, composite-material fuel tank during pressure testing ultimately led to the withdrawal of federal support for the program in early 2001. Lockheed Martin has conducted unrelated testing and has had a single success after a string of failures as recently as 2009 using a 2-meter scale model.

Lokcheed Martin image

An artists' impression of the X-33 in flight.

History

In 1994 NASA initiated the Reusable Launch Vehicle program. After a Phase I program developing proposals from Rockwell International, McDonnell Douglas, and Lockheed Martin, a Phase II contract to develop the X-33 as a demonstrator vehicle was awarded to Lockheed Martin in 1996. At the same time Orbital Sciences was awarded a contract to develop the X-34, an air-launched hypersonic research vehicle.

The goals of the RLV program were:

To "demonstrate technologies leading to a new generation of space boosters capable of delivering payloads at significantly lower cost"

To "provide a technology base for development of advanced commercial launch systems that will make U.S. aerospace manufacturers more competitive in the global market."

$1 billion was spent through 1999 with about 80 percent coming from NASA and additional money contributed by the industry partners. The goal was to have a first flight by March 1999, and to have the VentureStar, the operational resusable space vehicle, flying in 2006.

NASA photograph

The linear aerospike engine is tested at the Stennis Space Center in Mississippi.

Then NASA Administrator Dan Goldin said the goal was to build a vehicle that takes days, not months, to turn around; dozens, not thousands, of people to operate; with launch costs a tenth of what they are now. "Our goal is a reusable launch vehicle that will cut the cost of getting a pound of payload to orbit from $10,000 to $1,000."

The program was cancelled in February 2001.

Construction of the prototype was some 85 percent assembled with 96 percent of the parts and the launch facility 100 percent complete when the program was canceled by NASA in 2001, after a long series of technical difficulties including flight instability and excess weight.

In particular, the composite liquid hydrogen fuel tank failed during testing in November 1999. The tank was constructed of honeycomb composite walls and internal structures to reduce its weight. A lighter tank was needed for the craft to demonstrate necessary technologies for single-stage-to-orbit operations.

A hydrogen-fueled SSTO craft's mass fraction requires that the weight of the vehicle without fuel be 10 percent of the fully fueled weight. This would allow a vehicle to fly to low-Earth orbit without the need for the sort of external boosters and fuel tanks used by the Space Shuttle.

But, after the composite tank failed on the test stand during fueling and pressure tests, NASA concluded that the technology of the time was simply not advanced enough for such a design.

While the composite tank walls themselves were lighter, the hydrogen tank shape necessary to fit inside the aerodynamic moldline resulted in complex joints increasing the total mass of the composite tank to above that of an aluminum-based tank, and too heavy for an SSTO vehicle.

NASA had invested $922 million in the project before cancellation, and Lockheed Martin a further $357 million. Due to changes in the space launch business —including the challenges faced by companies such as Globalstar, Teledesic and Iridium and the resulting drop in the anticipated number of commercial satellite launches per year, Lockheed Martin concluded that continuing development of the X-33 privately without government support would not be profitable.

In 2004 Northrop Grumman successfully built and tested a simple cylindrical composite cryogenic hydrogen tank as part of early work for the Constellation program.

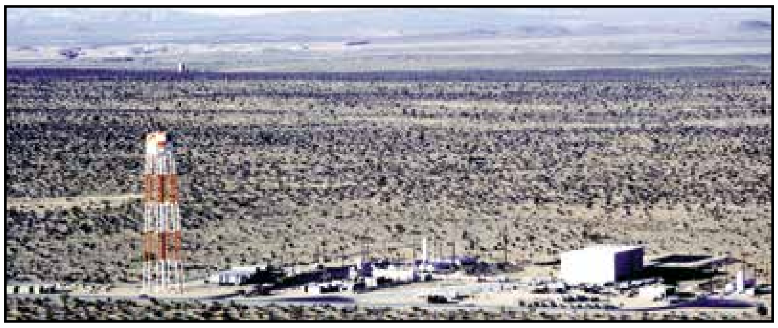
Design and development

Using the lifting body shape, composite multi-lobed liquid fuel tanks, and the aerospike engine, NASA and Lockheed Martin hoped to test fly a craft that would demonstrate the viability of a single-stage-to-orbit design. A spacecraft capable of reaching orbit in a single stage would not require external fuel tanks or boosters to reach low-Earth orbit.

Doing away with the need for "staging" with launch vehicles, such as with the Shuttle and the Apollo rockets, would lead to an inherently more reliable and safer space launch vehicle.

While the X-33 would not approach airplane-like safety, the X-33 would attempt to demonstrate 0.997 reliability, or 3 mishaps out of 1,000 launches, which would be an order of magnitude more reliable than the Space Shuttle. The 15 planned experimental X-33 flights could only begin this statistical evaluation.

The uncrewed craft would have been launched vertically from a specially designed facility constructed at Edwards Air Force Base, Calif., and landed horizontally on a runway at the end of its mission. Initial sub-orbital test flights were planned from Edwards to Dugway Proving Grounds Utah.



Air Force photograph

The X-33 launch facility at Edwards Air Force Base, Calif.

Once those test flights were completed, further flight tests were to be conducted from Edwards to Malmstrom AFB, Mont., to gather more complete data on aircraft heating and engine performance at higher speeds and altitudes.

On July 2, 1996, NASA selected Lockheed Martin Skunk Works in Palmdale, Calif., to design, build, and test the X-33 experimental vehicle for the RLV program. Lockheed Martin's design concept for the X-33 was selected over competing concepts from Rockwell International and McDonnell Douglas. Rockwell proposed a Space Shuttle-derived design, and McDonnell Douglas proposed a design based on its vertical takeoff and landing DC-XA test vehicle.

The uncrewed X-33 was slated to fly 15 suborbital hops to near 75.8 km altitude. It was to be launched upright like a rocket and rather than having a straight flight path it would fly diagonally up for half the flight, reaching extremely high altitudes, and then for the rest of the flight glide back down to a runway.

The X-33 was never intended to fly higher than an altitude of 100 km, nor faster than one-half of orbital velocity. Had any successful tests occurred, extrapolation would have been necessary to apply the results to a proposed orbital vehicle.

The decision to design and build the X-33 grew out of an internal NASA study titled "Access to Space." Unlike other space transport studies, "Access to Space" was to result in the design and construction of a vehicle.

Commercial spaceflight

Based on the X-33 experience shared with NASA, Lockheed Martin hoped to make the business case for a full-scale SSTO RLV, called VentureStar, that would be developed and operated through commercial means. The intention was that rather than operate space transport systems as it has with the Space Shuttle, NASA would instead look to private industry to operate the reusable launch vehicle and NASA would purchase launch services from the commercial launch provider.

Thus, the X-33 was not only about honing space flight technologies, but also about successfully demonstrating the technology required to make a commercial reusable launch vehicle possible.

The VentureStar was to be the first commercial aircraft to fly into space. The VentureStar was intended for long inter-continental flights and supposed to be in service by 2012, but this project was never funded or begun.

Continued research

After the cancellation in 2001, engineers were able to make a working liquid-oxygen tank from carbon-fiber composite. Tests showed that composites were feasible materials for liquid-oxygen tanks.

On Sept. 7, 2004, Northrop Grumman and NASA engineers unveiled a liquid-hydrogen tank made of carbon-fiber composite material that had demonstrated the ability for repeated fuelings and simulated launch cycles.

Northrop Grumman concluded that these successful tests have enabled the development and refinement of new manufacturing processes that will allow the company to build large composite tanks without an autoclave; and design and engineering development of conformal fuel tanks appropriate for use on a single-stage-to-orbit vehicle.

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McDonnell Douglas (later Boeing) X-36

The McDonnell Douglas (later Boeing) X-36 Tailless Fighter Agility Research Aircraft was an American stealthy subscale prototype jet designed to fly without the traditional empennage found on most aircraft. This configuration was designed to reduce weight, drag, and radar cross section, and increase range, maneuverability, and survivability.

The X-36 was built to 28 percent scale of a possible fighter aircraft and was controlled by a pilot in a ground-based virtual cockpit with a view provided by a video camera mounted in the canopy of the aircraft.

For control, a canard forward of the wing was used as well as split ailerons and an advanced thrust vectoring nozzle for directional control. The X-36 was unstable in both pitch and yaw axes, so an advanced digital fly-by-wire control system was used to provide stability.

First flown on May 17, 1997, it made 31 successful research flights. It handled very well, and the program is reported to have met or exceeded all project goals. McDonnell Douglas merged with Boeing in August 1997 while the test program was in progress; the aircraft is sometimes referred to as the Boeing X-36.

The X-36 possessed high maneuverability that would be ideal for use as a fighter. Despite its potential suitability, and highly successful test program, there have been no reports regarding further development of the X-36 or any derived design as of 2017.

Including the design and production of the two aircraft and flight testing, the total budget for the X-36 program was only $17 million.

NASA X-43 hypersonic research aircraft

NASA's X-43A hypersonic research aircraft became the first scramjet-powered aircraft to successfully operate in flight, in 2004.

NASA flew two integrated scramjets (the engine and airframe are necessary for each other to operate) in 2004, the first to a speed just shy of Mach 7, the second to a speed just under Mach 10. The most significant detail about the flights — apart from the successful operation of the engines themselves — was that on the first flight the engine developed enough thrust to overcome drag, and on the second, it developed enough thrust to cruise at Mach 10.

Unlike rockets, which must carry both their fuel and oxidizer, scramjets carry only fuel; they take oxygen from the atmosphere. This reduces weight, raising payload or increasing capability.

The first plane in the series, the X-43A, was a single-use vehicle, of which three were built. The first X-43A was destroyed after malfunctioning in flight in 2001. Each of the other two flew successfully in 2004, setting speed records, with the scramjets operating for approximately 10 seconds followed by 10-minute glides and intentional crashes into the ocean.

The X-43A was designed to be fully controllable in high-speed flight, even when gliding without propulsion. However, the aircraft was not designed to land and be recovered. Test vehicles crashed into the†Pacific Ocean†when the test was over.

The X-43B, was expected to be a full-size vehicle, incorporating a turbine-based combined cycle engine or a rocket-based combined cycle ISTAR engine. Jet turbines or rockets would initially propel the vehicle to supersonic speed. A ramjet might take over starting at Mach 2.5, with the engine converting to a scramjet configuration at approximately Mach 5.

The X-43C would have been somewhat larger than the X-43A and was expected to test the viability of hydrocarbon fuel, possibly with the HyTech engine. While most scramjet designs have used hydrogen for fuel, HyTech runs with conventional kerosene-type hydrocarbon fuels, which are more practical for support of operational vehicles.

The building of a full-scale engine was planned which would use its own fuel for cooling. The engine cooling system would have acted as a chemical reactor by breaking long-chain hydrocarbons into short-chain hydrocarbons for a rapid burn.

NASA photograph

A NASA NB-52 Stratofortress with a X-43 Scramjet (modified Pegasus rocket).

The X-43D would have been almost identical to the X-43A, but expanded the speed envelope to Mach 15. As of September 2007, only a feasibility study had been conducted. According to the introduction of the study, "The purpose of the X-43D is to gather high Mach flight environment and engine operability information which is difficult, if not impossible, to gather on the ground."

NASA image

Artist's concept of X-43A with scramjet attached to the underside.

NASA photograph by Jeff Caplan

A full-scale model of the X-43 plane in Langley's 8-foot, high-temperature wind tunnel.


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General Dynamics X-62 VISTA

The General Dynamics X-62 VISTA (Variable Stability In-flight Simulator Test Aircraft) is an experimental aircraft, derived from the F-16D Fighting Falcon, which was modified as a joint venture between General Dynamics and Calspan for use by the U.S. Air Force.

Originally designated NF-16D, the aircraft was redesignated X-62A on June 14, 2021, as part of an upgrade to a Skyborg, with System for Autonomous Control of Simulation.

X-62A remains on the curriculum of the Air Force Test Pilot School as a practice aircraft for test pilots.

Design and development

The NF-16D VISTA testbed aircraft incorporated a multi-axis thrust vectoring engine nozzle that provides for more active control of the aircraft in a post-stall situation. As a result, the aircraft is supermaneuverable, retaining pitch and yaw control at angles of attack beyond which the traditional control surfaces cannot change attitude.

The NF-16D VISTA is a Block 30 F-16D based on the airframe design of the Israeli Air Force version, which incorporates a dorsal fairing running the length of the fuselage aft of the canopy and a heavyweight landing gear derived from the Block 40 F-16C/D. The fairing houses most of the variable-stability equipment and test instrumentation. The heavyweight gear permits simulation of aircraft with higher landing sink rates than a standard F-16.

The program was notable for the development of Direct Voice Input and the "Virtual HUD," which were both eventually to be incorporated into the cockpit design for the F-35 Lightning II.

The VISTA aircraft is now operated by the U.S. Air Force Test Pilot School and maintained by Calspan at Edwards Air Force Base, Calif. It is regularly used in student curriculum sorties, special academic projects, and flight research.

As part of its upgrades, the VISTA Simulation System was replaced with a newer, upgraded version of the same system, and a System for Autonomous Control of Simulation was added in order to operate X-62A as a Skyborg. One application is as autonomously piloted aircraft, perhaps as robotic wingman to a manned aircraft.

Lockheed Martin photograph

The Variable In-flight Simulator Aircraft (VISTA) flies in the skies over Edwards Air Force Base, Calif., shortly after receiving its new paint scheme in early 2019. The aircraft was resdesignated from NF-16D to the X-62A, June 14, 2021.

Introducing NASA's newest X-Plane: The X-66A

by Rob Margetta
NASA

The world was introduced to a new X-plane on June 12, 2023.

NASA and Boeing announced that the aircraft produced through the agency's Sustainable Flight Demonstrator project has been designated by the U.S. Air Force as the X-66A.

The new X-plane seeks to inform a potential new generation of more sustainable single-aisle aircraft ñ the workhorse of passenger airlines around the world. Working with NASA, Boeing will build, test, and fly a full-scale demonstrator aircraft with extra-long, thin wings stabilized by diagonal struts, known as a Transonic Truss-Braced Wing concept.

"At NASA, our eyes are not just focused on stars but also fixated on the sky. The Sustainable Flight Demonstrator builds on NASA's world-leading efforts in aeronautics as well climate," said NASA Administrator Bill Nelson. "The X-66A will help shape the future of aviation, a new era where aircraft are greener, cleaner, and quieter, and create new possibilities for the flying public and American industry alike."

The X-66A is the first X-plane specifically focused on helping the United States achieve the goal of net-zero aviation greenhouse gas emissions, which was articulated in the White House's U.S. Aviation Climate Action Plan.

"To reach our goal of net zero aviation emissions by 2050, we need transformative aircraft concepts like the ones we're flying on the X-66A," said Bob Pearce, associate administrator for NASA's Aeronautics Research Mission Directorate, who announced the designation at the American Institute of Aeronautics and Astronautics Aviation Forum in San Diego. "With this experimental aircraft, we're aiming high to demonstrate the kinds of energy-saving, emissions-reducing technologies the aviation industry needs."

NASA and Boeing sought the X-plane designation shortly after the agency announced the Sustainable Flight Demonstrator project award earlier this year.

The Air Force confers X-plane status for development programs that set out to create revolutionary experimental aircraft configurations. The designation is for research aircraft. With few exceptions, X-planes are intended to test designs and technologies that can be adopted into other aircraft designs, not serve as prototypes for full production.

"We're incredibly proud of this designation, because it means that the X-66A will be the next in a long line of experimental aircraft used to validate breakthrough designs that have transformed aviation," said Todd Citron, Boeing chief technology officer. He said that with the knowledge gained from "design, construction, and flight-testing, we'll have an opportunity to shape the future of flight and contribute to the decarbonization of aerospace."

For the X-66A, the Air Force provided the designation for an aircraft that validates technologies for a Transonic Truss-Braced Wing configuration that, when combined with other advancements in propulsion systems, materials, and systems architecture, could result in up to 30% less fuel consumption and reduced emissions when compared with today's best-in-class aircraft.

Due to their heavy usage, single-aisle aircraft today account for nearly half of worldwide aviation emissions. Creating designs and technologies for a more sustainable version of this type of aircraft has the potential for profound impact on emissions.

NASA's history with the X-plane designation dates to the 1940s, when its predecessor agency, the National Advisory Committee for Aeronautics (NACA) jointly created an experimental aircraft program with the Air Force and the U.S. Navy. The X-66A is the latest in a long line of NASA X-planes. Additionally, NASA's Armstrong Flight Research Center in Edwards, Calif., has provided technical expertise and support for several additional X-planes.

For the Sustainable Flight Demonstrator, NASA has a Funded Space Act Agreement with Boeing through which the agency will invest $425 million over seven years, while the company and its partners will contribute the remainder of the funding, estimated at about $725 million. NASA also will contribute technical expertise and facilities.

The Sustainable Flight Demonstrator project is an activity under NASA's Integrated Aviation Systems Program and a key element of the agency's Sustainable Flight National Partnership, which focuses on developing new sustainable aviation technologies.

Learn more about the Sustainable Flight Demonstrator at https://go.nasa.gov/3X4t9MD

NASA image

The X-66A is the X-plane specifically aimed at helping the United States achieve the goal of net-zero greenhouse gas emissions by 2050. To build the X-66A, Boeing will work with NASA to modify an MD-90 aircraft, shortening the fuselage and replacing its wings and engines. The resulting demonstrator aircraft will have long, thin wings with engines mounted underneath and a set of aerodynamic trusses for support. The design, which Boeing submitted for NASA's Sustainable Flight Demonstrator project, is known as a Transonic Truss-Braced Wing.

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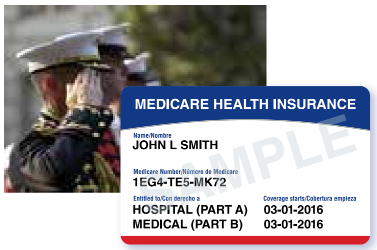

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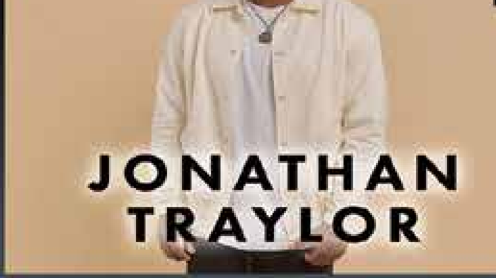
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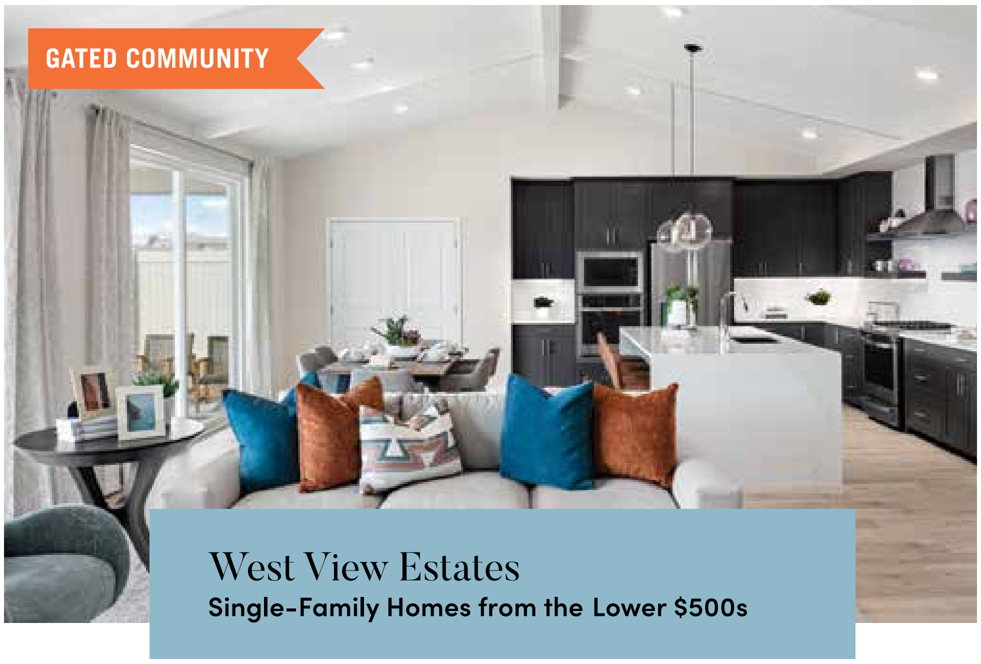

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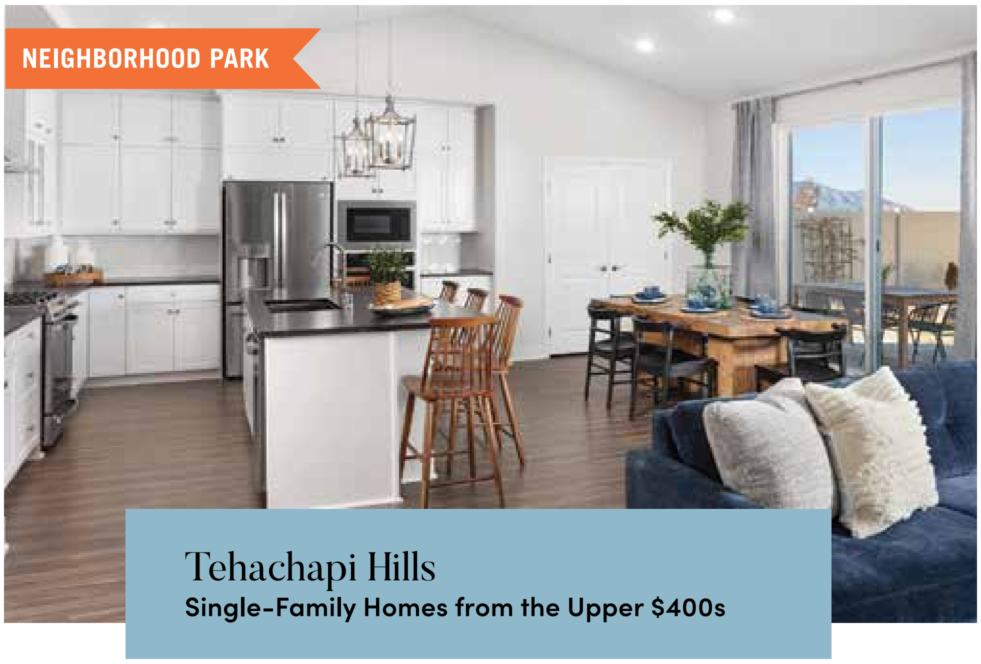

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