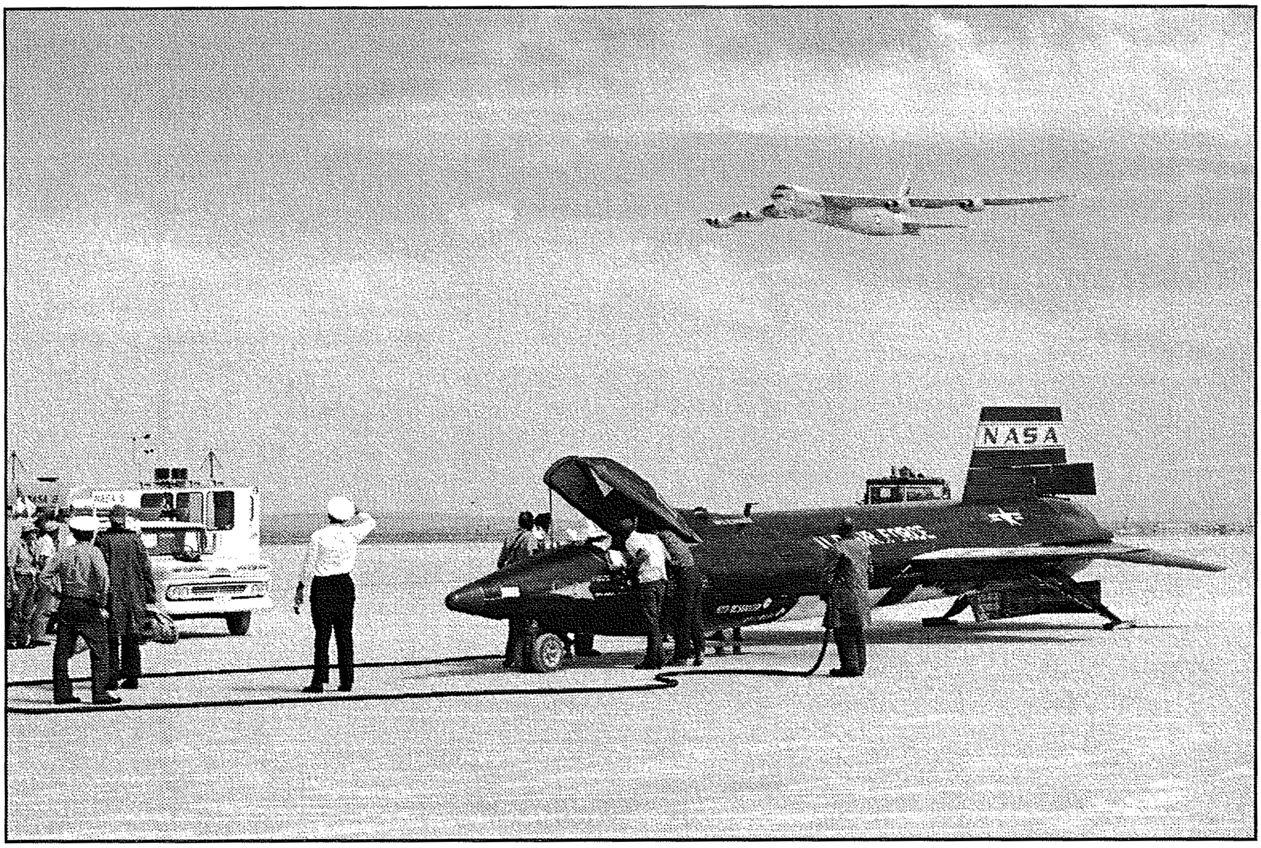
American X-Vehicles

An Inventory — X-1 to X-45



by Jay Miller and Dennis R. Jenkins

Prepared for the AIAA X-Vehicles Symposium
Washington, DC, 16 June 2000

Suggested Further Reading

The X-Planes: X-1 to X-45, by Jay Miller, Midland Counties Publishing, to be published in 2001
At the Edge of Space: The X-15 Flight Program, by Milton O. Thompson, Smithsonian Institution Press, 1992
Hypersonics Before the Shuttle: A Concise History of the X-15, by Dennis R. Jenkins, SP-2000-4518, NASA, 2000
Toward Mach 2: The Douglas D-558 Program, edited by J. D. Hunley, SP-4222, NASA, 1999
Flying Without Wings: NASA Lifting Bodies and the Birth of the Space Shuttle, by Milton O. Thompson and Curtis Peebles, Smithsonian Institution Press, 1999

Front Cover Photo
An NB-52 flies over an X-15 at Edwards AFB in September 1961. (NASA photo EC61-0034)

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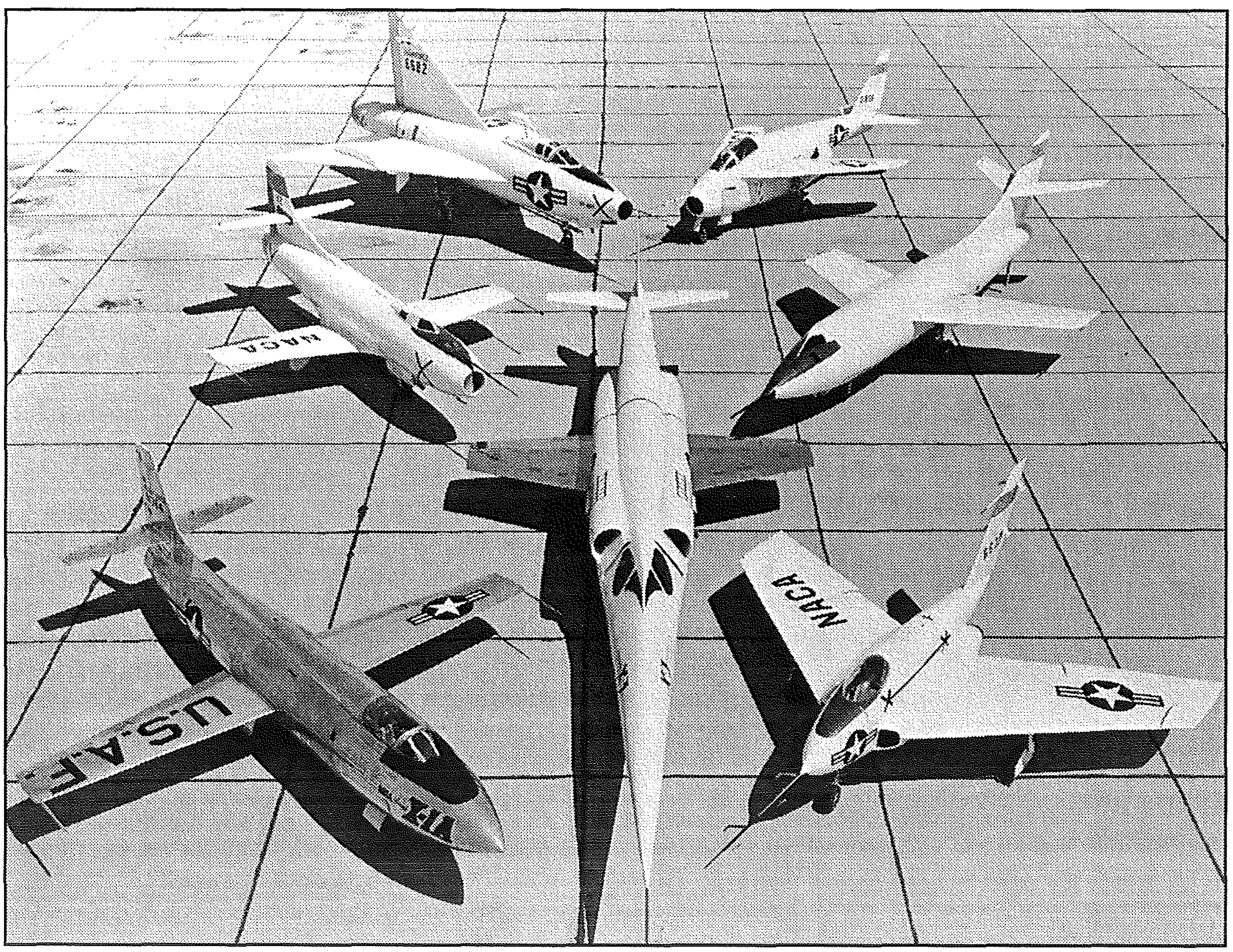
For a while, it seemed the series of experimental aircraft sponsored by the Air Force and the National Aeronautics and Space Administration had run its course. Between the late 1940s and the late 1970s, almost thirty designations had been allocated to aircraft meant to explore new flight regimes or untried technologies. Then, largely, it ended. But there was a resurgence in the mid- to late-1990s, and as we enter the year 2000 the designations are up to X-45.

Many have a misconception that X-Planes have always explored the high-speed and high-altitude flight regimes—something popularized by Chuck Yeager in the original X-1 and the exploits of the twelve men that flew the X-15. Although these flight regimes have always been in the spotlight, many others have been explored by X-Planes. The little Bensen X-25 never exceeded 85 mph, and others were limited to speeds of several hundred mph.

There has been some criticism that the use of X designations has been corrupted somewhat by including what are essentially prototypes of future operational aircraft, especially the two JSF demonstrators. But this is not new—the X-11 and X-12 from the 1950s were going to be prototypes of the Atlas intercontinental ballistic missile, and the still-born Lockheed X-27 was always intended as a prototype of a production aircraft. So although this practice does not represent the best use of X designations, it is not without precedent.

Jay Miller
Arlington, Texas

Dennis R. Jenkins
Cape Canaveral, Florida



The experimental aircraft fleet at the Flight Research Center in 1957. Clockwise from left front: X-1A, D-558-I, XF-91A, X-5, D-558-II, X-4, and the X-3 in the center. (NASA photo E-2889 via the Dennis R. Jenkins Collection)

Bell Aircraft Company

First Generation **X-1**

First Flight:	25 January 1946	**Sponsors:**	USAF, NACA
Last Flight:	23 October 1951	**Fastest Flight:**	Mach 1.45 (960 mph)
Total Flights:	157	**Highest Flight:**	69,000 feet

The second of the three first generation Bell X-1s. Chuck Yeager used the first X-1 to break the sound barrier on 14 October 1947.
(Bell Aircraft via the Jay Miller Collection)

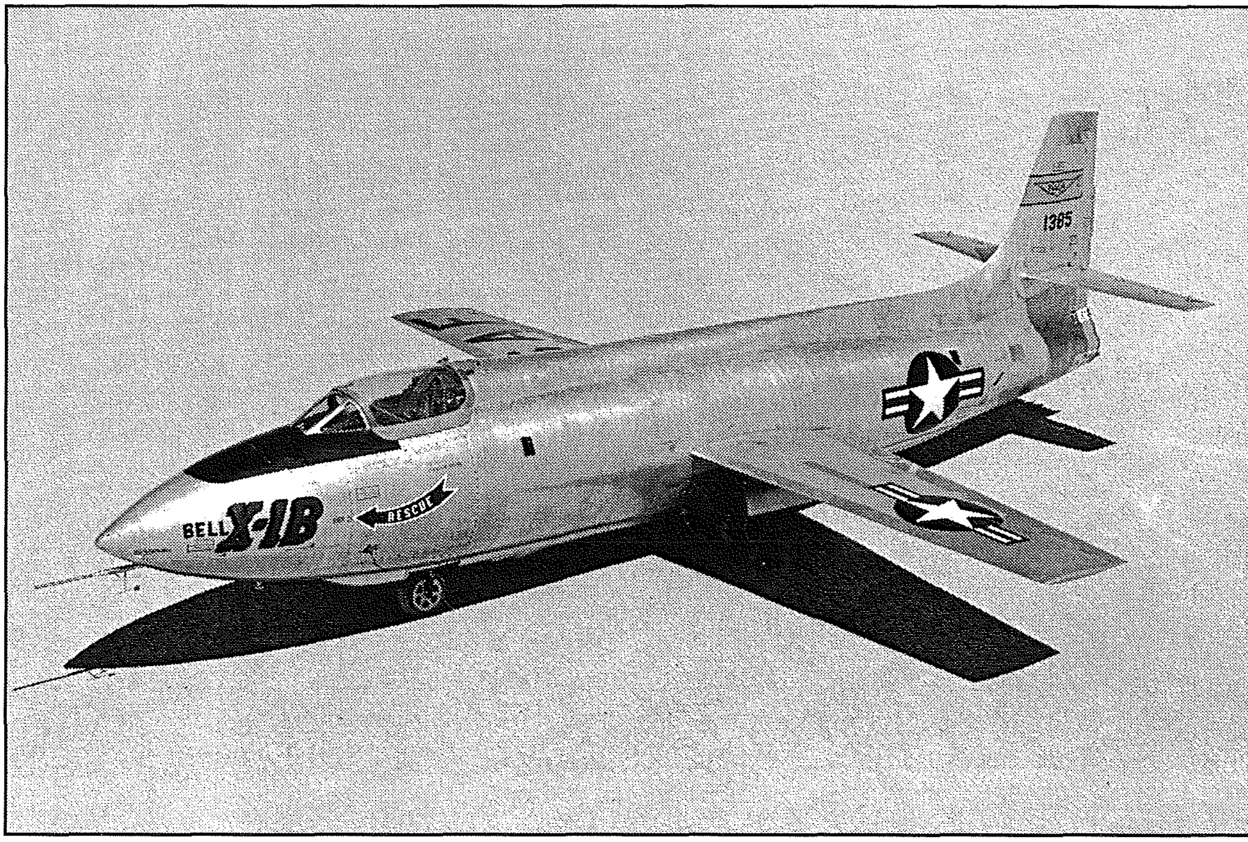
Initially designated the XS-1, (the S, which stood for Supersonic, was dropped early in the program), the X-1 was the first aircraft given an "X" designation, and became the first aircraft to exceed the speed of sound in controlled level flight on 14 October 1947. On this flight, the first X-1 (nicknamed *Glamorous Glennis*) was piloted by Captain Charles (Chuck) Yeager, who achieved 700 mph (Mach 1.06) at approximately 45,000 feet.

Beginning a precedent that survives to this day, the X-1 was air-launched—in this case carried under a Boeing B-29 Superfortress to an altitude of approximately 20,000 feet. The X-1 program was extremely productive, proving much of the technology necessary to produce the first-generation of supersonic combat aircraft. Many structural and aerodynamic advances were pioneered by the first generation X-1s, including extremely thin yet exceptionally strong wing sections, supersonic fuselage configurations, and advanced control system designs.

The first X-1 is on permanent display in the National Air and Space Museum in Washington, DC. The second X-1, configured as the X-1E, is on display in front of the NASA Dryden Flight Research Center. The third X-1 was destroyed on 9 November 1951 at Edwards AFB, California.

X-1 Second Generation — Bell Aircraft Corporation

First Flight:	24 July 1951	**Sponsors:**	USAF, NACA
Last Flight:	23 January 1958	**Fastest Flight:**	Mach 2.44 (1,650 mph)
Total Flights:	54	**Highest Flight:**	90,440 feet



The X-1B was mainly used by the Air Force as a rocket research aircraft trainer, but under NACA auspices had the honor of conducting the last second-generation X-1 flight. (NASA via the Jay Miller Collection)

The second generation X-1s were designed to double the speed of sound and set altitude records in excess of 90,000 feet. Only the X-1A and X-1B were truly productive—the X-1C, which was designed to test high-speed armaments, was cancelled before completion. The X-1D was destroyed during what was to be its first powered flight.

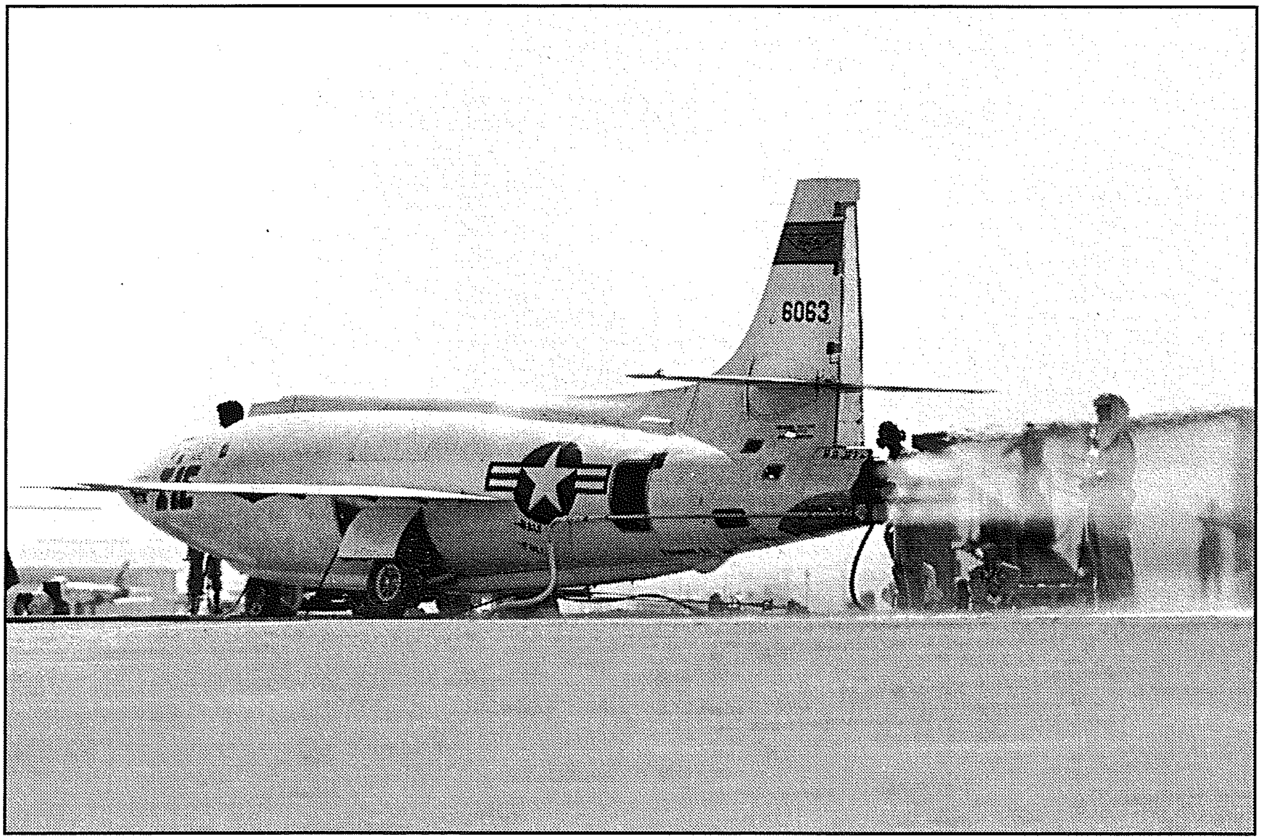
Possibly the most famous flight of the second generation X-1 series occurred on 12 December 1954 with Chuck Yeager at the controls of the X-1A. While flying at Mach 2.44 and 75,000 feet, the aircraft developed a slight left roll. When Yeager attempted to correct the roll, the aircraft snapped to the right and began a violent tumble toward earth. The pilot was rendered unconscious from being tossed about in the cockpit. The aircraft continued out of control until Yeager regained consciousness and managed to recover at approximately 25,000 feet.

The X-1A was destroyed after it was jettisoned following an inflight explosion over Edwards AFB on 8 August 1955. The X-1B is on permanent display at the Air Force Museum in Dayton, Ohio.

Bell Aircraft Corporation

X-1E

First Flight:	12 December 1955	**Sponsors:**	USAF, NACA
Last Flight:	06 November 1958	**Fastest Flight:**	Mach 2.24 (1,450 mph)
Total Flights:	26	**Highest Flight:**	75,000+ feet



The X-1E was modified from the second aircraft in the original first generation X-1 series, and is currently displayed in front of the main building at the Dryden Flight Research Center. (NASA via the Jay Miller Collection)

Despite the loss of the third X-1 and the X-1D, a requirement still existed for a higher performance X-1 for the NACA to continue high-speed research. To satisfy this requirement, the second X-1 was almost completely rebuilt and redesignated the X-1E. Significant modifications include an updated canopy, ultra-thin wings (4 percent thickness/chord ratio), and a rocket assisted ejection seat.

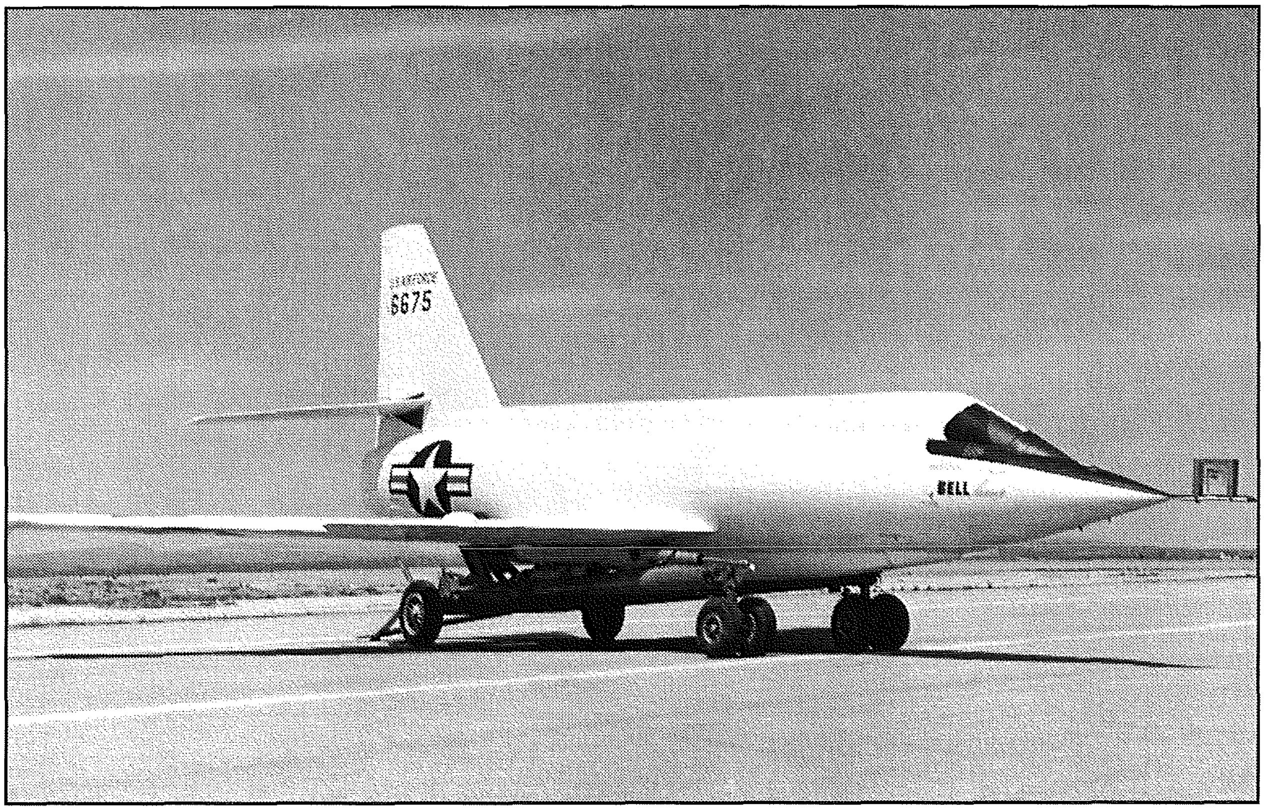
The maximum altitude achieved by the X-1E was over 75,000 feet, and the top speed was Mach 2.24 (1,450 mph). During its test series, the X-1E demonstrated that the thin wing section was technically feasible for use on supersonic aircraft. An improved Reaction Motors XLR11, using a low-pressure turbopump, was also validated during X-1E test flights.

The aircraft was retired from service in November 1956 after 26 flights, and is now on permanent display in front of the NASA Dryden Flight Research Center.

X-2

Bell Aircraft Corporation

First Flight:	27 June 1952	**Sponsors:**	USAF, NACA
Last Flight:	27 September 1956	**Fastest Flight:**	Mach 3.196 (2,094 mph)
Total Flights:	20	**Highest Flight:**	125,907 feet



The X-2 was designed to explore flight at speeds and altitudes far beyond those attainable by the X-1s. The X-2 was originally ordered under the designation XS-2. (NASA via the Jay Miller Collection)

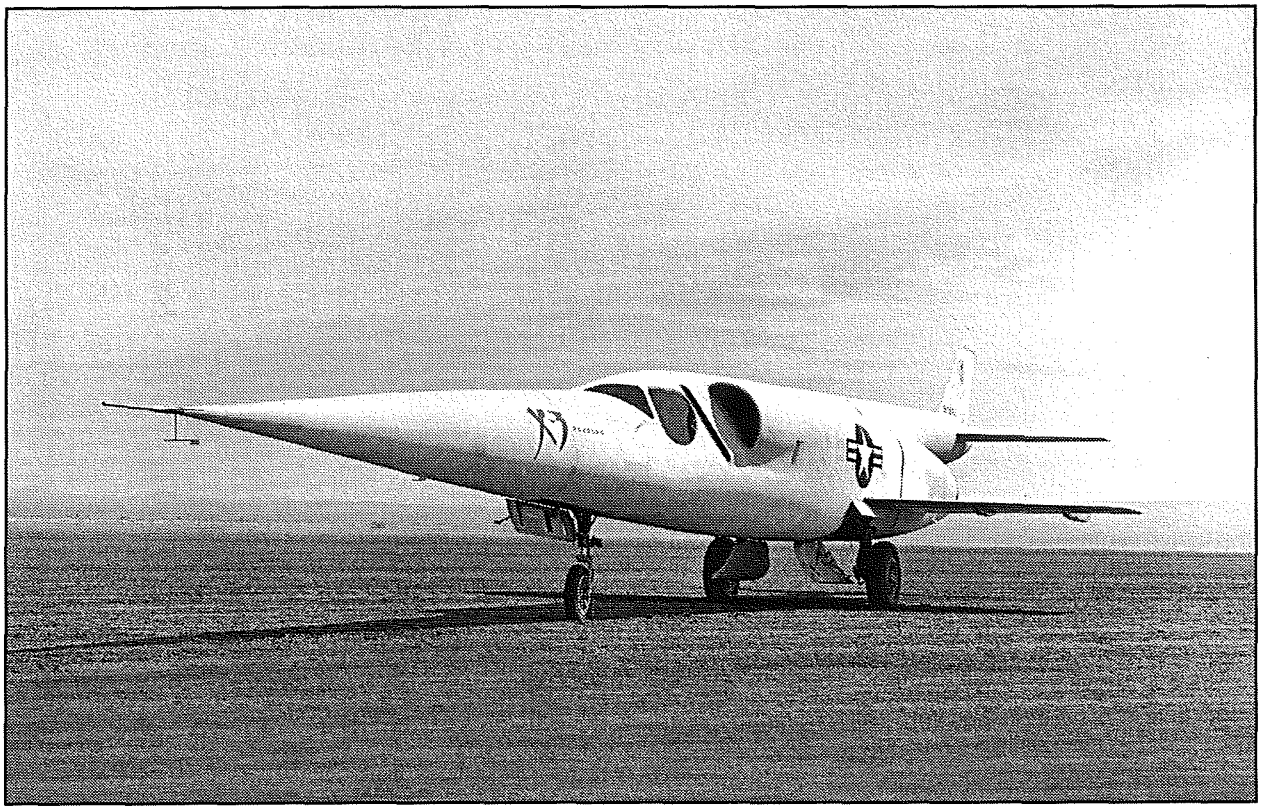
Two X-2s were built by Bell Aircraft at their Niagara Falls, New York, facility. The airframes were composed primarily of stainless steel and "K-Monel," an advanced lightweight heat-resistant steel alloy.

Like the X-1, the X-2 was air launched, this time from a Boeing B-50 bomber. Although plagued with a variety of problems, the X-2 program did produce a number of technological advances that helped pave the way for future high-speed, high-altitude aircraft. Among the most important was the use of high-strength steel alloys in aircraft construction—which gave rise to several innovative construction techniques and the development of specialized tooling. Additionally, the X-2 contributed to the continued understanding of high-Mach aerodynamics.

The first X-2 was dropped into Lake Ontario on 12 May 1953 following an explosion and fire that also caused extensive damage to the EB-50A launch aircraft. The second X-2 was lost in a crash on 27 September 1956 after setting an unofficial world speed record of Mach 3.196. The aircraft experienced "inertia coupling" resulting in complete loss of control—pilot Milburn Apt was killed in the accident. No examples of the X-2 survive.

Douglas Aircraft Company X-3

First Flight:	20 October 1952	**Sponsors:**	USAF, NACA
Last Flight:	23 May 1956	**Fastest Flight:**	0.95 Mach (650 mph)
Total Flights:	51	**Highest Flight:**	35,000+ feet



The X-3 was designed to explore high speed aerodynamic phenomenon at speeds of Mach 2 for periods of not less than 30 minutes. A lack of suitable engines ultimately doomed the aircraft as a research tool. (Gerald Balzer Collection via the Jay Miller Collection)

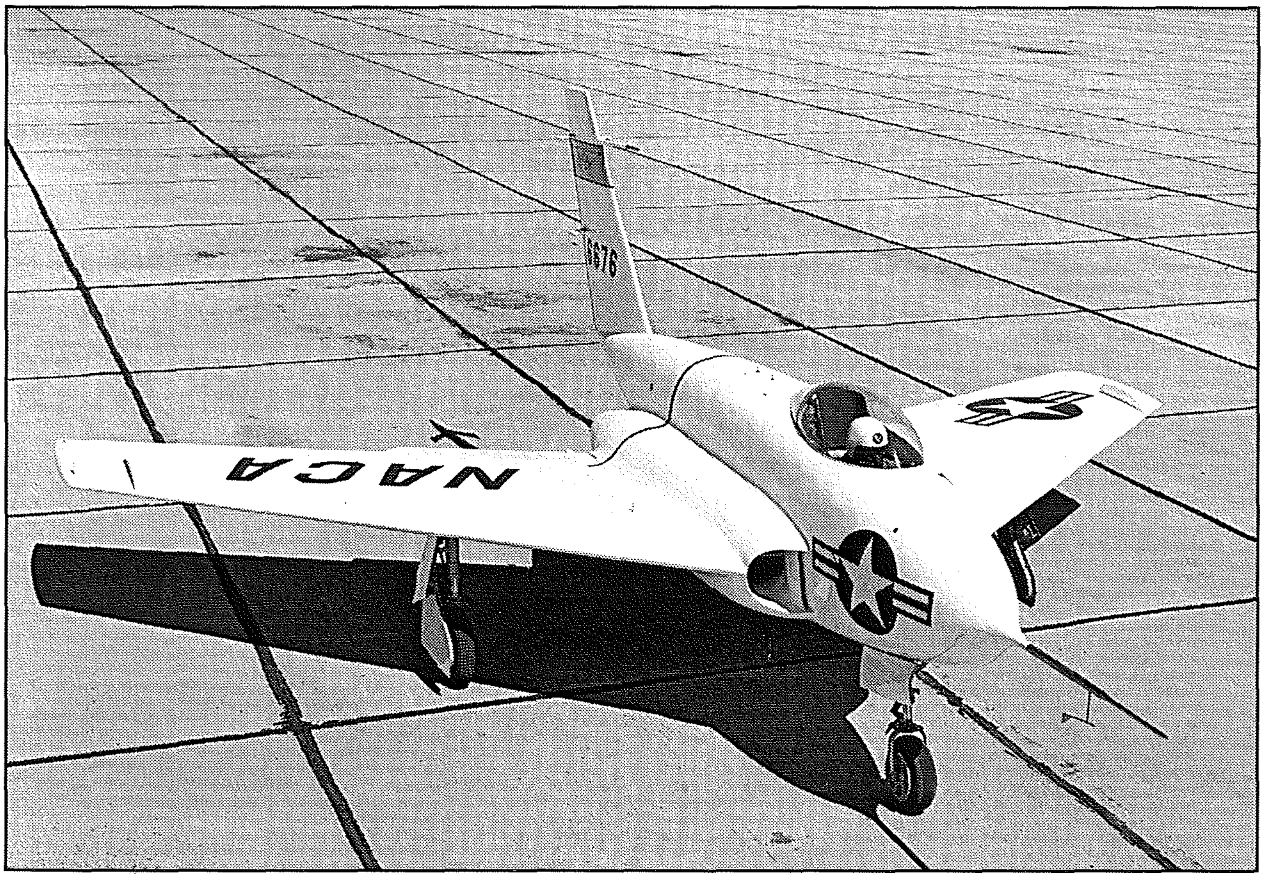
The X-3 Stiletto was a radical departure from the X-1 series and the X-2. Built by Douglas Aircraft, the X-3 was jet powered and used conventional take-off and landing methods, instead of being air launched. Two X-3s were ordered. However, due to limited funding, lack of expected performance, and on-going engine difficulties, only one was completed for flight—the second was used for spare parts.

As a high-speed research aircraft, the X-3 was unquestionably a failure. It did, however, contribute somewhat to the understanding of the roll-coupling phenomenon, and pioneered the short-span low-aspect ratio wing used on several later aircraft. But the X-3's most significant contribution may have been in the field of aircraft landing gear, namely the tires. Because the X-3 had to achieve high speeds to maintain lift, take-off and landing speeds were very high (260 mph for takeoff, 200 mph for landing), and it was common for the tires to come apart. Several aircraft tire manufactures used data gather by the X-3 when developing new tires for high speed applications.

The X-3 is currently on display at the Air Force Museum in Dayton, Ohio.

X-4 Northrop Aircraft Corporation

First Flight:	16 December 1948	**Sponsors:**	USAF, NACA
Last Flight:	September 1953	**Fastest Flight:**	Mach 0.90 (630 mph) (approx)
Total Flights:	102	**Highest Flight:**	42,300 feet (approx)



The X-4 was the first U.S. effort to explore the transonic flight characteristics of tailless aircraft. The aircraft exhibited considerable pitch, roll, and yaw instabilities at approximately Mach 0.88. (Gerald Balzer Collection via the Jay Miller Collection)

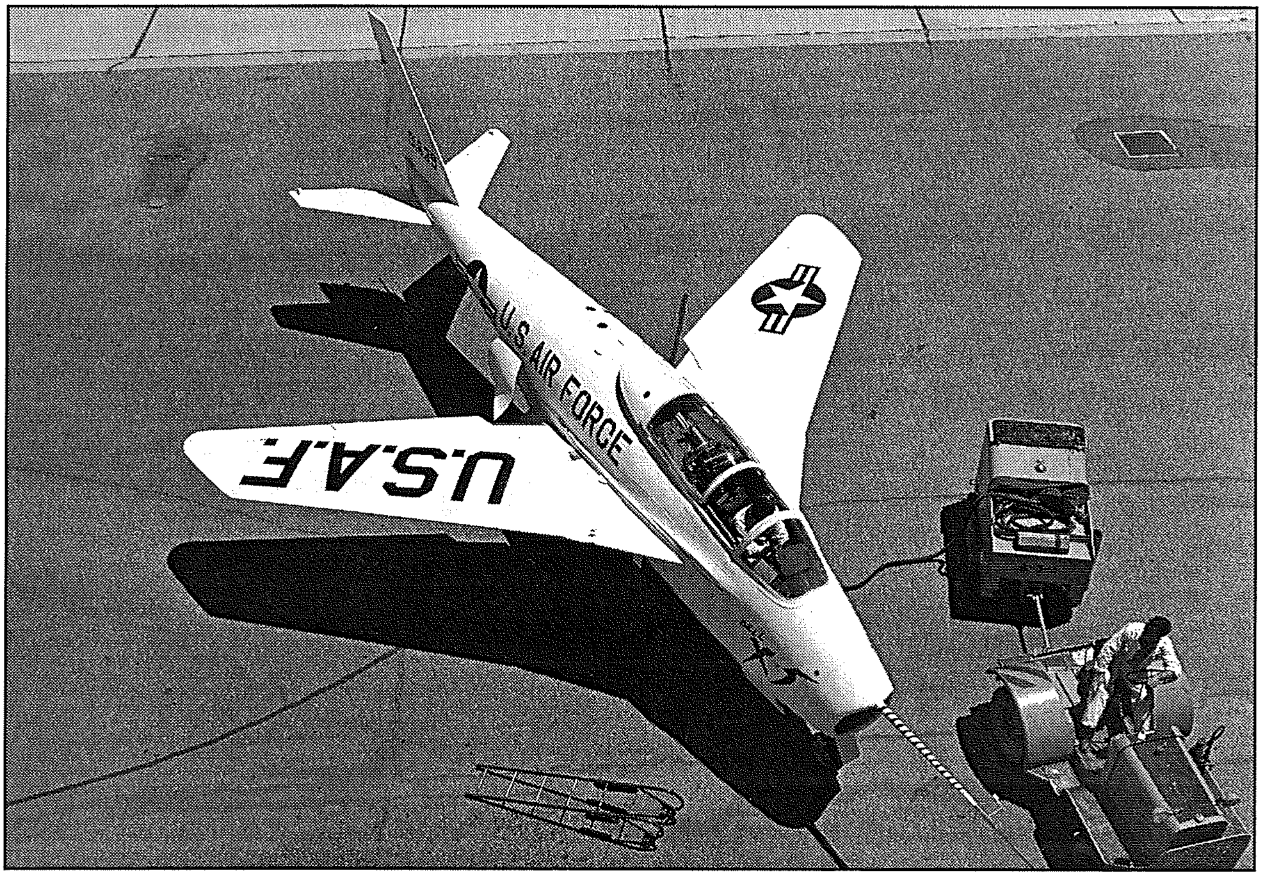
The Northrop X-4 was the first example of an X-Plane intended to research something besides supersonic flight. The jet-powered X-4 was designed to evaluate the characteristics of a tailless aircraft at high subsonic speeds, a configuration believed to hold a great deal of promise for future aircraft.

Although not designed for supersonic speeds, the X-4 nevertheless proved that tailless swept-wing aircraft were not well suited for high transonic or supersonic performance. Pitch, roll, and yaw instabilities were very pronounced at speeds in excess of Mach 0.88, and there was no solution to the problem using the technology available at the time.

It is notable that both aircraft survived the flight test program, and there were no serious accidents during 102 flights. The first X-4 is currently on display at the Air Force Academy in Colorado Springs, Colorado. The second aircraft, after long being displayed at Maxwell AFB, Alabama, is currently at the Air Force Museum.

Bell Aircraft Corporation X-5

First Flight:	20 June 1951	**Sponsors:**	USAF, NACA
Last Flight:	25 October 1955	**Fastest Flight:**	Mach 0.98 (705 mph) (approx)
Total Flights:	149	**Highest Flight:**	42,000 (approx)



The X-5s were the first high-performance variable-geometry wing aircraft to fly. The aircraft exhibited viscous spinning tendencies, but nevertheless accomplished all of the research goals originally envisioned. (Bell Aircraft via the Jay Miller Collection)

The X-5 was largely based on the design of the German Messerschmitt P.1101 which was captured near the end of World War II and brought to the United States for technical review and inspection. Two X-5s were manufactured by Bell, differing from their German ancestor primarily in being able to adjust their wing sweep angle in flight. The variable sweep wing could be adjusted from 20 to 60 degrees.

The first X-5 crashed on 13 October 1953, killing Air Force Major Raymond Popson. The other X-5 went on to a productive flight test career, in spite of the fact that the entire wing had to be translated fore-aft to maintain an acceptable center of gravity while the wing was being swept. The X-5 was the first successful variable-geometry aircraft and provided a great deal of data for programs such as the Grumman XF10F-1 and General Dynamics F-111.

The surviving X-5 was retired from service in 1955, and is now on display at the Air Force Museum in Dayton, Ohio.

X-6 Consolidated-Vultee Aircraft

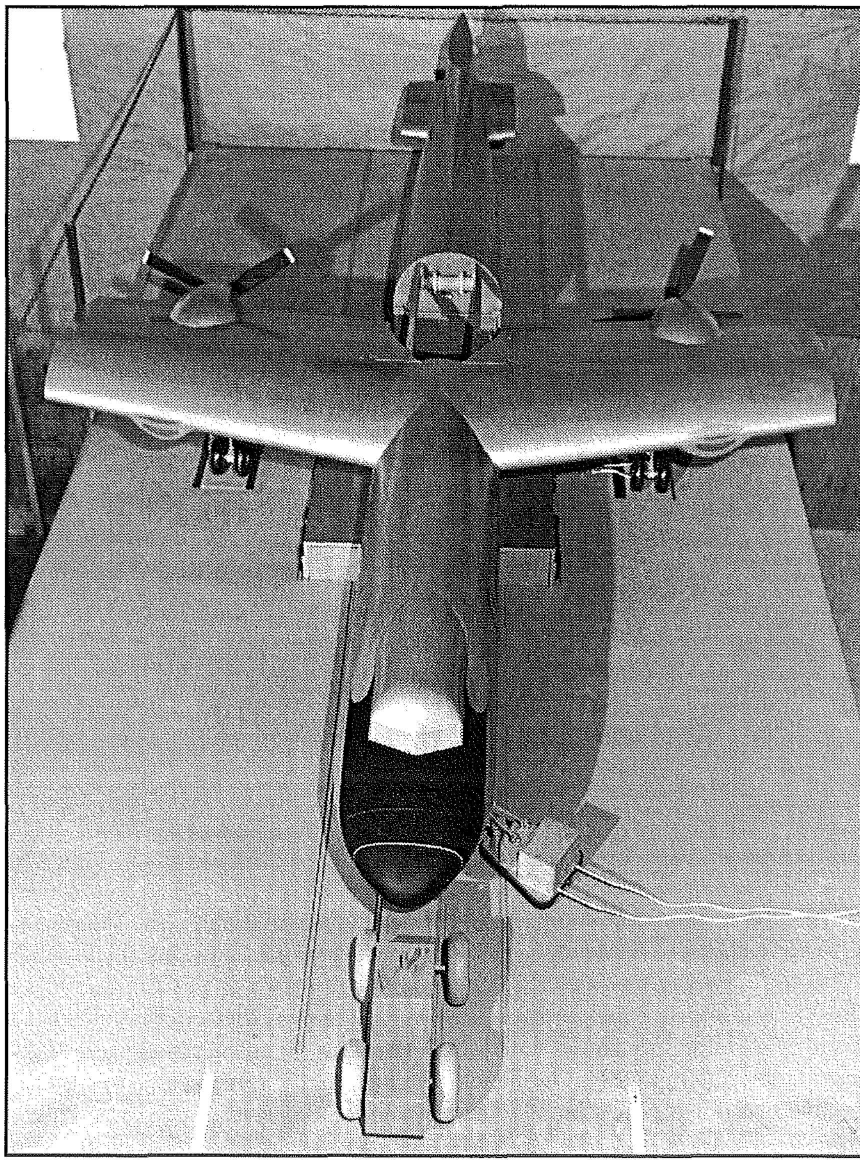
First Flight:	Not Applicable	**Sponsors:**	USAF, AEC
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	None	**Highest Flight:**	Not Applicable

Two Convair X-6s were ordered to evaluate the operational practicality of airborne nuclear propulsion systems prior to committing to building a prototype of a dedicated military design. The specific areas to be tested included crew shielding, propulsion, radiobiology, and the effects of radiation on various aircraft systems.

In addition to the X-6s, a single NB-36H was ordered to serve as an early flyable test bed. In the NB-36H, the nuclear reactor was functioning but provided no power to the aircraft itself. The X-6s would have been powered by a prototype airborne nuclear propulsion system.

In the end, the X-6 program was cancelled before either of the two aircraft were built. The NB-36H was completed, however, making its first flight in September 1955. After conducting tests for approximately two years, the NB-36H was scrapped after its nuclear reactor was removed.

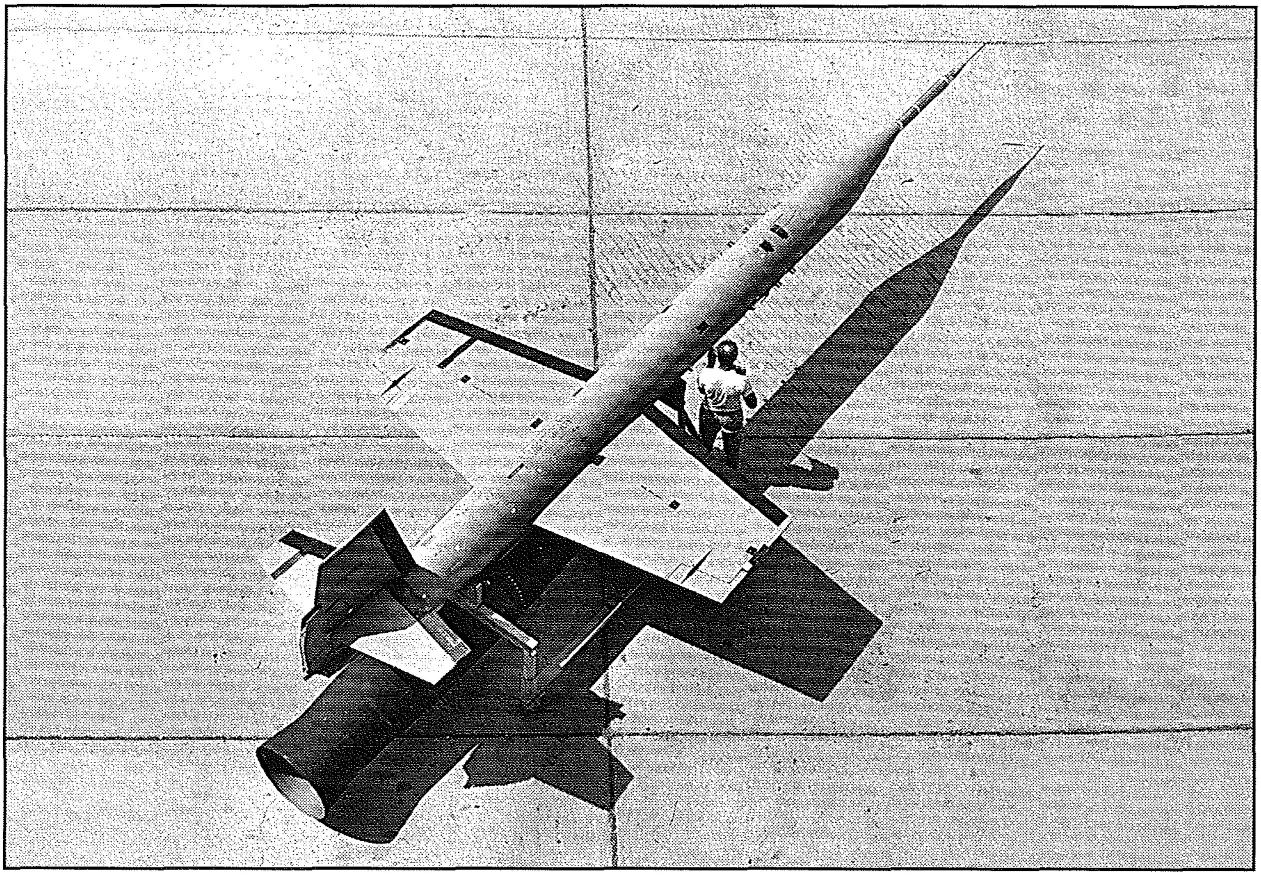
A great deal was learned about the potential for airborne nuclear propulsion systems during the development phase for the X-6, but concerns over the potential for nuclear accidents if an aircraft should crash have prevented further work on such systems.



The X-6s were to be used to evaluate the operational practicality of nuclear propulsion systems prior to committing to building a true nuclear-powered design. The X-6s were to be modified from two Convair B-36 Peacemakers. In the end, a single NB-36H was equipped with a functioning reactor that did not provide any power to the aircraft and used for a simple research effort. (Convair via the Jay Miller Collection)

Lockheed Missiles & Space Co. X-7

First Flight:	26 April 1951	**Sponsors:**	USAF, USA, USN
Last Flight:	20 July 1960	**Fastest Flight:**	Mach 4.31 (2,881 mph)
Total Flights:	130	**Highest Flight:**	106,000 feet



The X-7's distinctive low aspect ratio wings had a thickness/chord ratio of only 4 percent. Small ailerons were mounted at the tips of the wing trailing edges, and the slab stabilator operated in pitch mode only. (Lockheed via the Jay Miller Collection)

The X-7 was designed as a research tool for high-speed ramjet propulsion systems. During the course of a successful flight test program that lasted over nine years, a large ramjet results data base was generated. There were four basic X-7 configurations: the X-7A-1 that was optimized for testing 20-28-inch diameter ramjets; the X-7A-3 that could accommodate larger engines; the X-7B that was similar in most respects to the X-7A-3 but was meant to test communications equipment; and the XQ-5 that was a dedicated high-speed, high-altitude target drone. In addition to basic engine research, the X-7s also tested various fuel additives and exotic fuel mixtures, such as boron-based propellants.

At least eight X-7s and XQ-5s are known to still exist. These include examples outside the NCO club in Sunnyvale, in the missile garden at White Sands, on display at Holloman AFB, New Mexico, and in both the Planes of Fame Museum in Chino, California, and the Air Force Museum in Dayton, Ohio.

X-8

Aerojet General

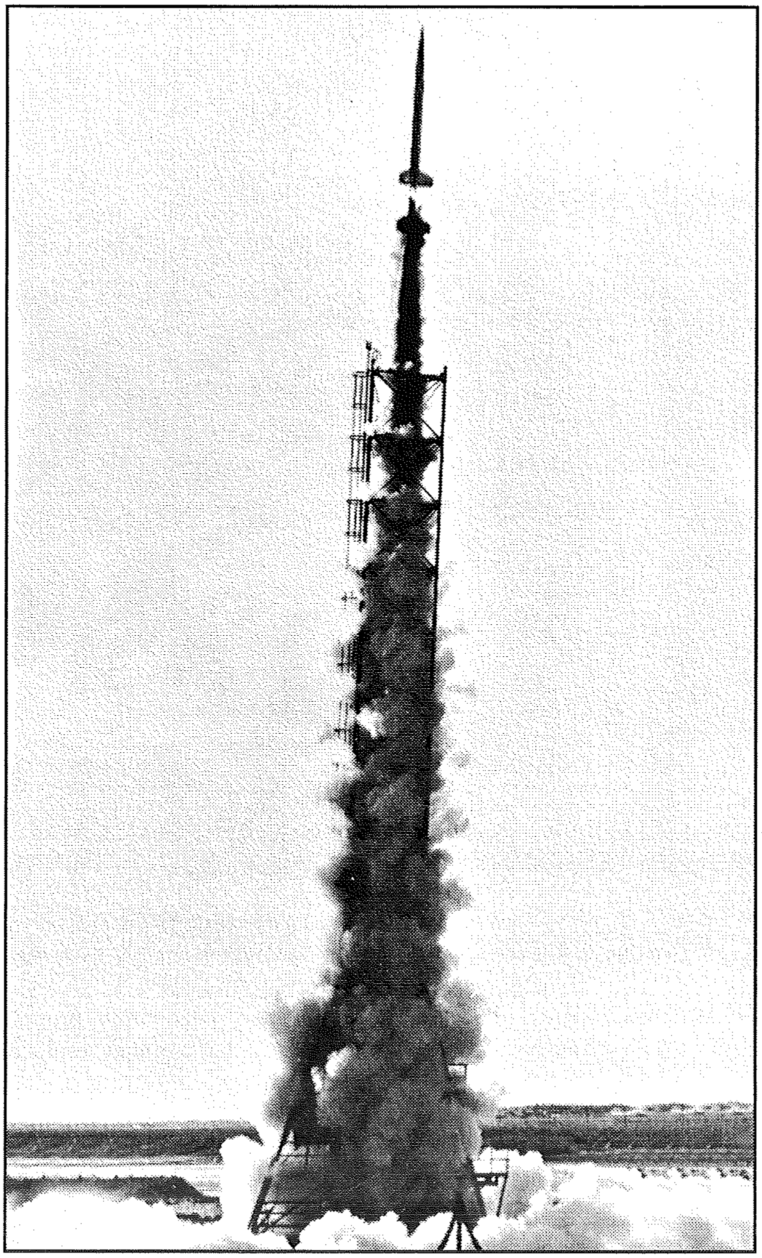
First Flight:	24 April 1947	**Sponsors:**	NACA, USAF, USN
Last Flight:	Unknown	**Fastest Flight:**	Mach 6.0 (4,020 mph) (approx)
Total Flights:	108	**Highest Flight:**	800,000 feet (approx)

The X-8 was conceived to fulfill a requirement for a relatively inexpensive upper air research vehicle and sounding rocket. Most X-8 flights were conducted at either the White Sands Missile Range, or nearby Holloman AFB, New Mexico. The missile was launched from a 143-foot high tower elevated at an angle of approximately 87 degrees.

The standard X-8 vehicle consisted of a payload section with the experimental package, a parachute recovery system, a liquid-fueled sustainer engine, stabilizing fins, and a solid-fueled booster engine.

The payloads carried by the X-8 varied considerably from mission to mission, but on the average weighed about 150 pounds. During the course of the X-8 program, data was obtained on high-altitude winds, solar radiation, high-altitude temperatures, cosmic radiation, the earth's magnetic field, warhead trajectories, effects of high-altitude on warhead design, propulsion anomalies at high altitudes, vehicle dynamics, and general atmospheric phenomenon.

A total of 108 vehicles were manufactured for both the Air Force and the Navy: 68 X-8s, 34 X-8As, 1 X-8B, 2 X-8Cs, and 3 X-8Ds. But perhaps more significantly, the type directly spawned the Aerobee sounding rocket, of which more than 800 were eventually manufactured and used by both military and civilian agencies around the country. Perhaps not surprisingly, no X-8s are known to have survived. However, numerous Aerobee rockets are on display around the country and are generally similar in appearance.

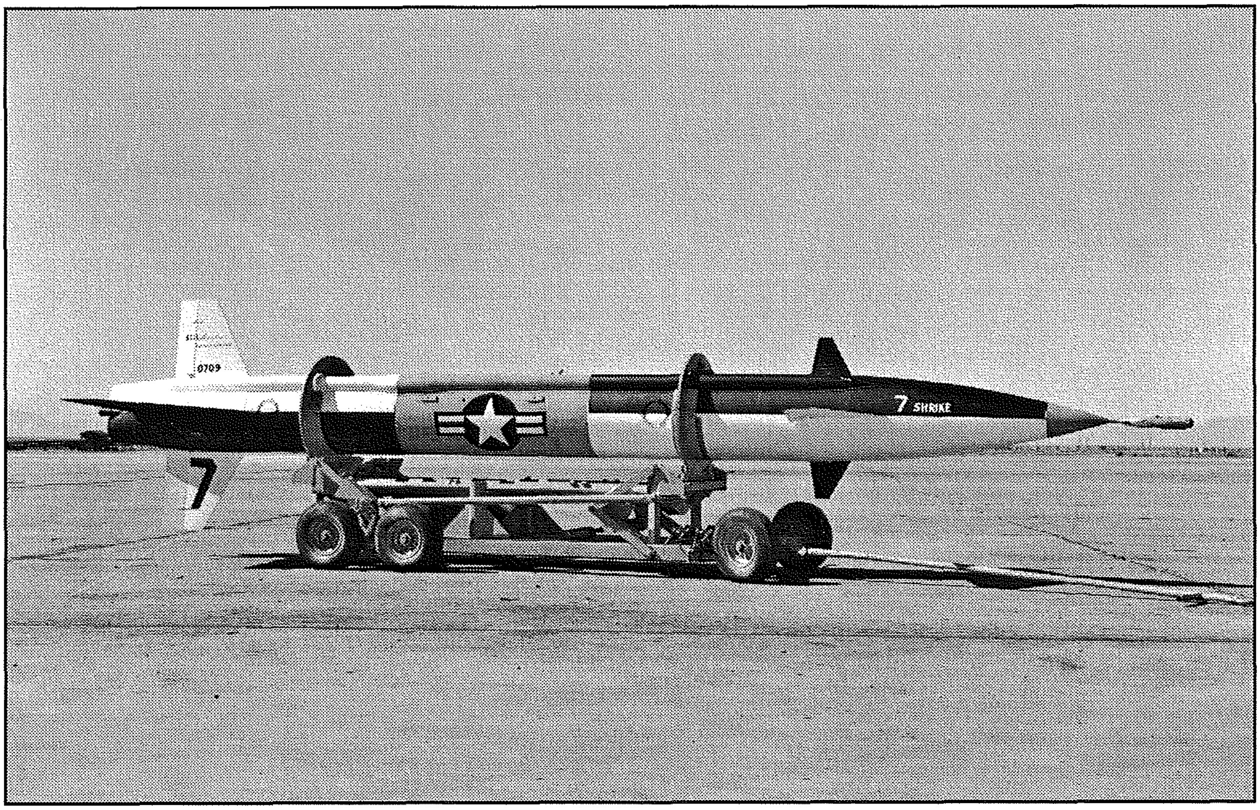


An X-8 accelerates from its launch tower at Holloman AFB under the power of its booster rocket. (William Pearson Collection via the Jay Miller Collection)

Bell Aircraft Corporation

X-9

First Flight:	28 April 1949	**Sponsors:**	USAF
Last Flight:	23 January 1953	**Fastest Flight:**	Mach 2.0 (1,300 mph) (approx)
Total Flights:	28	**Highest Flight:**	65,000 feet (approx)



This X-9 was launched on 16 February 1951 over Holloman AFB, New Mexico, but its flight was cut short by a servo system malfunction. The area around the national insignia was day-glo orange. (Bell Aerospace via the Jay Miller Collection)

The X-9 Shrike (also designated the RTV-A-4) will remain perhaps the least heralded of all the early X-Planes. Designed to serve as a test bed for the ill-fated GAM-63 Rascal air-to-surface missile, the X-9 was doomed to an unspectacular, but nevertheless productive, flight test career. The intent was to obtain aerodynamic, stability, guidance system, and propulsion data prior to proceeding into full-scale development of the Rascal.

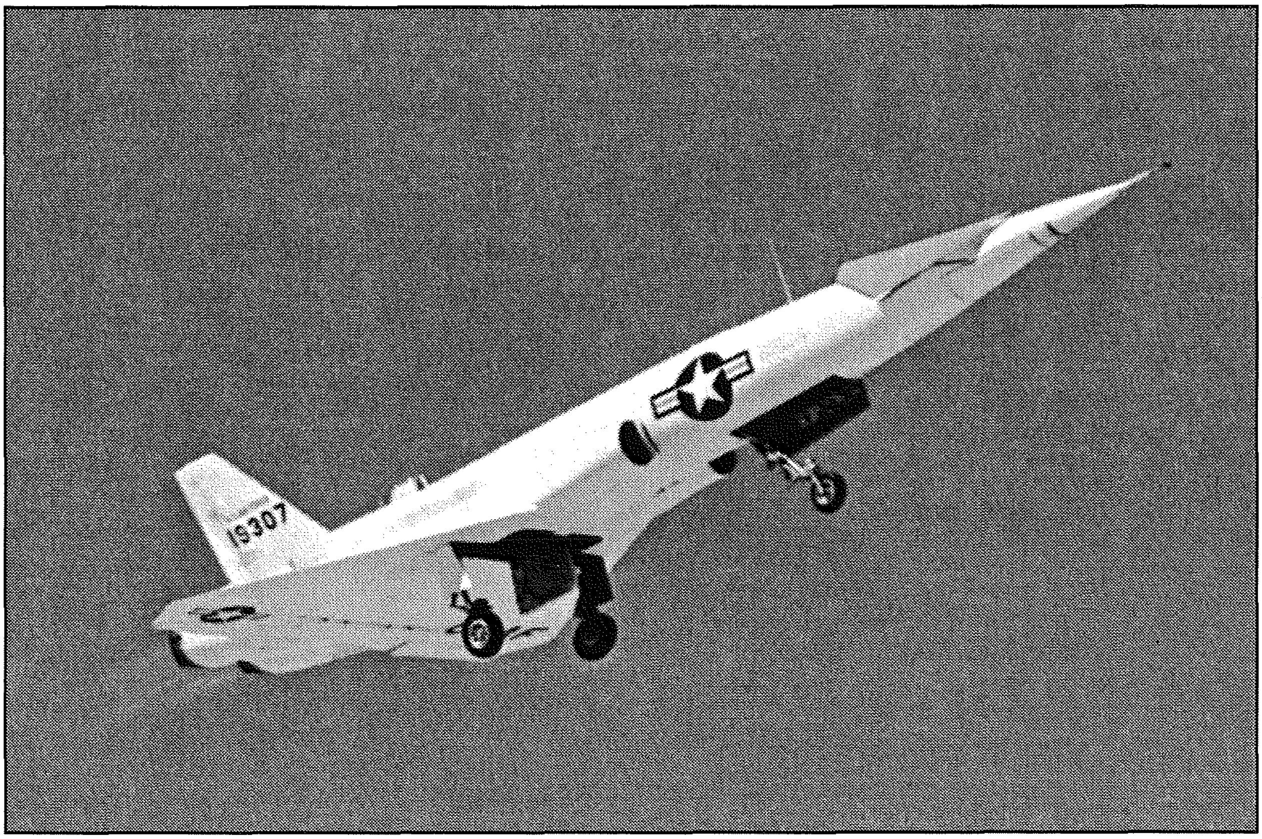
The X-9 contributed significantly to the data base then being generated to support the air-to-surface missile programs. The vehicle provided useful insight into guidance and control system technology, and subsequently served as an instructional tool for engineering, maintenance, and support personnel. In addition, it was the first weapon of its kind to mate the potential of a liquid-fueled rocket engine with the destructive power of the atomic bomb. The missile served as a conceptual prototype for many later stand-off weapons such as the Hound Dog and Skybolt.

Although 93 X-9s were initially ordered, only 31 were actually delivered. None survived, and the only remaining identifiable piece is a large part of a vertical stabilizer in the Larry Bell Museum in Mentone, Indiana.

X-10

North American Aviation

First Flight:	14 October 1953	**Sponsors:**	USAF
Last Flight:	26 January 1959	**Fastest Flight:**	Mach 2.05 (1,350 mph) (approx)
Total Flights:	27	**Highest Flight:**	44,800 feet (approx)



The X-10 was an aerodynamic and systems test bed for the MX-770 (B/SM-64) Navaho cruise missile. A total of 13 X-10s were manufactured, although only 10 were flown. (U.S. Air Force via the Jay Miller Collection)

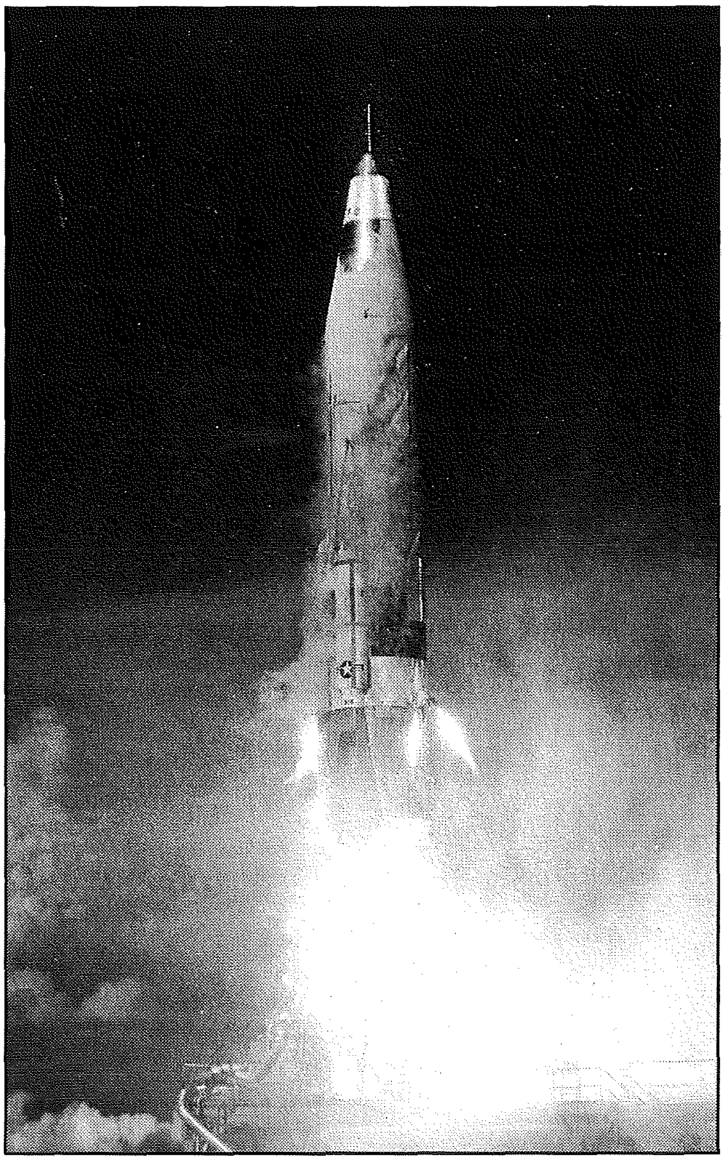
The primary mission of the X-10 was to serve as an aerodynamic and systems test bed for the cruise component of the SM-64 (B-64) Navaho missile. The X-10 was powered by a pair of Westinghouse J40 turbojet engines. At a later date, the X-10 itself was considered a cruise missile candidate, armed with a nuclear warhead and capable of taking off and flying to its target under its own power—but the successful development of the Atlas and Titan intercontinental ballistic missiles (ICBM) precluded this.

The X-10 successfully contributed to the development of the much larger Navaho missile, although that program would subsequently be cancelled in favor of the rocket-powered ICBMs. The X-10 verified the aerodynamics of the cruise component of the Navaho, as well as its complex navigation system.

Thirteen X-10s were manufactured, but only ten were test flown—only a single example still survives, displayed at the Air Force Museum. An SM-65 Navaho missile is on display outside the gate at the Cape Canaveral AFS, Florida.

Consolidated-Vultee Aircraft X-11

First Flight:	Not Applicable	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	None	**Highest Flight:**	Not Applicable



The last Atlas A (vehicle 16A) is launched at Cape Canaveral on 3 June 1958. The Atlas A was an early test version of the three-engine Atlas intercontinental ballistic missile that only used the two booster engines. This was very similar to what the X-11 would have accomplished for the earlier five-engine Atlas design. (USAF/45SW-HO via the Dennis R. Jenkins Collection)

When the Atlas ICBM was being developed, Convair proposed constructing two incremental test vehicles to assist in verifying the technologies necessary to complete the program. At this point Atlas was envisioned as an enormous 160-foot high, 12-foot diameter missile weighing 440,000 pounds and powered by four booster engines and a single sustainer engine.

The first of these test vehicles was the X-11. Using an incremental flight test program, the X-11 would test the overall airframe using only the single sustainer engine while the subsequent X-12 would integrate more components including the four booster engines.

In the meantime, the national laboratories made breakthrough discoveries that allowed the nuclear payload for the Atlas to be drastically reduced in size. Based on the new estimates, Convair significantly reduced the size and weight of the Atlas ICBM, allowing the use of only three engines (two boosters and one sustainer) instead of the original five. The X-11 fell by the wayside.

Still, Convair wanted to proceed with an incremental test program, but this time the resultant vehicle was called the Atlas Series A (later shortened to simply Atlas A) instead of X-11. The test missile would be powered by the two booster engines; the sustainer would be added on the later Atlas B.

In the end, 16 Atlas As were built and 8 were launched from Cape Canaveral. They successfully demonstrated the pressure-stabilized propellant tanks and propulsion system components destined to equip the Atlas ICBM—which later became one of the premier space launch vehicles.

X-12 Consolidated-Vultee Aircraft

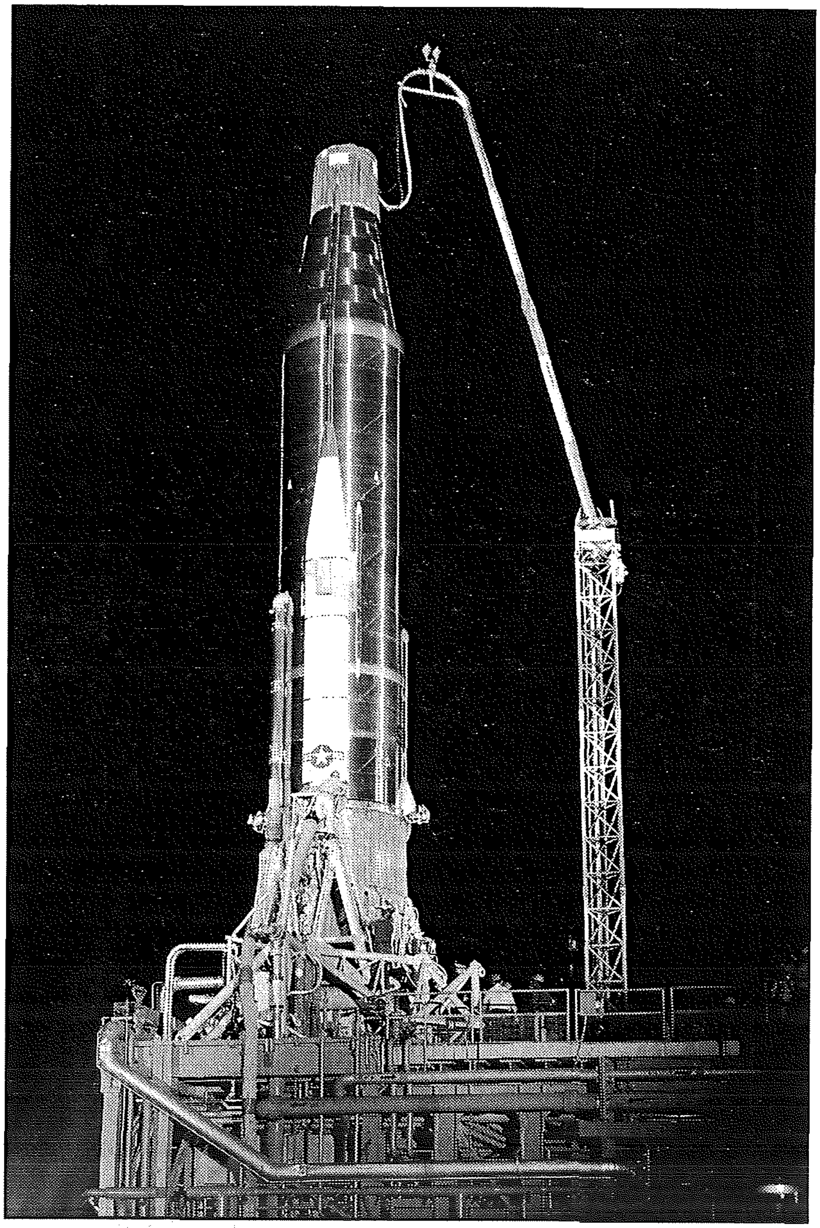
First Flight:	Not Applicable	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	None	**Highest Flight:**	Not Applicable

The X-12 was envisioned as the second incremental test vehicle for the five-engine Atlas ICBM design. This vehicle would have added the four booster engines to the single sustainer previously tested on the X-11.

Like the X-11, the X-12 was to demonstrate the viability of the unique pressure-stabilized propellant tanks that were so thin they needed to be supported by internal pressure to keep them from collapsing. This construction technique greatly reduced the weight of the empty airframe, but brought its own set of concerns. The X-12 was also to demonstrate the radio-inertial guidance system and reentry (warhead) section being developed for Atlas.

When the Atlas was redesigned into a three-engine vehicle, the X-12 was dropped, although its place in the incremental test program was taken by the Atlas Series B.

The Atlas B was generally similar to the earlier Atlas A but incorporated the planned sustainer engine to prove the stage-and-a-half concept. A total of 13 vehicles were manufactured for flight and ground tests. All of the basic subsystems were tested in this series, including the MA-1 propulsion system, the Mod 1 radio guidance system, and the Mark 2 heat-sink reentry vehicle. The Atlas B series demonstrated booster staging and reentry vehicle separation, and attained a range of 6,500 miles with vehicle 12B

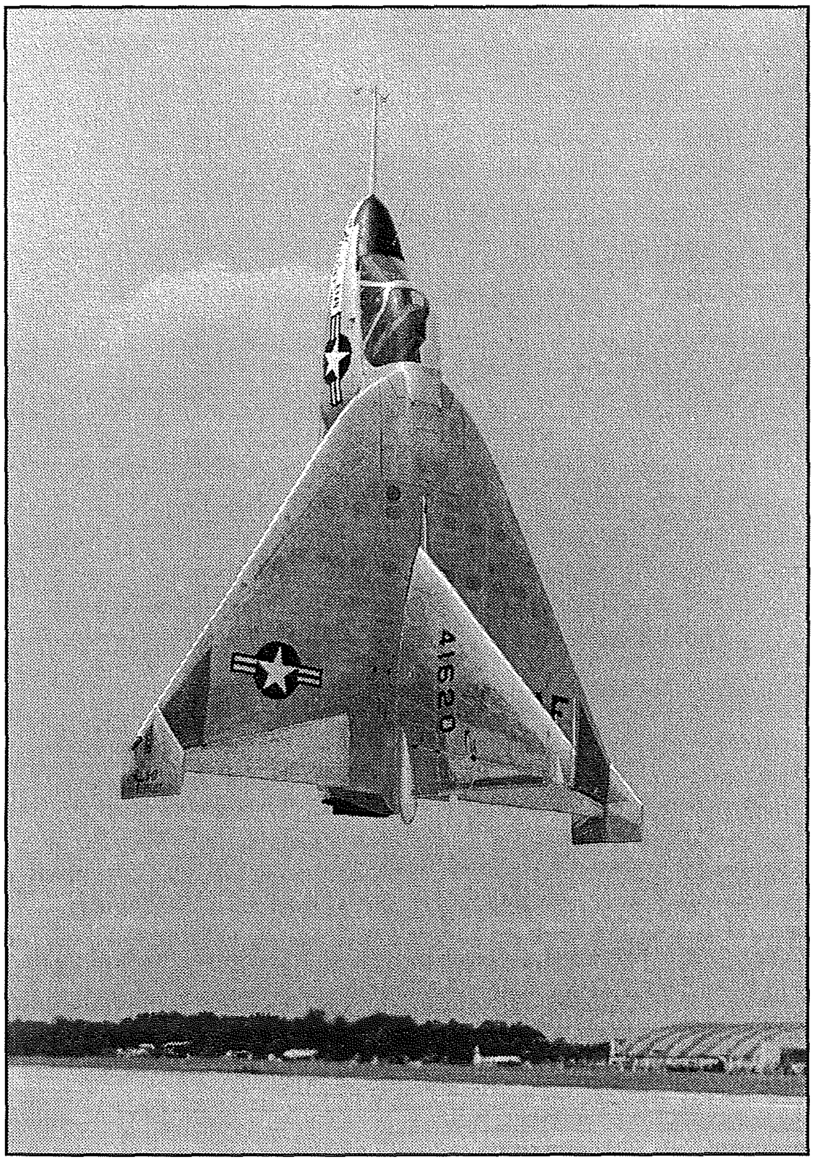


One of the Atlas B (9B) test missiles is shown on Complex 11 at Cape Canaveral on 17 November 1958, just before it was launched. This flight would end in a propulsion system failure. (USAF/45SW-HO via the Dennis R. Jenkins Collection)

Ryan Aeronautical Company

X-13

First Flight:	10 December 1955	**Sponsors:**	USN, USAF
Last Flight:	30 July 1957	**Fastest Flight:**	483 mph (approx)
Total Flights:	Unknown (many)	**Highest Flight:**	10,000 feet (approx)



The X-13s were truly pioneers of jet-powered vertical flight. They proved that VTOL flight, on jet thrust alone, was both technically feasible and practical. The ease with which the aircraft routinely transitioned from vertical to horizontal flight, and back again, left little question as to the flexibility and operational utility of such flight modes. (Teledyne Ryan via the Jay Miller Collection)

The X-13 was designed to explore the feasibility of building a pure-jet vertical takeoff and landing (VTOL) fighter aircraft. Secondary purposes included validating the Ryan-designed VTOL control system concepts. The diminutive X-13 was powered by a single Rolls-Royce Avon turbojet engine.

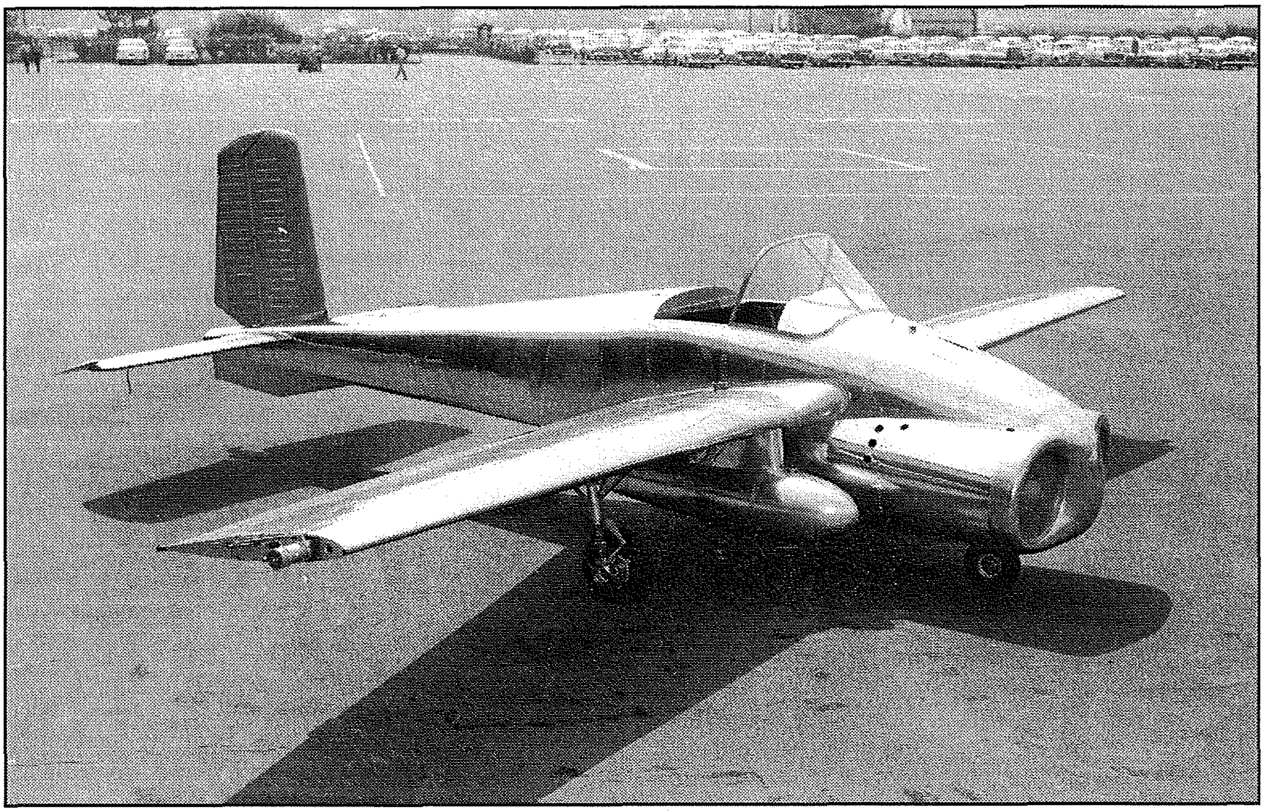
The success and efficiency of the X-13 flight test program remains a high water mark in the history of research aircraft development. They provided a significant amount of data to the designers of subsequent VTOL aircraft designs. The X-13s proved that vertical flight, on jet thrust alone, was both technically feasible and practical. The ease with which the aircraft routinely transitioned from vertical to horizontal attitude, and back again, left little question as to the flexibility and operational utility of such flight modes.

Perhaps the only significant failing of the program was its lack of success in generating a follow-on production effort. This was due mainly to the aircraft's small size and limited payload capacity—and the inability of existing turbojet engines to power a larger version.

Both X-13s survived their test program. The first aircraft is on loan from the National Air and Space Museum to the San Diego Aerospace Museum in San Diego, California. The second aircraft is on display at the Air Force Museum.

X-14 Bell Aircraft Corporation

First Flight:	17 February 1957	**Sponsors:**	USAF, NASA
Last Flight:	29 May 1981	**Fastest Flight:**	172 mph
Total Flights:	Unknown (many)	**Highest Flight:**	18,000 feet (approx)



The X-14 was used to verify that the concept of using vectored thrust in a VTOL aircraft was practical. Sir Stanley Hooker would later utilize this data when designing the Hawker P.1127 (Harrier prototype). (Bell Aerospace via the Jay Miller Collection)

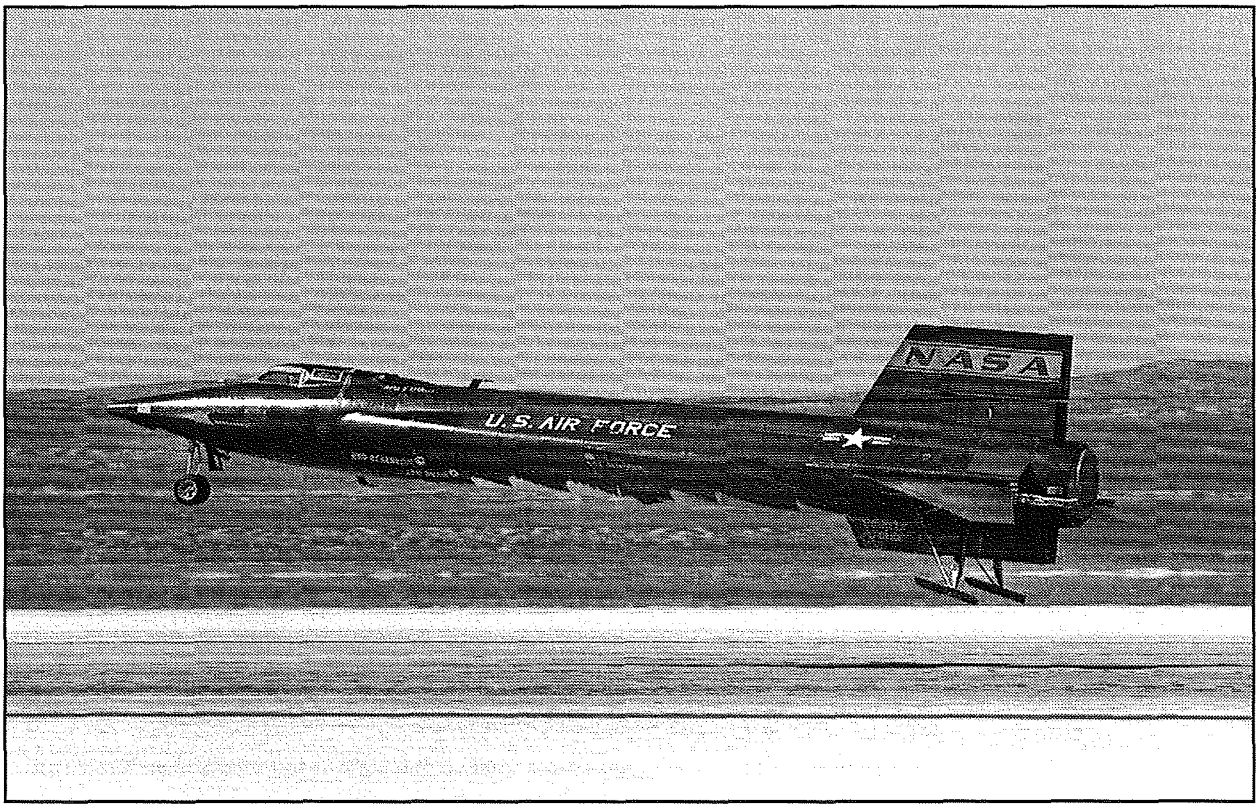
The X-14 was another X-Plane dedicated to exploring vertical flight. The X-14 was originally created to explore the feasibility of operating a VTOL aircraft from a normal pilot station using standard flight instruments and references. Of equal importance, the X-14 was to demonstrate various VTOL systems and engine technologies—the aircraft was the first to demonstrate the concept of using vectored jet thrust as the only power system.

The X-14 successfully demonstrated that the concept of vectored jet thrust was viable, as subsequently used on the BAe/McDonnell Douglas Harrier. Flight tests using the X-14's variable stability control system resulted in major contributions to the understanding of V/STOL handling characteristics. The X-14 also proved useful as a test bed for various unique V/STOL concepts, such as NASA's direct side-force maneuvering system.

Over 25 pilots from around the world "previewed" V/STOL handing qualities in the X-14 prior to making test flights in other V/STOL designs. The single X-14 continued flying for nearly a quarter century before being retired to the Army Aviation Museum at Fort Rucker, Alabama.

North American Aviation X-15

First Flight:	08 June 1959	**Sponsors:**	USAF, NACA/NASA, USN
Last Flight:	24 October 1968	**Fastest Flight:**	Mach 6.04 (4,093 mph)
Total Flights:	177	**Highest Flight:**	354,200 feet



Several Air Force pilots earned Astronaut Wings in the X-15 for flights above 50 miles, the standard by which the Air Force (but not NASA) measured the beginning of space. (NASA via the Dennis R. Jenkins Collection)

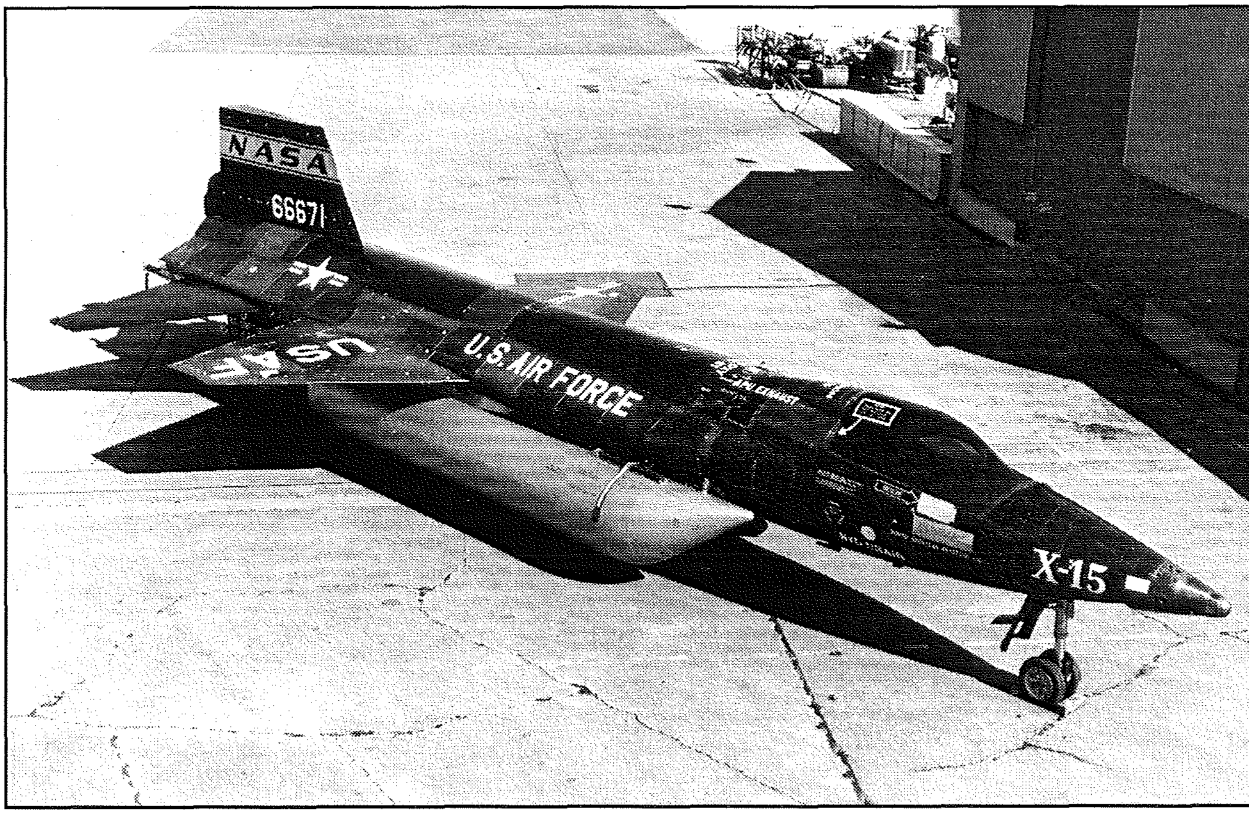
The X-15 was arguably the most successful high-speed flight research program ever undertaken.The X-15 was constructed specifically to explore the hypersonic (Mach 5+) flight regime, along with the necessary structures, propulsion systems, and control techniques. Although widely discounted at the time, a tertiary purpose of the original X-15 program was to explore the possibilities of flight outside the sensible atmosphere.

The aircraft proved remarkably flexible as a research tool. In fact, most of the later flights used the X-15 as a carrier vehicle for other experiments rather than as a research aircraft in its own right. An assortment of experiments were carried, including micrometeorite collection pods, missile detection systems, ablative heat shield samples destined for the Apollo program, and a wide variety of others. The aircraft itself demonstrated a throttleable rocket engine, Inconel X heat-sink construction, and an advanced adaptive control system.

Of the three X-15s manufactured, one was rebuilt as the X-15A-2 after an accident, one crashed while returning from space—killing test pilot Major Michael J. Adams, and one survives in the National Air and Space Museum.

X-15A-2 North American Aviation

First Flight:	25 June 1964	**Sponsors:**	USAF, NASA
Last Flight:	03 October 1967	**Fastest Flight:**	Mach 6.70 (4,520 mph)
Total Flights:	22	**Highest Flight:**	249,000 feet



The modified X-15A-2 still holds the worlds speed record for a flight flown by a winged aircraft that has not flown into space. The flight was piloted by Major William J. "Pete" Knight on 3 October 1967. (North American via the Jay Miller Collection)

Before the end of 1961, the X-15 had attained its Mach 6 design goal and flown well above 200,000 feet; by the end of 1962 the X-15 was routinely flying above 300,000 feet. The X-15 had already extended the range of winged aircraft flight speeds from Mach 3.2 to Mach 6.04, the latter achieved by Bob White on 9 November 1961.

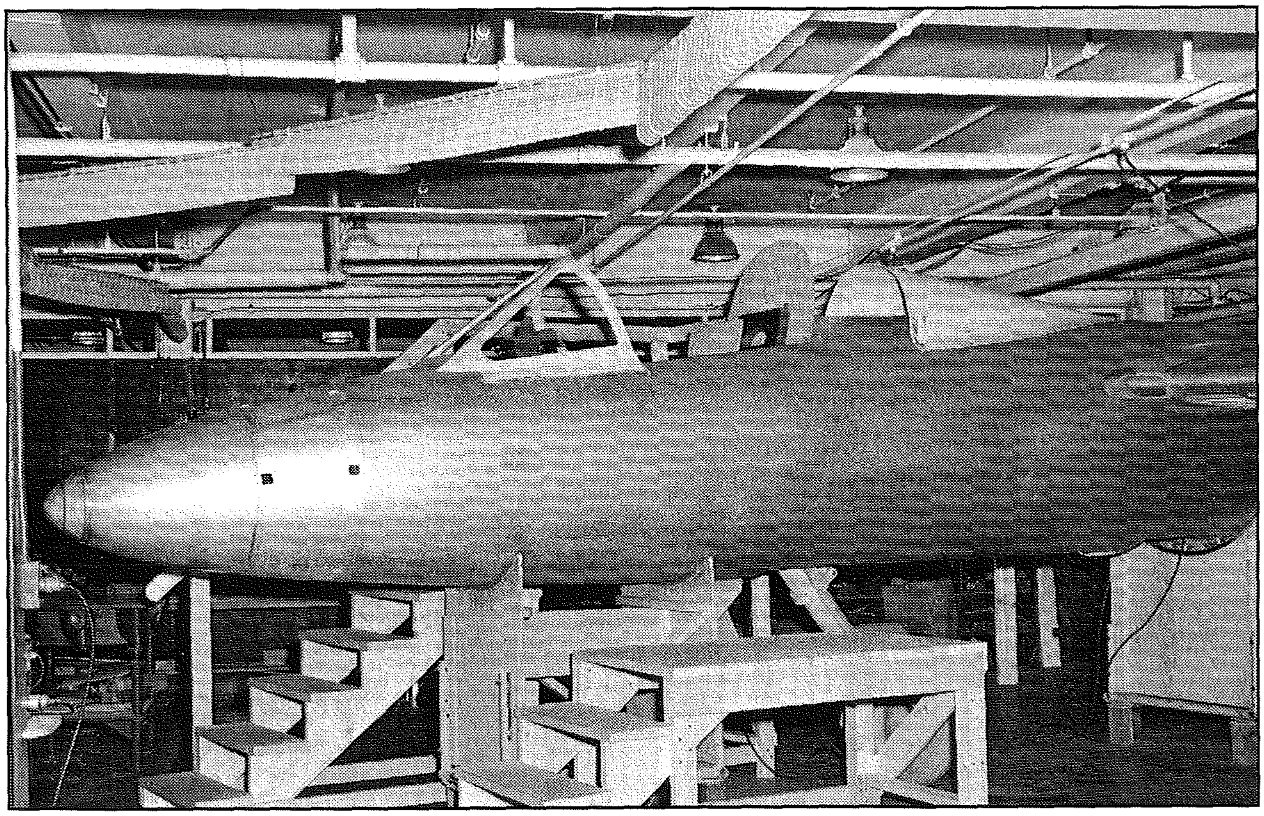
A year later, on 9 November 1962, the second X-15 crashed while executing an abort landing on Mud Lake near Edwards AFB. Pilot Jack McKay was seriously injured but later returned to flight status. The X-15 itself was nearly a write-off, but eventually the Air Force and NASA decided to rebuild it to a slightly different configuration. The fuselage was lengthened and external drop tanks were added to accommodate additional propellants. It was hoped this would allow the X-15A-2 to achieve at least Mach 7 while testing experimental scramjet engines. Using an experimental ablative coating, Major Pete Knight took the X-15A-2 to Mach 6.72 (4,520 mph) on 3 October 1967, the fastest piloted flight of the X-Plane program.

Due to damage resulting from this flight, the aircraft was retired and subsequently transferred to the Air Force Museum.

Bell Aircraft Corporation

X-16

First Flight:	None	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



The X-16 was designed as a high-altitude reconnaissance aircraft, but was ultimately cancelled in favor of the Lockheed U-2. A full-scale mockup was completed, but no aircraft were actually built. (Bell Aerospace via the Jay Miller Collection)

The X-16 was the most blatant misuse of the X-Plane designation system—it was simply an attempt to hide what would today be called a spy-plane. The X-16 was designed to be a high-altitude long-range reconnaissance aircraft. A total of 28 aircraft were ordered, but none would be completed before the Lockheed U-2 successfully demonstrated its ability to perform the spy mission. The first X-16 was reportedly over 80 percent complete when it was cancelled.

The X-16 was a designer's nightmare—the wing was an extremely long-span high-aspect ratio unit that was significantly lighter and more flexible than any in existence at the time. In fact, the entire airframe was extremely flexible—a result of the need to make the aircraft as light as possible to allow it to achieve its 70,000-foot mission altitude. A 3,000 mile unrefueled range was predicted for the production aircraft.

Although never built, the X-16 pioneered several notable advances in lightweight structure design, and also was the driving force behind the development of high-altitude versions of the J57 jet engine that would go on to power the U-2 and other aircraft.

X-17 Lockheed Missiles & Space Co.

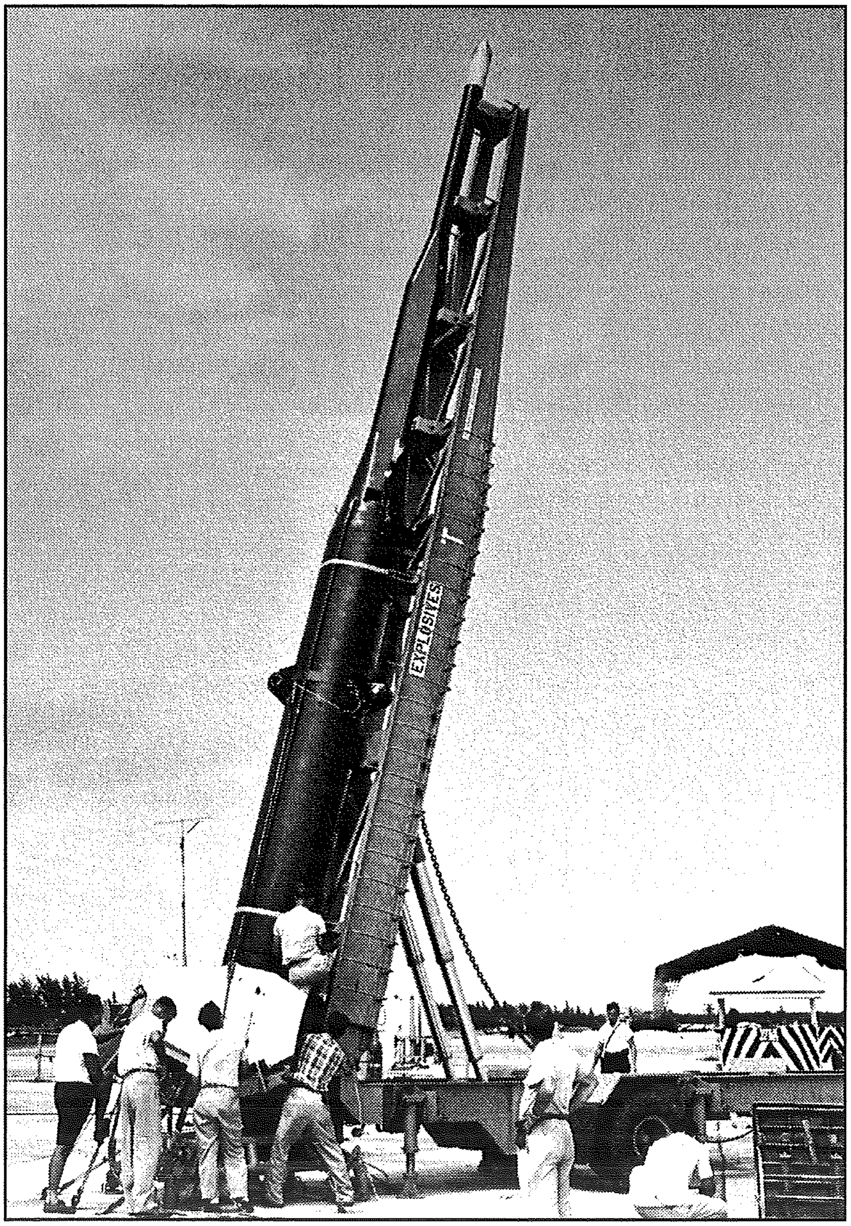
First Flight:	17 April 1956	**Sponsors:**	USAF, USN
Last Flight:	22 August 1957	**Fastest Flight:**	Mach 14.4 (9,504 mph)
Total Flights:	34	**Highest Flight:**	50,000 feet (approx)

The X-17 was a multistage rocket used to transport various reentry vehicle configurations to very high altitudes so that their flight characteristics could be examined in a natural environment. The original program objectives included operation at speeds in excess of Mach 15 and Reynolds-numbers of 24,000,000.

The X-17 proved to be one of the most significant missile programs during the 1950s. Its research into reentry characteristics contributed to the development of the warheads for the early intercontinental ballistic missiles, as well as to the early piloted space program capsules.

Perhaps more importantly, the X-17 produced the first realistic data ever obtained on heat transfer at extremely high Mach numbers and Reynolds numbers. Particularly valuable was the information generated relating to the hypersonic airflow around various blunt-body shapes as they made the transition from laminar to turbulent conditions.

A total of 26 X-17s were completed and tested, and as many as 7 others were later constructed from spare parts under Project Argus. No flightworthy X-17s survived, but what is presumably a structural test vehicle is on display at the Air Force Museum in Dayton, Ohio.

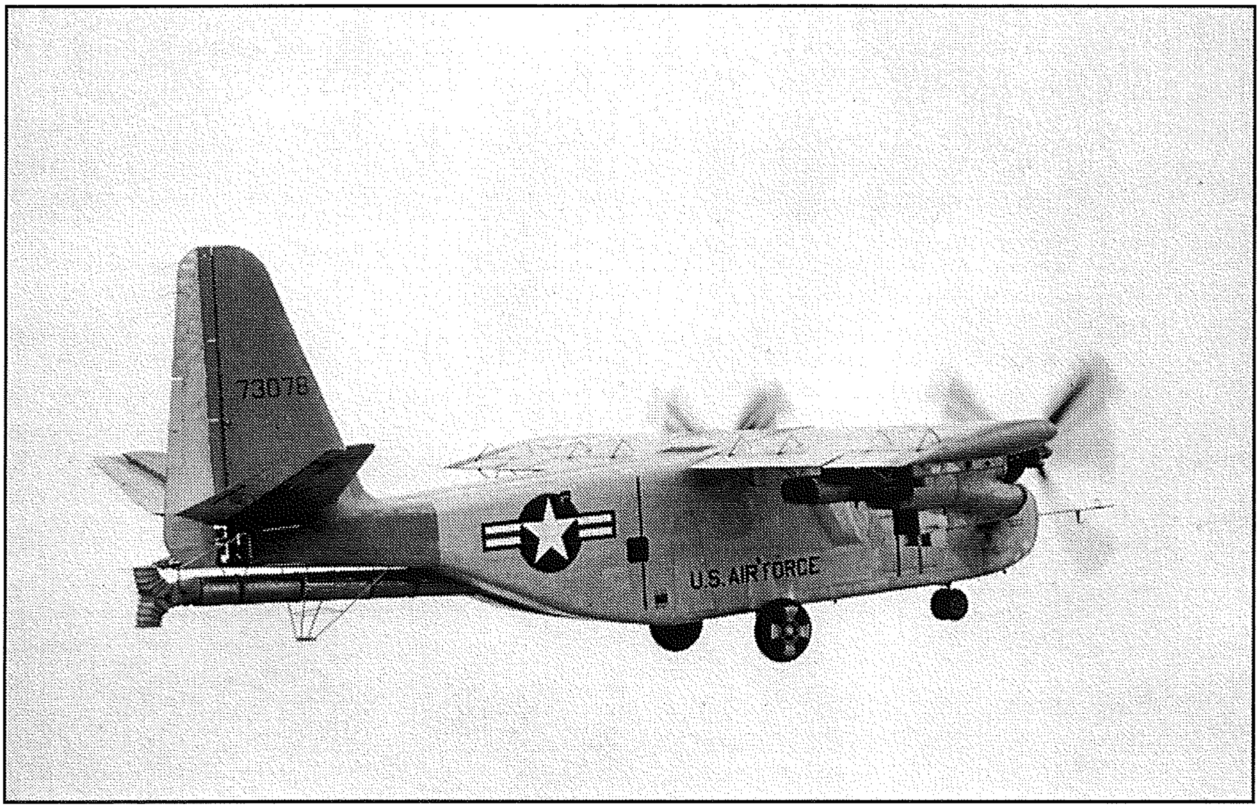


The X-17 used solid rocket motors to carry reentry vehicles to altitude. The original program objectives included reentry speeds of Mach 15 and Reynolds Numbers as high as 24 million. (U.S. Air Force via the Jay Miller Collection)

Hiller Aircraft Corporation

X-18

First Flight:	20 November 1959	**Sponsors:**	USAF, USN
Last Flight:	July 1961	**Fastest Flight:**	253 mph
Total Flights:	20	**Highest Flight:**	35,300 feet



The X-18 was built to investigate the feasibility of a large tilt-wing transport. Unlike the current V-22 Osprey, the entire wing (and the engine assemblies) on the X-18 translated to vertical to support V/STOL flight. (Fairchild via the Jay Miller Collection)

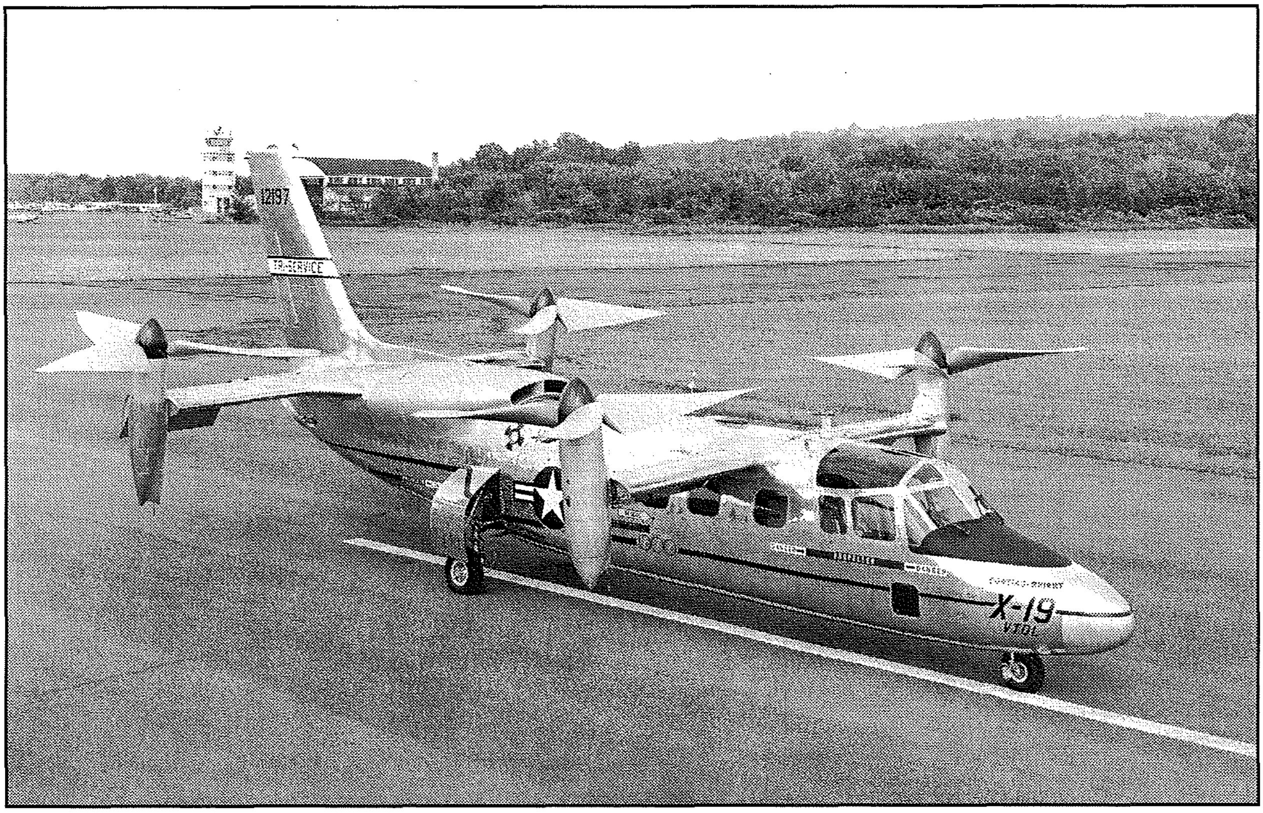
The X-18 was conceived to assess the feasibility and practicality of a large tilt-wing V/STOL aircraft. The primary objectives were to investigate major problem areas associated with the tilt-wing concept while establishing criteria for the possible future development of similar aircraft.

Although its flight test program was short and inconclusive, the X-18 was nevertheless the first large aircraft to investigate the tilt-wing concept. An engine failure on the 20th flight prematurely terminated the flight test program. Data from this program was used during the design and development of the Vought XC-142 experimental transport aircraft in the early 1960s.

Only a single X-18 was completed—interestingly it used the fuselage from the Chase YC-122C and two turboprop engines that were surplused from the Navy's cancelled VTOL fighter program (Lockheed XFV-1 and Convair XFY-1 Pogo). No definitive information has been uncovered concerning the aircraft's ultimate fate, but it is generally assumed to have been scrapped at Edwards AFB.

X-19 Curtiss-Wright Corporation

First Flight:	20 November 1963	**Sponsors:**	USAF, USA, USN
Last Flight:	25 August 1965	**Fastest Flight:**	454 mph
Total Flights:	50	**Highest Flight:**	25,600 feet



The X-19 was the spiritual predecessor of the V-22 and demonstrated the feasibility of tilt rotor aircraft. The power available from existing engines dictated the use of four powerplants and rotors/propellers. (Curtiss-Wright via the Jay Miller Collection)

Originally developed as a private venture by Curtiss-Wright, the X-19 was intended to demonstrate the practicality of the tilt rotor concept. The X-19 was also used to explore the general feasibility of VTOL operations for such missions as the evacuation of personnel, missile site support, delivery of high priority cargo, counter-insurgency operations, reconnaissance, and close support operations.

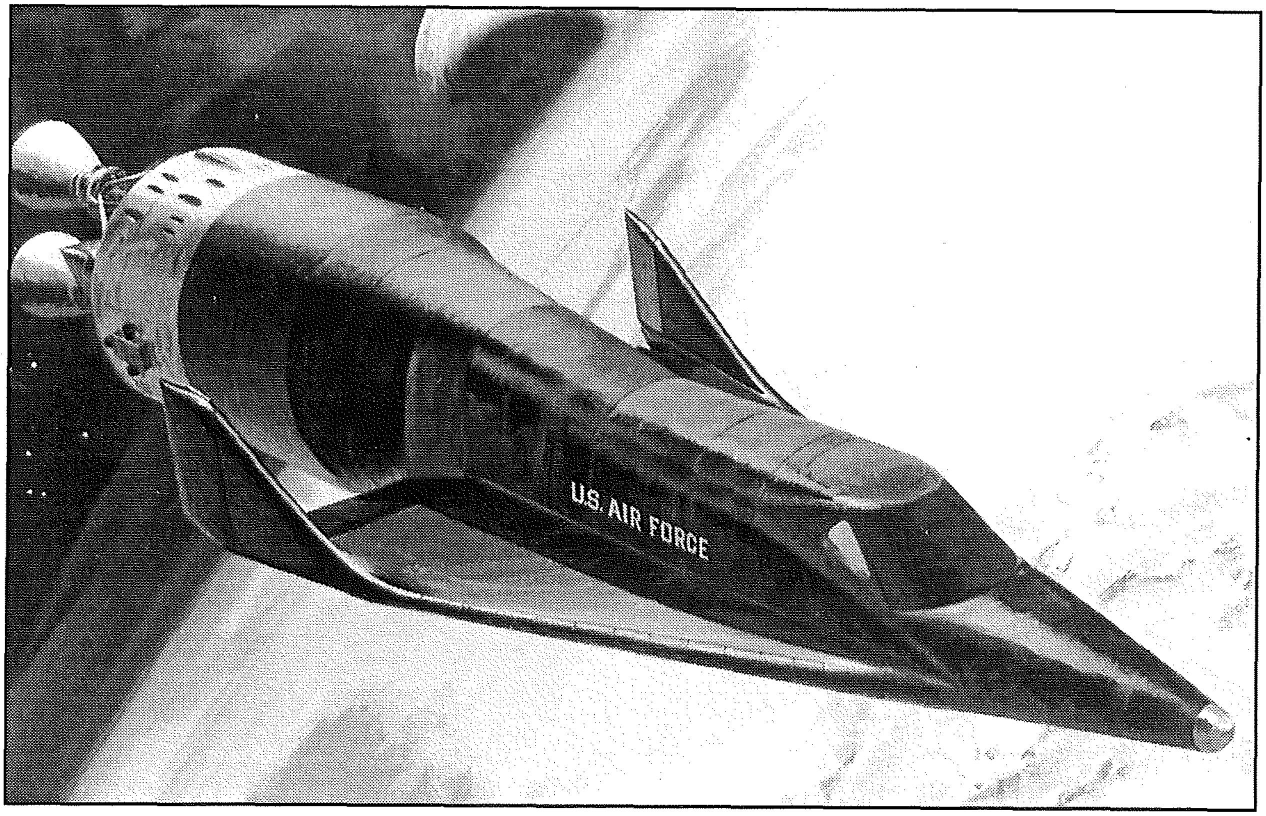
Within the limited flight envelope explored by the X-19 prior to its demise, the aircraft demonstrated the general feasibility of the tandem tilt rotor concept. The program successfully verified the dynamic and longitudinal stability, hover, and transition performance of the basic design. Although the tandem tilt rotor design would not find further application, much of the data proved useful during the development of the XV-15 and later V-22 tilt rotor aircraft.

Two X-19s were built—the first was destroyed in an accident on 25 August 1965, and the second aircraft was never completed. After all the useable components from the second aircraft were removed, the airframe was scrapped.

The Boeing Company

X-20

First Flight:	None	**Sponsors:**	USAF, NASA
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



The X-20 Dyna-Soar was cancelled prior to the first flight vehicle being completed. The Dyna-Soar would have been launched on a Titan III booster to fill both experimental and, possibly, operational roles. (Boeing via the Dennis R. Jenkins Collection)

The X-20 Dyna-Soar was designed to provide a piloted maneuverable vehicle for conducting flight research in the hypersonic and flight regime. The X-20 was the final outgrowth of concepts that had begun with Eugen Sänger in 1928 and progressed through the Bell BoMi and RoBo concepts of the 1950s. At some points during its development, the Dyna-Soar was intended to be a quasi-operational system.

Although the X-20 never progressed beyond the preliminary construction stage, it effectively served as a test bed for a variety of advanced technologies that contributed enormously to various follow-on projects, including the Space Shuttle. In addition, numerous subsystems designed for Dyna-Soar found their way into the X-15 later in that aircraft's flight research program.

The X-20 program was cancelled before the first vehicle was completed. Most of the subsystems manufactured for the uncompleted vehicle were used for various ground tests. Very few vehicles have contributed more to the science of very high-speed flight—especially vehicles that were never actually built.

X-21A

Northrop Corporation

First Flight:	18 April 1963	**Sponsors:**	USAF
Last Flight:	1964	**Fastest Flight:**	560 mph (approx)
Total Flights:	Unknown	**Highest Flight:**	42,500 feet (approx)

The two X-21As were modified from Douglas WB-66D Destroyer light bombers—the modifications were performed at Northrop's Hawthorne, California, facility. (Northrop via Gerald Balzer via the Jay Miller Collection)

The X-21A was designed to explore the feasibility of utilizing full-scale boundary layer control on a large aircraft. Paper and wind tunnel studies conducted by Northrop had indicated boundary layer control would offer numerous performance benefits. After successfully demonstrating the ability to achieve laminar flow over approximately 75 percent of the wing surface, the X-21As were used to explore the impact of rain, sleet, snow, and other weather anomalies on the system.

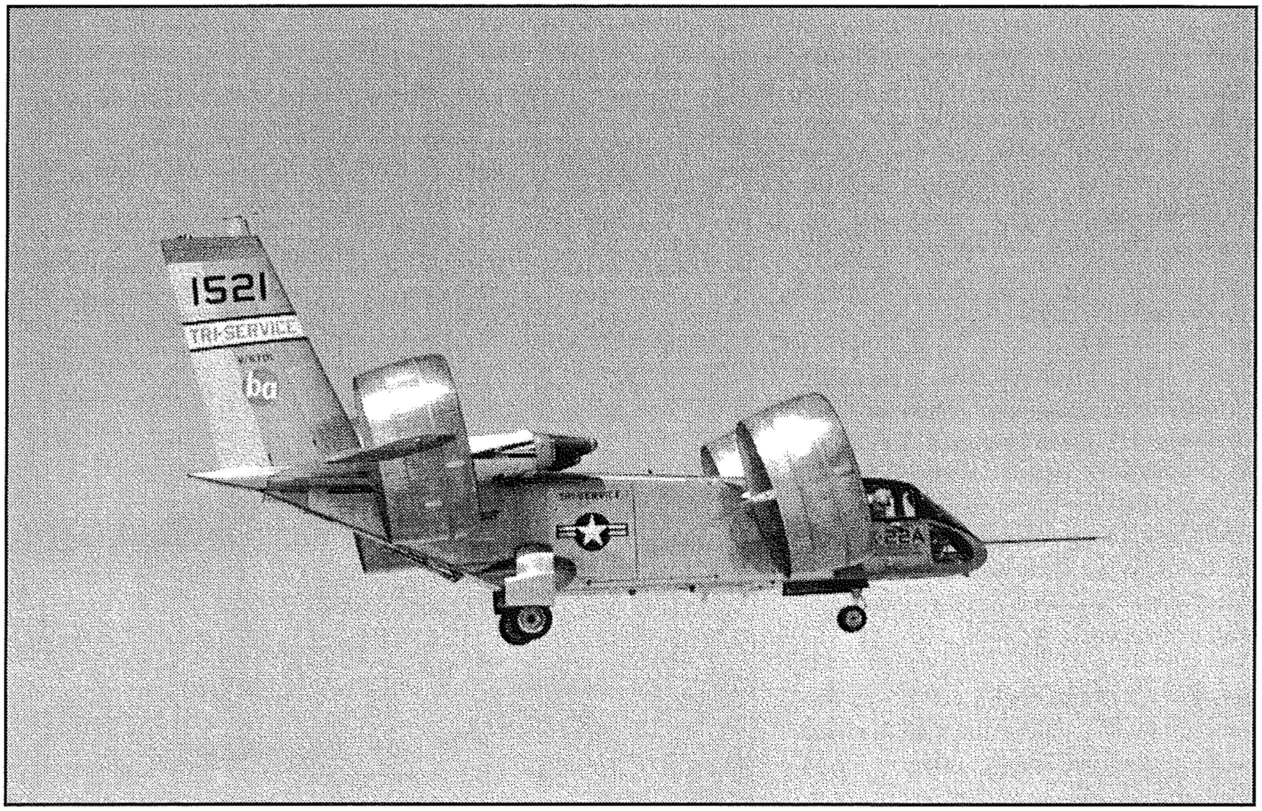
During the flight test program, the X-21As demonstrated that the boundary layer control technique, called laminar flow control, was both effective and viable. However, they also showed that these benefits came at a significant maintenance penalty—the numerous small slots required for the airflow constantly plugged up.

The two X-21As were originally built as Douglas WB-66D light bomber derivatives that had been retired from active service. Both X-21As survived the flight test program and are currently in a bad state of repair on the photo range at Edwards AFB.

Bell AeroSpace Textron

X-22

First Flight:	17 March 1966	**Sponsors:**	USN, USA, USAF
Last Flight:	1988	**Fastest Flight:**	255 mph
Total Flights:	500+	**Highest Flight:**	27,800 feet (approx)



The X-22A made a number of significant contributions to AeroSpace science, not the least of which was its exploration of V/STOL technologies and its use as a V/STOL aircraft analog. (Bell Aerospace via the Jay Miller Collection)

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. The flight test program was undertaken by Calspan Corporation, in Buffalo, New York, under the auspices of the U.S. Navy. After demonstrating its basic handling qualities, most of the X-22A flights were oriented towards advancing the science of V/STOL flight, not the specific aircraft configuration itself. By the end of its long-lived test program, the X-22A had made a number of contributions, but perhaps the most significant was its ability to serve as a V/STOL analog for various advanced sensors and instrumentation destined for other V/STOL aircraft. The ducted-fan configuration itself proved quite workable, although it has not been selected for any further aircraft to date.

Two X-22As were built. The first was damaged beyond economical repair on 8 August 1966, and it was cannibalized to keep the second aircraft flying, although the fuselage was retained for a considerable time for use as a ground simulator at Calspan. The second aircraft is in storage at the Air Force Museum in Dayton, Ohio.

X-23 Martin Marietta Corporation

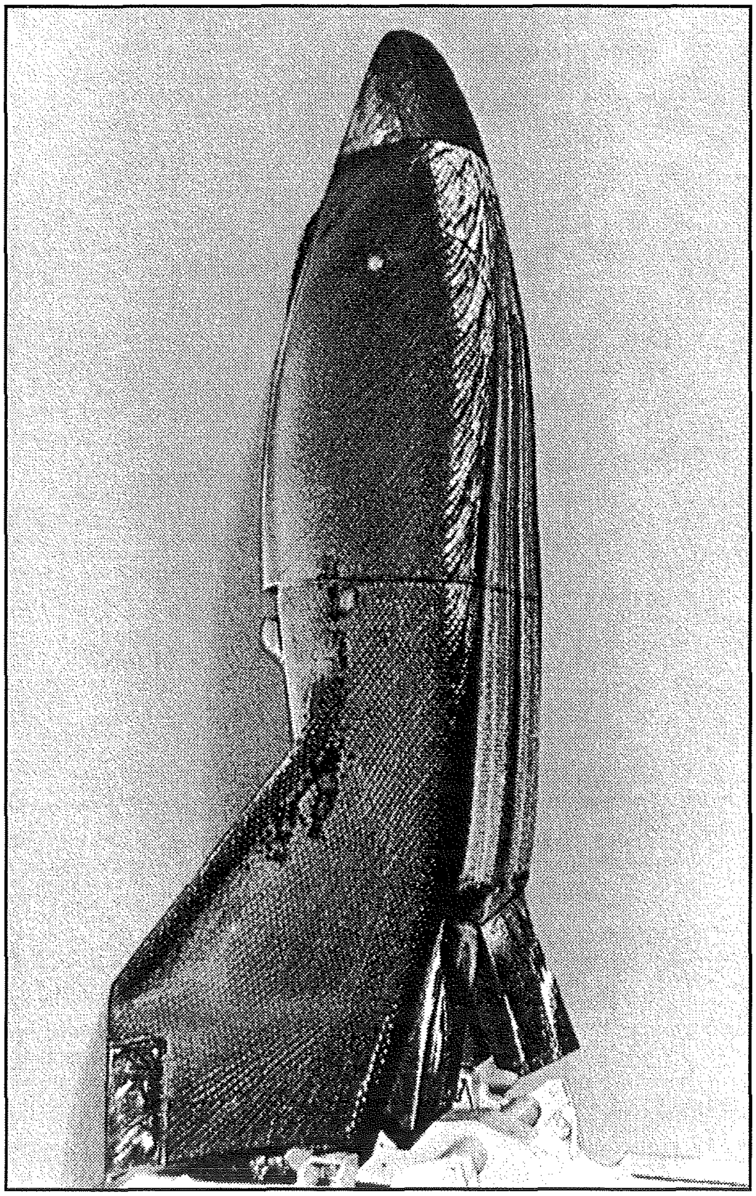
First Flight:	21 December 1966	**Sponsors:**	USAF
Last Flight:	19 April 1967	**Fastest Flight:**	16,500 mph (reentry) (approx)
Total Flights:	3	**Highest Flight:**	500,000 feet (approx)

The X-23A, also known as the SV-5D, was designed to acquire data relating to lifting maneuverable reentry vehicles in support of several Air Force and NASA programs. The effort was under the auspices of Project PRIME (precision recovery including maneuvering entry) and was part of the larger three-part START (spacecraft technology and advanced reentry test) program.

Under these programs, the same SV-5 lifting-body shape was tested at both extremes of its speed range—X-23A tested the very-high speed reentry phase; X-24A tested the low-speed landing characteristics. To study the effects of reentry on the ablative heat shield, the X-23A vehicles was intended to be recovered in mid-air by parachute.

The X-23A represented a major step forward in understanding the requirements imposed by atmospheric reentry on a maneuvering vehicle. Additionally, information was gathered on the effectiveness of its ablative heat shield, and on the possibility of refurbishing such a heat shield for multiple uses. The information derived from the X-23A program assisted the designers of the Space Shuttle and various maneuvering warhead projects in determining their requirements.

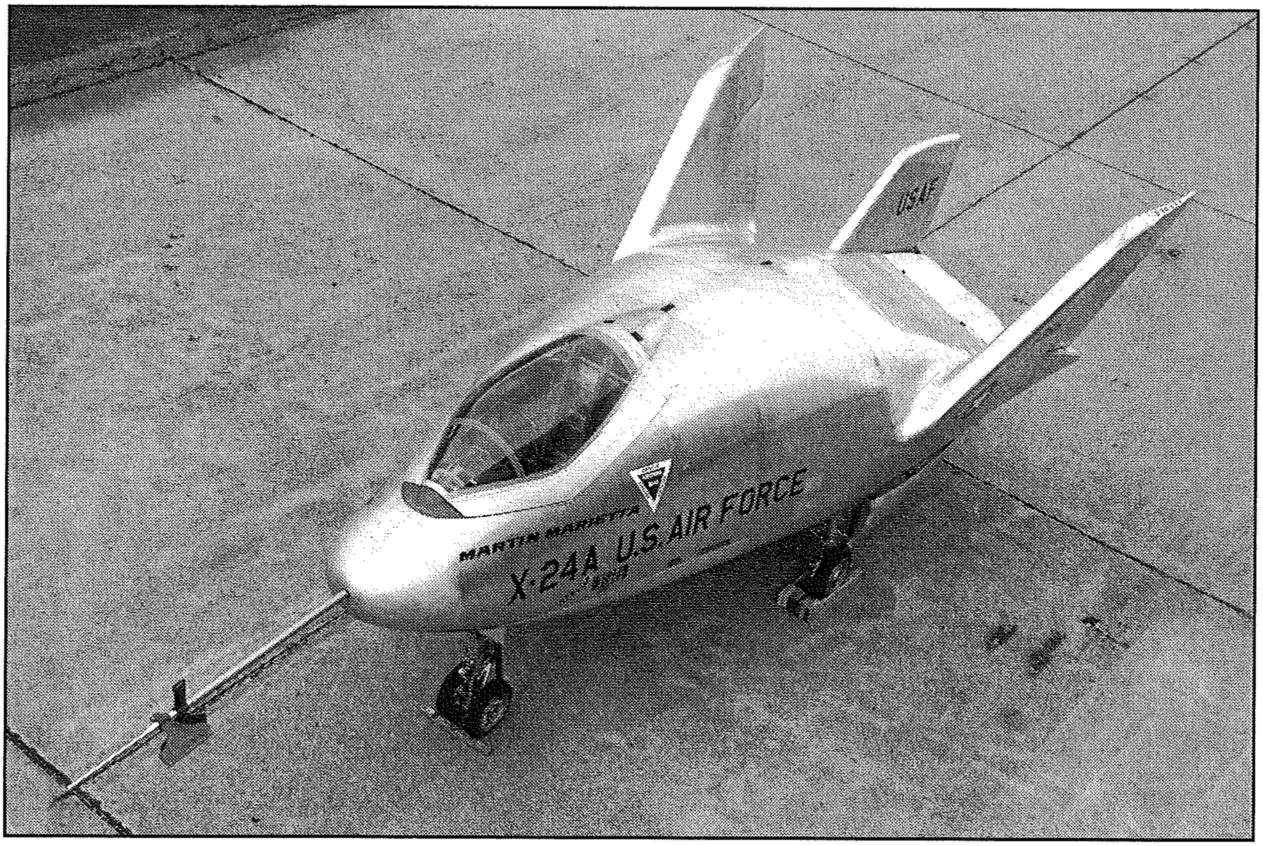
Four X-23As were manufactured, and three were launched using SLV-3 Atlas launch vehicles from SLC-3E at Vandenberg AFB, California. The first two vehicles were not recovered, but the third was and is currently on display at the Air Force Museum. There is no record of the disposition of the fourth vehicle.



The X-23A/SVD-5D program represented a major step forward in the design of maneuvering reentry vehicles, and provided valuable data for the eventual design of the Space Shuttle Orbiter. *This is the recovered third X-23A, currently on display at the Air Force Museum.* (Martin Marietta via the Jay Miller Collection)

Martin Marietta Corporation X-24

First Flight:	17 April 1969	**Sponsors:**	USAF, NASA
Last Flight:	4 June 1971	**Fastest Flight:**	Mach 1.60 (1,036 mph)
Total Flights:	28	**Highest Flight:**	71,400 feet



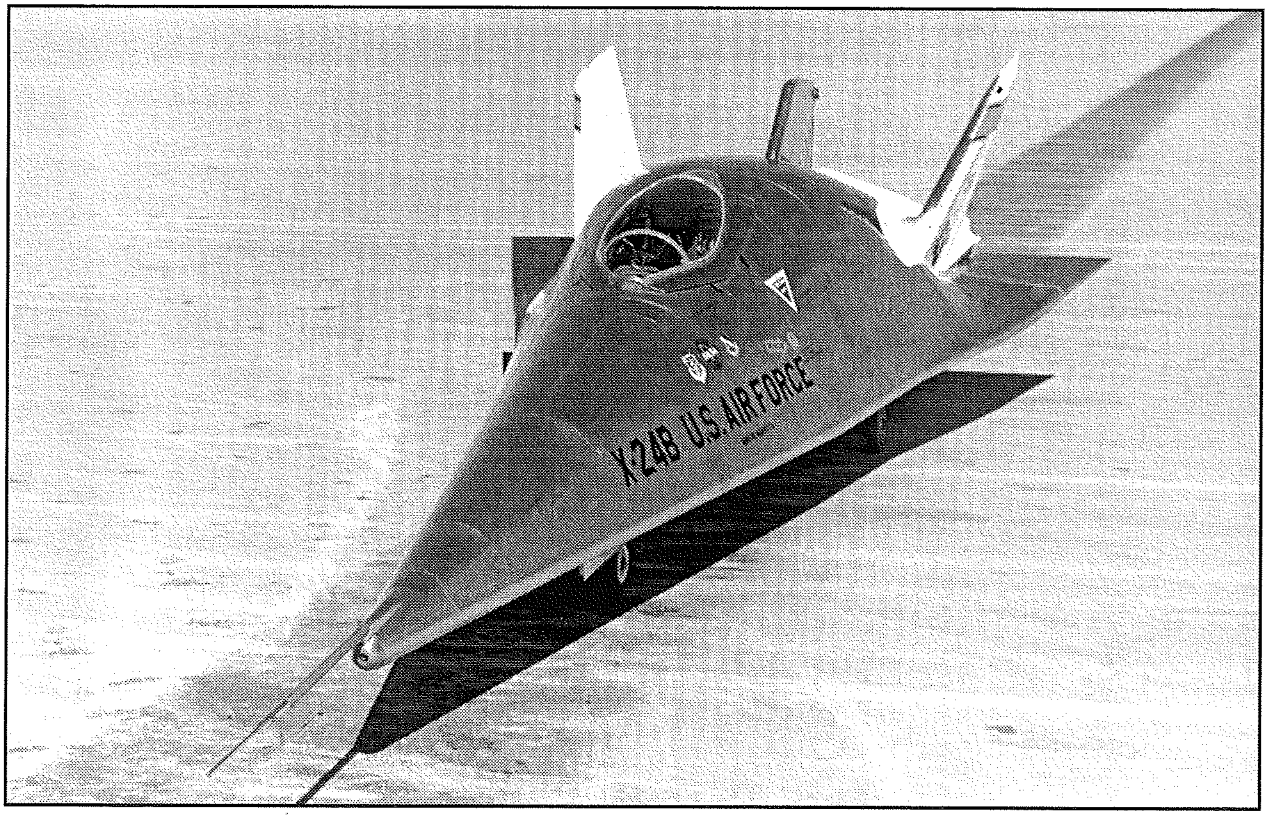
The shape of the X-24A was essentially an enlarged X-23A. Unlike the X-23A, which was designed to explore high-speed flight, the X-24A was designed to explore the low-speed and landing stability of the design. (Martin Marietta via the Jay Miller Collection)

The X-24A (SV-5P) represented the low-speed end of the test spectrum for the START program that had also tested the X-23A. The X-24A was used in Project PILOT (piloted low-speed tests). The rocket-powered X-24A was specifically designed to explore the low-speed flight characteristics of a maneuverable lifting-body design. The design was essentially identical to the SV-5D used in Project PRIME as the X-23A, allowing both ends of the flight spectrum to be tested on the same shape. The X-24A decisively demonstrated that lifting-bodies could consistently make precision landings onto a hard runway, proving the concept for the future Space Shuttle.

Only a single X-24A was manufactured, but two extremely similar jet-powered SV-5Js were also built. The SV-5Js were to be powered by a single J60 turbojet engine and used as trainers to introduce pilots to the low-speed handling characteristics of lifting-bodies, but in the end neither aircraft ever flew. One of the SV-5Js is on display at the Air Force Academy near Colorado Springs, Colorado, , while the other has been superficially modified into an X-24A and is on display at the Air Force Museum. The X-24A itself was heavily modified to become the X-24B.

X-24B Martin Marietta Corporation

First Flight:	01 August 1973	**Sponsors:**	USAF, NASA
Last Flight:	09 September 1975	**Fastest Flight:**	Mach 1.76 (1,164 mph)
Total Flights:	36	**Highest Flight:**	74,140 feet



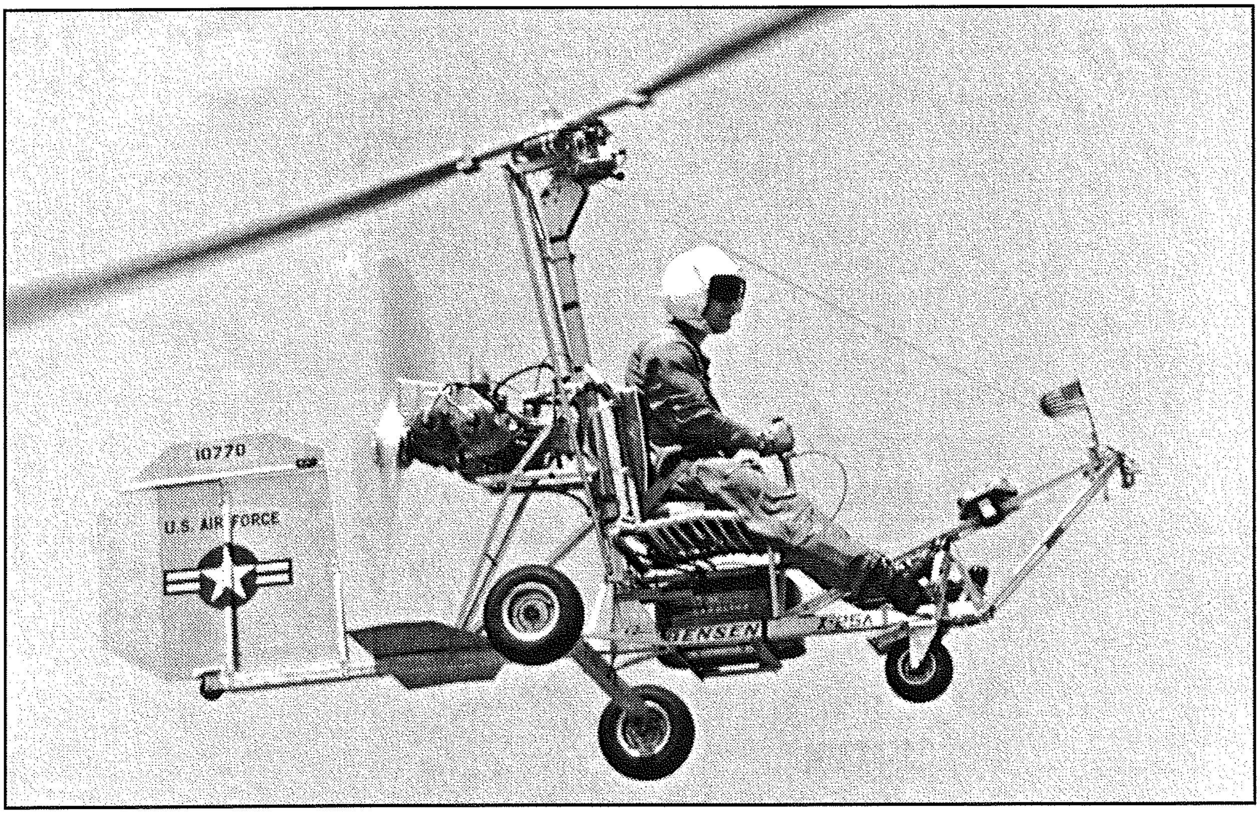
Underneath the sleek skin of the X-24B lurked the original X-24A. The streamlined shape was designed by the Air Force Flight Dynamics Laboratory as the FDL-7/FDL-8. (Martin Marietta via the Jay Miller Collection)

Although the X-24A program successfully met all of its objectives, engineers and scientists at the Air Force Flight Dynamics Laboratory (FDL) wanted to conduct similar tests on an even more advanced lifting-body shape called the FDL-7/FDL-8. The original plan was to convert one of the jet-powered SV-5Js into the advanced test bed, but since this would have entailed extensive modifications to fit a rocket engine in place of the turbojet, these plans were shelved. As the rocket-powered X-24A was nearing the end of its test program, it was finally decided to utilize it instead since the modifications were expected to be less extensive.

Underneath the sleek shell of the X-24B lived the original X-24A—the new skin was essentially "gloved on" to the original aircraft. Most systems were retained intact. Although the X-24B was intended to evaluate the flight characteristics of the FDL-7 shape, in reality it spent most of its 36 flights demonstrating precision landing techniques that would be used on the forthcoming Space Shuttle. When Bill Dana completed the X-24B's final flight on 9 September 1975, it marked the end of rocket-powered research aircraft at Edwards—at least for 25 years. The X-24B is currently on display at the Air Force Museum, alongside one the the SV-5Js configured as the X-24A.

Bensen Aircraft Corporation X-25

First Flight:	5 June 1968	**Sponsors:**	USAF
Last Flight:	1968	**Fastest Flight:**	85 mph
Total Flights:	Unknown	**Highest Flight:**	12,500 feet



A small 4-cylinder air-cooled McCulloch piston engine mounted directly behind the pilot powered the rotor system of the X-25A. Three different versions of the X-25 were manufactured. (Bensen Aircraft via the Jay Miller Collection)

The X-25 program was begun in response to a perceived need for an emergency egress capability for downed pilots. The vehicle was part of the Air Force's Discretionary Descent Vehicle (DDV) program intended to give aircrew members forced to abandon their aircraft an option of landing somewhere other than where wind and gravity dictated.

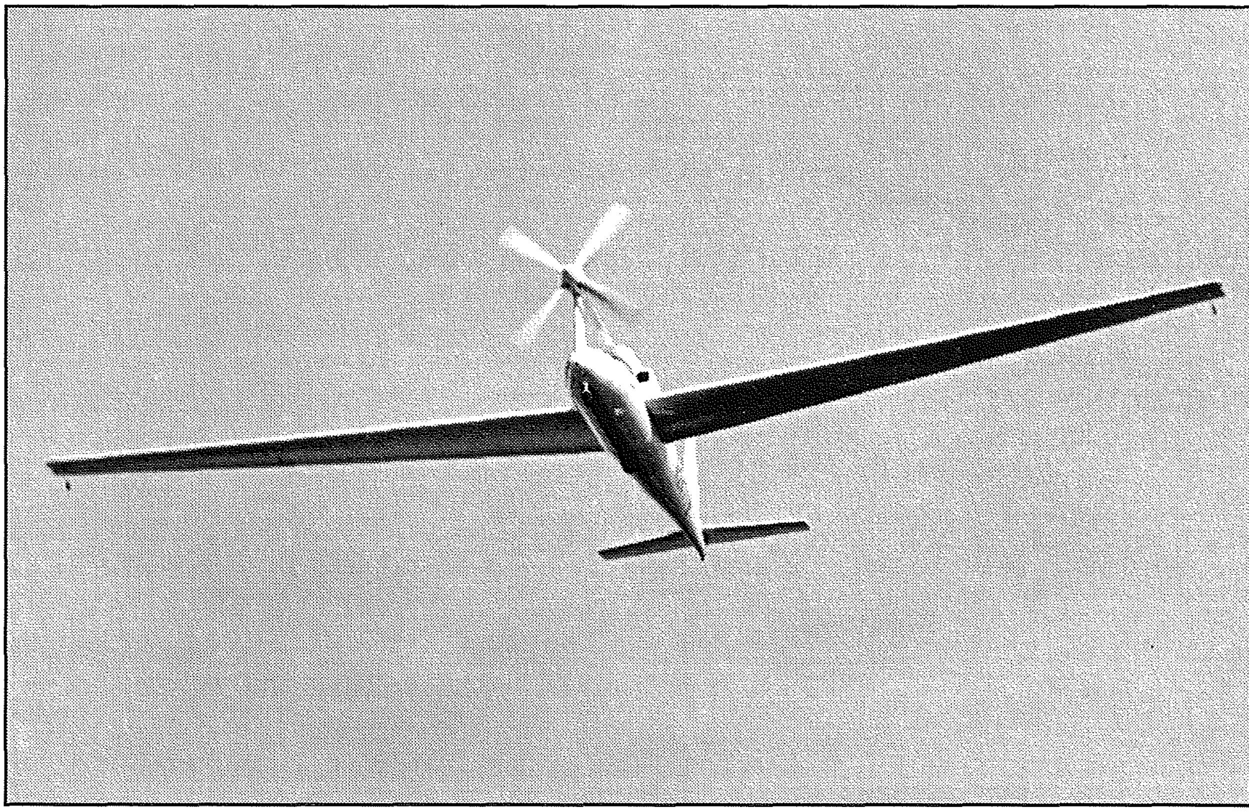
The concept was to equip combat aircraft with a small ultralight autogryo that could be used by the aircrew. To test the concept, modified versions of the well-known Bensen autogyro were ordered, and three vehicles were manufactured—an X-25, X-25A, and X-25B. The basic X-25 was termed a "gyro-chute" and was unpowered. It was intended for one-time use and had a rotor system designed for automatic blade deployment at any ejection speed, including supersonic. As far as is known, no piloted tests were ever conducted with this vehicle. The other two X-25s were used to evaluate piloting techniques and training requirements of the autogyro. The end of the war in Vietnam caused the Air Force to lose interest in the DDV concept, and no full-scale operational tests were ever conducted.

One X-25A is currently in the Air Force Museum in Dayton, Ohio, while another is on display at another museum.

X-26

Lockheed / Schweizer

First Flight:	3 July 1962	**Sponsors:**	DARPA, USA, USN
Last Flight:	1973	**Fastest Flight:**	158 mph
Total Flights:	Unknown (many)	**Highest Flight:**	18,500 feet



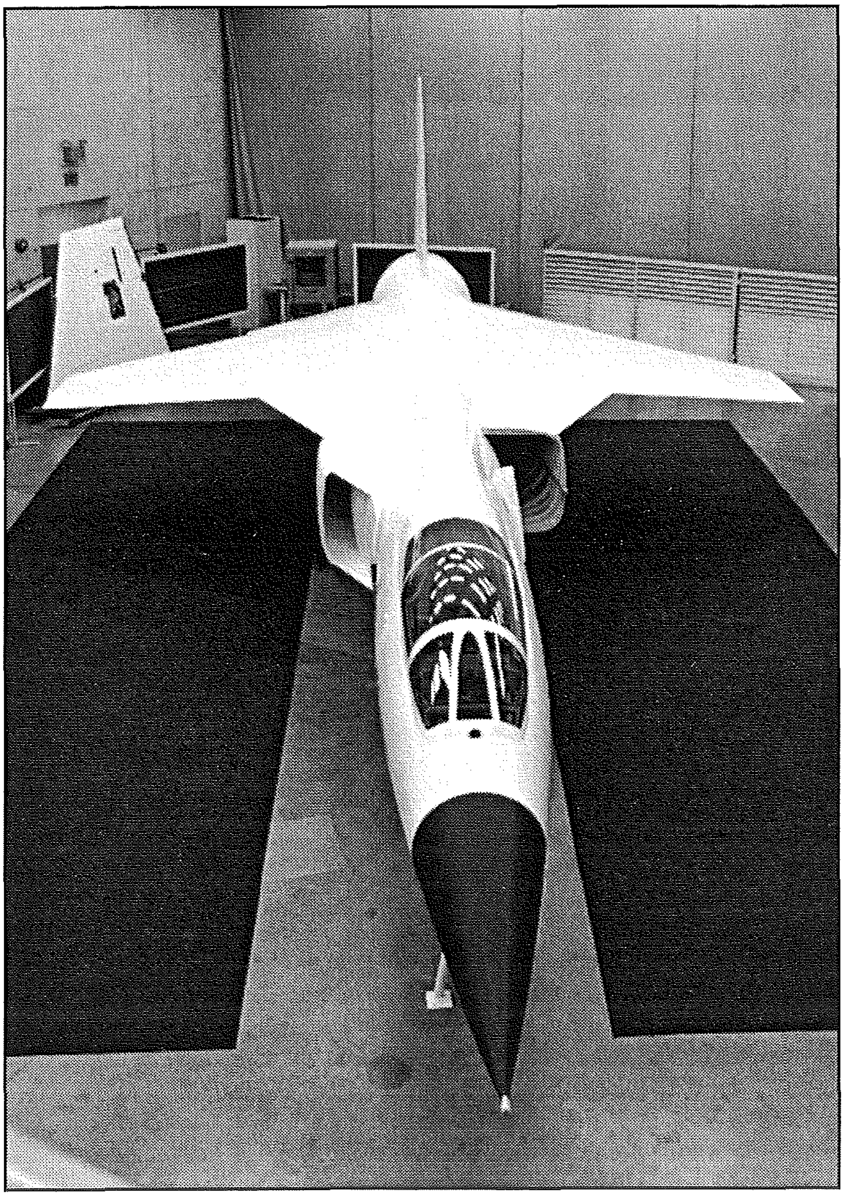
The X-26As were unpowered gliders used by the Navy Test Pilot School. This is an X-26B, a powered derivative used as a stealthy observation aircraft. (Lockheed via the Jay Miller Collection)

The X-26A was a Schweizer SGS 2-32 sailplane that was used by the Navy to expose novice pilots to the phenomenon of yaw/roll coupling. Conventional jet trainers reacted much too quickly and dangerously for effective instruction—an aircraft that had unusually slow roll rates and excellent recovery characteristics was needed instead. Four of the gliders were originally delivered, but accidents soon claimed three of them. In each case the aircraft was replaced with a new one, and the training program continues to this day, making the X-26 the longest-lived X-Plane.

The Lockheed X-26B was created in response to a requirement for a stealth-type observation aircraft in Vietnam. Two of the Navy X-26A aircraft were temporarily modified with small engines and slow-speed propellers, and were eventually equipped with a variety of intelligence-gathering sensors. Testing in Vietnam was evidently successful as 14 further aircraft were acquired under various designations, including 11 YO-3As. The original X-26As were demodified and returned to the Navy after the construction of the YO-3As. At least one of the YO-3As was later used by NASA as an acoustical signature research tool. One X-26B and a YO-3A are preserved in the Army Aviation Museum at Fort Rucker, Alabama.

Lockheed-California Company X-27

First Flight:	None	**Sponsors:**	Lockheed-California
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



The X-27 was a major modification of the Lockheed F-104 Starfighter designed as an advanced lightweight fighter for foreign sales. The project did not progress beyond the mockup stage when the U.S. Air Force declined to purchase a version of the aircraft. (Lockheed via the Jay Miller Collection)

The X-27 Lancer program can trace its roots to a Lockheed desire to develop a replacement for the F-104 Starfighter that was in wide service around the world. Lockheed's goal was to create a new aircraft with considerably improved performance while maintaining significant commonality with the F-104 to ease maintenance and training concerns.

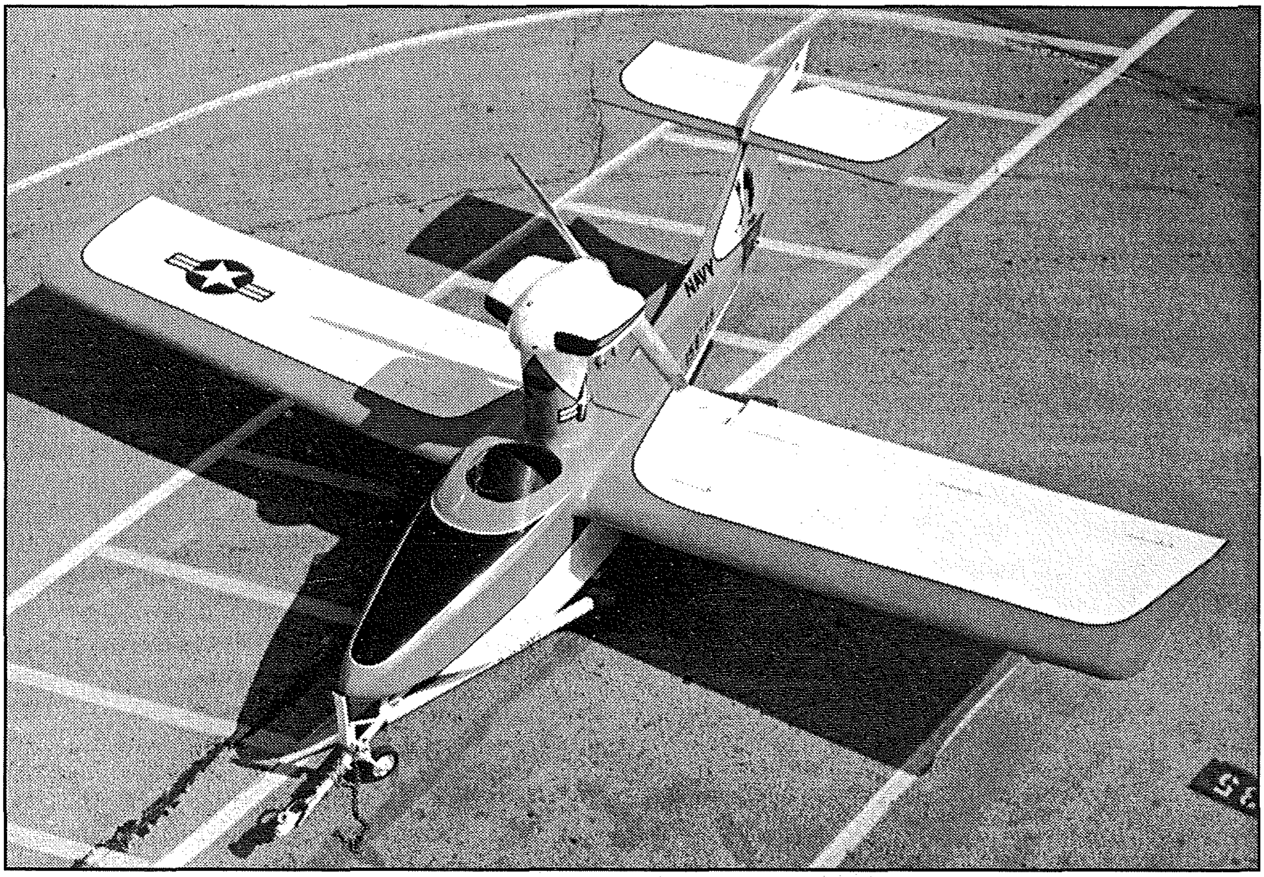
The X-27 was conceived as the prototype of the desired advanced lightweight fighter and was based on the CL-1200 Lancer design developed by the Lockheed Skunk Works. The program, however, failed to obtain any significant congressional or DoD support, and no actual aircraft were built. Nevertheless, a full-scale mockup was completed.

In the end, the X-27 program was a lesson in political maneuvering as much as technological advances. Lockheed's Kelly Johnson almost managed to get official backing of a commercial program, but in the end was defeated by military services that did not want to see competition for the funding necessary to complete the F-14 and F-15 programs.

Eventually the Air Force and Navy would embrace the lightweight fighter concept with the F-16 and (sort of) F/A-18, but Lockheed would not be a participant.

X-28 George Pereira / Osprey Aircraft

First Flight:	12 August 1970	**Sponsors:**	USN
Last Flight:	22 October 1971	**Fastest Flight:**	135 mph
Total Flights:	Unknown	**Highest Flight:**	18,000 feet



The X-28A was equipped with a simple constant-chord wing. The entire trailing edge, except for a small area near the root, was occupied by flaps and ailerons. The small size of the cockpit is noteworthy. (Howard Levy via the Jay Miller Collection)

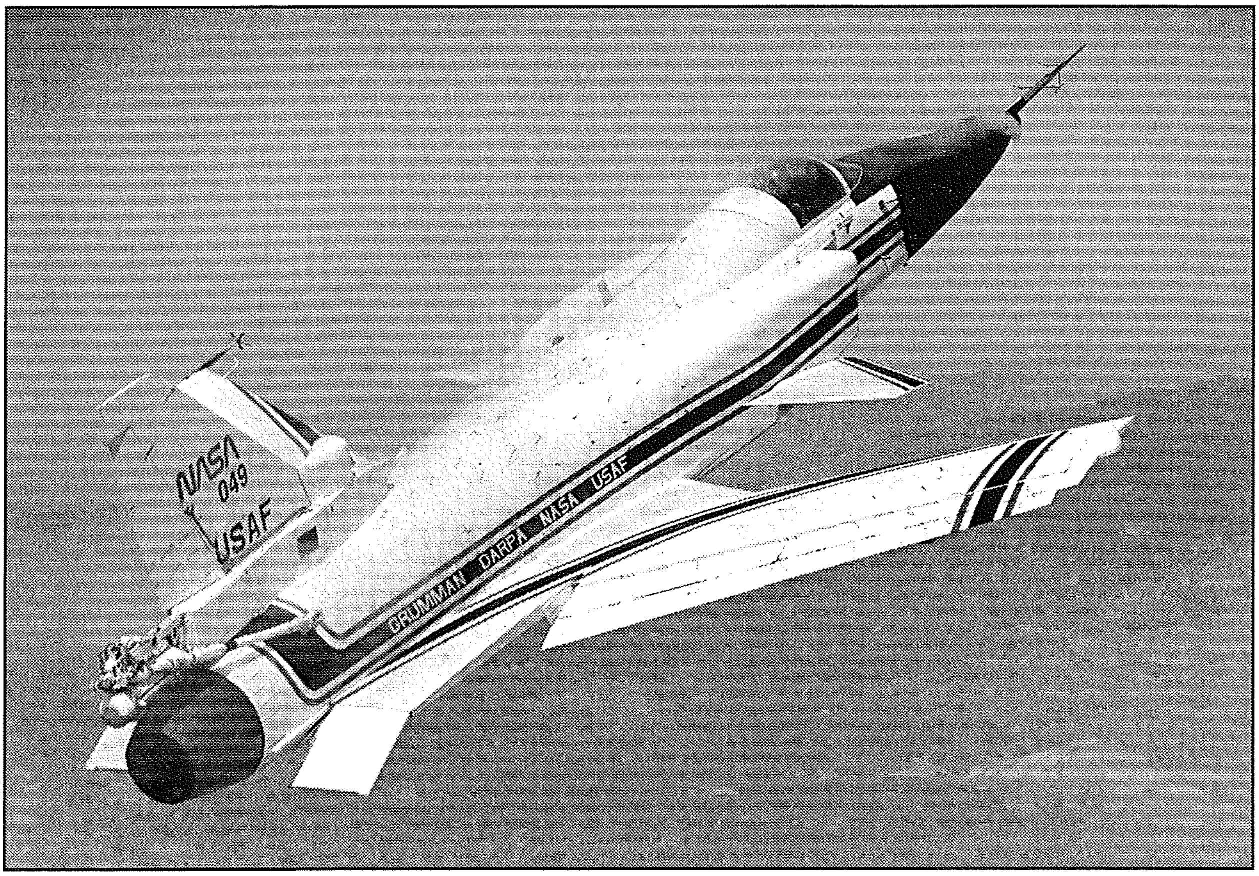
The homebuilt Osprey I was ordered by the Navy as the X-28 in response to a study that indicated the potential usefulness of a small single-engine seaplane for police-type duties in Southeast Asia. The Naval Air Development Center acquired the aircraft as part of the Air Skimmer program. The only requirements levied on the program were that the aircraft be small, lightweight, capable of VFR flight, able to be manufactured in Southeast Asia without a major tooling investment, and cost under $5,000 when purchased in quantity.

The Navy evaluation of the X-28A showed that it was generally easy to fly and that most pilots would have no trouble mastering it. Performance was considered exceptionally good considering its 90 horsepower engine.

The single X-28 is currently at the Mid-America Air Museum in Sioux City, Kansas. Numerous other versions of the Osprey I design have been built by individuals around the country.

Grumman AeroSpace Corporation X-29

First Flight:	14 December 1984	**Sponsors:**	DARPA, USAF, NASA
Last Flight:	30 September 1991	**Fastest Flight:**	Mach 1.8 (1,100 mph) (approx)
Total Flights:	442	**Highest Flight:**	55,000 feet (approx)



The X-29A proved many of the advantages of the forward swept wing, but also showed that the configuration generated a great deal more drag in some flight regimes than expected. (Grumman via the Jay Miller Collection)

The concept of the forward swept wing had been tested during World War II, but it was soon found that this type of wing must be thin to be maneuverable. When these early tests were conducted, strong lightweight materials were not readily available. It was not until the late 1970s and 1980s that these materials were available and could be incorporated into high speed aircraft.

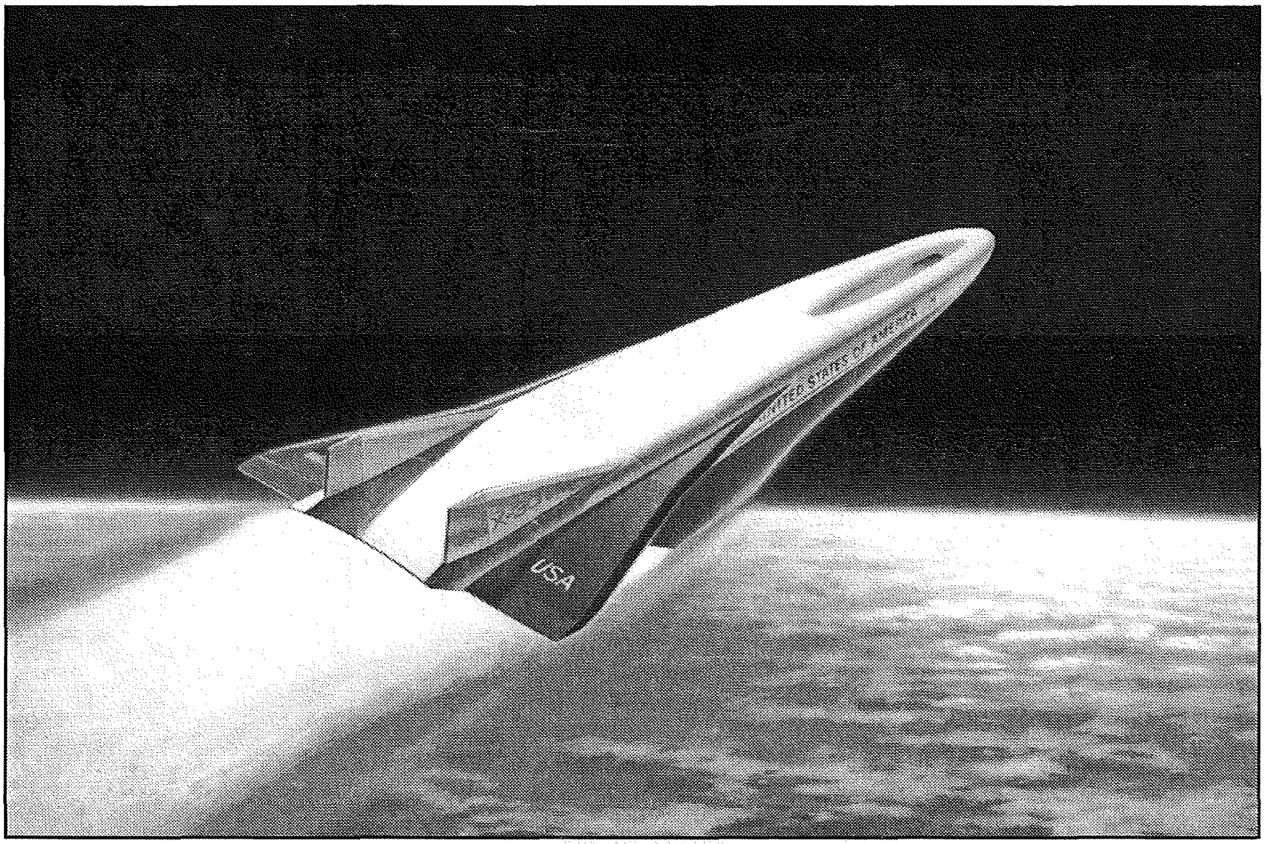
Two X-29As were built and flown—each served as test bed for multiple missions including aerodynamics, composite building techniques, and advanced avionics. Although most X-29A flights were conducted from Edwards AFB, one X-29A was flown to the Dayton (Ohio) International Air Show and to the Experimental Aircraft Association's (EAA) International Convention and Sport Aviation Exhibition at Oshkosh, Wisconsin.

One of the X-29s is at the Air Force Museum; the other is at the National Air and Space Museum.

X-30

National Team

First Flight:	None	**Sponsors:**	DARPA, USAF, NASA
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



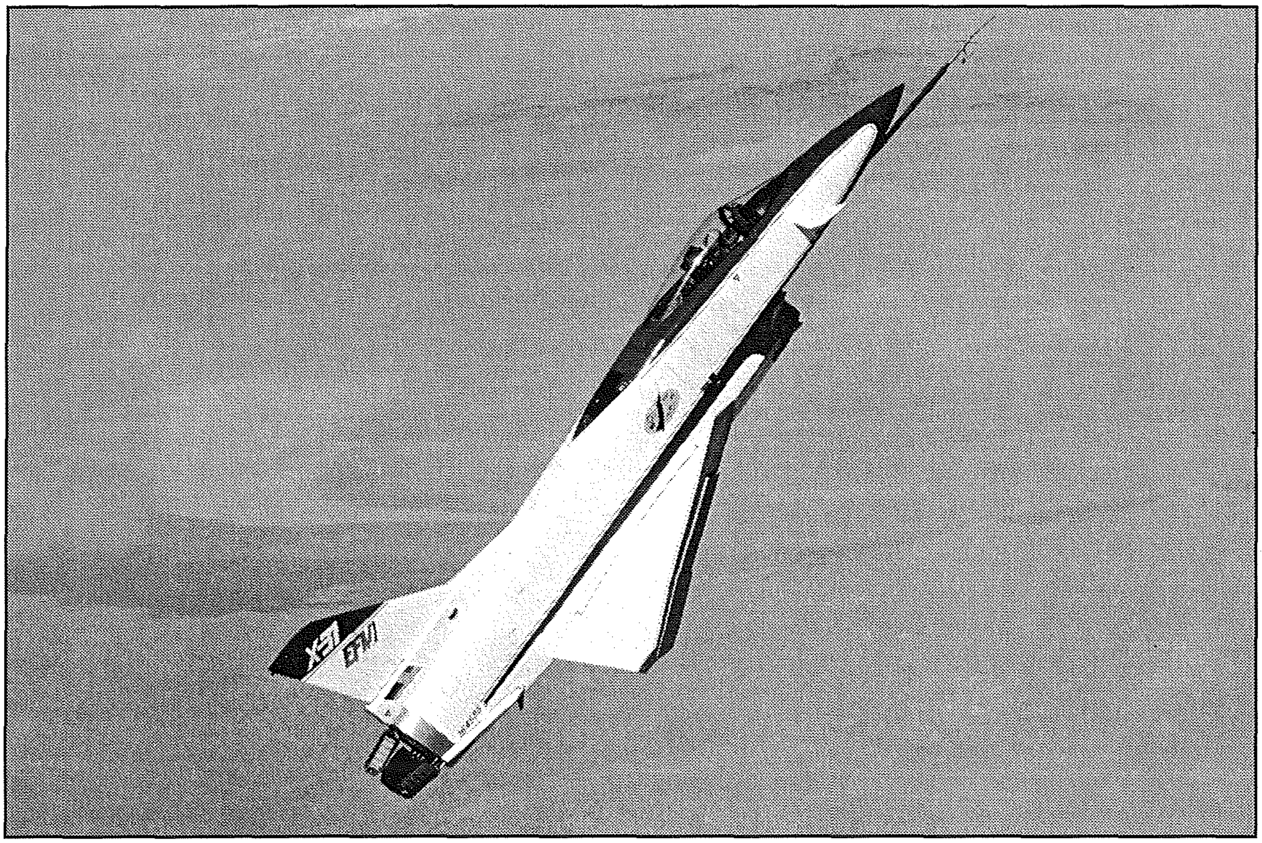
Begun as part of President Reagan's "Orient Express" initiative, the X-30 ultimately proved to be too advanced for the available budget. Nevertheless, the program did prove instrumental in developing a great many new technologies. (Dennis R. Jenkins Collection)

The program to develop what was called the National AeroSpace Plane (NASP) had its roots in a highly classified Defense Advanced Research Projects Agency (DARPA) project called Copper Canyon that ran from 1982 to 1985. Originally conceived as a feasibility study for a single-stage-to-orbit (SSTO) vehicle that could take off and land horizontally, Copper Canyon became the starting point for what Ronald Reagan called "... a new Orient Express that could, by the end of the next decade, take off from Dulles Airport and accelerate up to twenty-five times the speed of sound, attaining low-Earth orbit or flying to Tokyo within two hours..." It was not to be.

In an ambitious program that involved every major aerospace company in the U.S., DARPA proposed building a prototype NASP designated X-30. Unfortunately, the X-30 ran into significant cost and technical difficulties, resulting in its cancellation. The Hypersonic Systems Technology Program (HySTP), initiated in late 1994, was designed to transfer the accomplishments made in hypersonic technologies by the NASP program into a technology development program. The X-43A Hyper-X is one of the results of the HySTP program.

Rockwell International / MBB X-31

First Flight:	11 October 1990	**Sponsors:**	DARPA, USN, German MoD
Last Flight:	Unknown	**Fastest Flight:**	Mach 1.28 (900 mph)
Total Flights:	300+	**Highest Flight:**	40,000 feet (approx)



The X-31 was designed to investigate extremely high angle-of-attack maneuverability and its potential application to future fighter aircraft. It represents one of the few X-Planes built in cooperation with a non-U.S. agency. (Rockwell via the Jay Miller Collection)

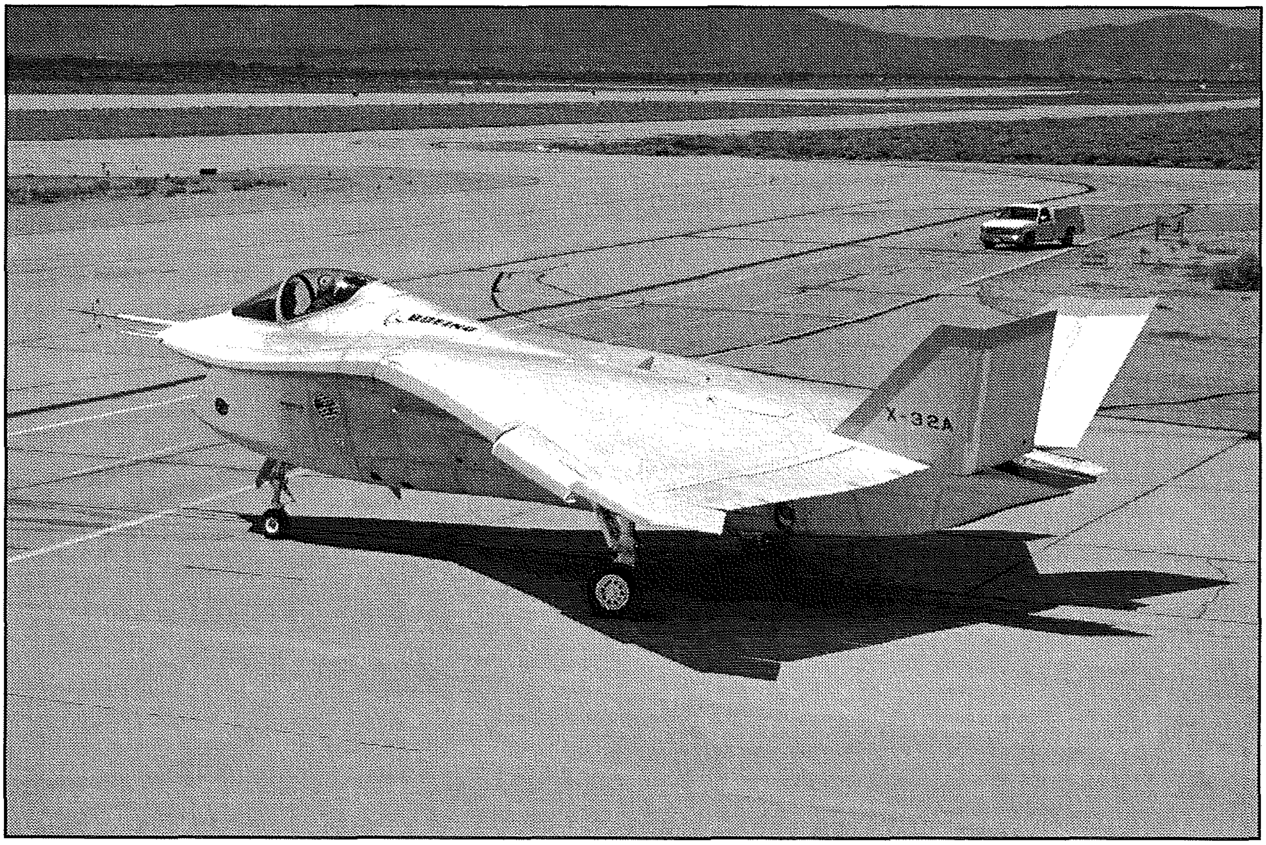
The X-31 was designed to break the "stall barrier," allowing it to flight at angles of attack which would typically cause an aircraft to stall with a complete loss of control. The X-31 program demonstrated the use of redirected engine exhaust (thrust vectoring) coupled with advanced flight control systems—the X-31 was able to maintain controlled flight through extremely high angles of attack. The X-31 employed thrust vectoring paddles which were located in the jet exhaust and utilized small computer-controlled canards to help keep the aircraft stable at high attack angles.

A total of 160 flights were completed by the X-31 program during 1993 setting a new annual experimental aircraft record. One of the two X-31s flew 103 of those flights. The program also set a new monthly record of 21 research flights in August 1993. The first X-31 was lost on 19 January 1995—the pilot, Karl Lang, ejected safely at 18,000 feet before the aircraft crashed into an unpopulated region of the desert just north of Edwards AFB. The second X-31 remains at the Dryden Flight Research Center.

X-32

The Boeing Company

First Flight:	Pending	**Sponsors:**	USAF, USN, USMC, RAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



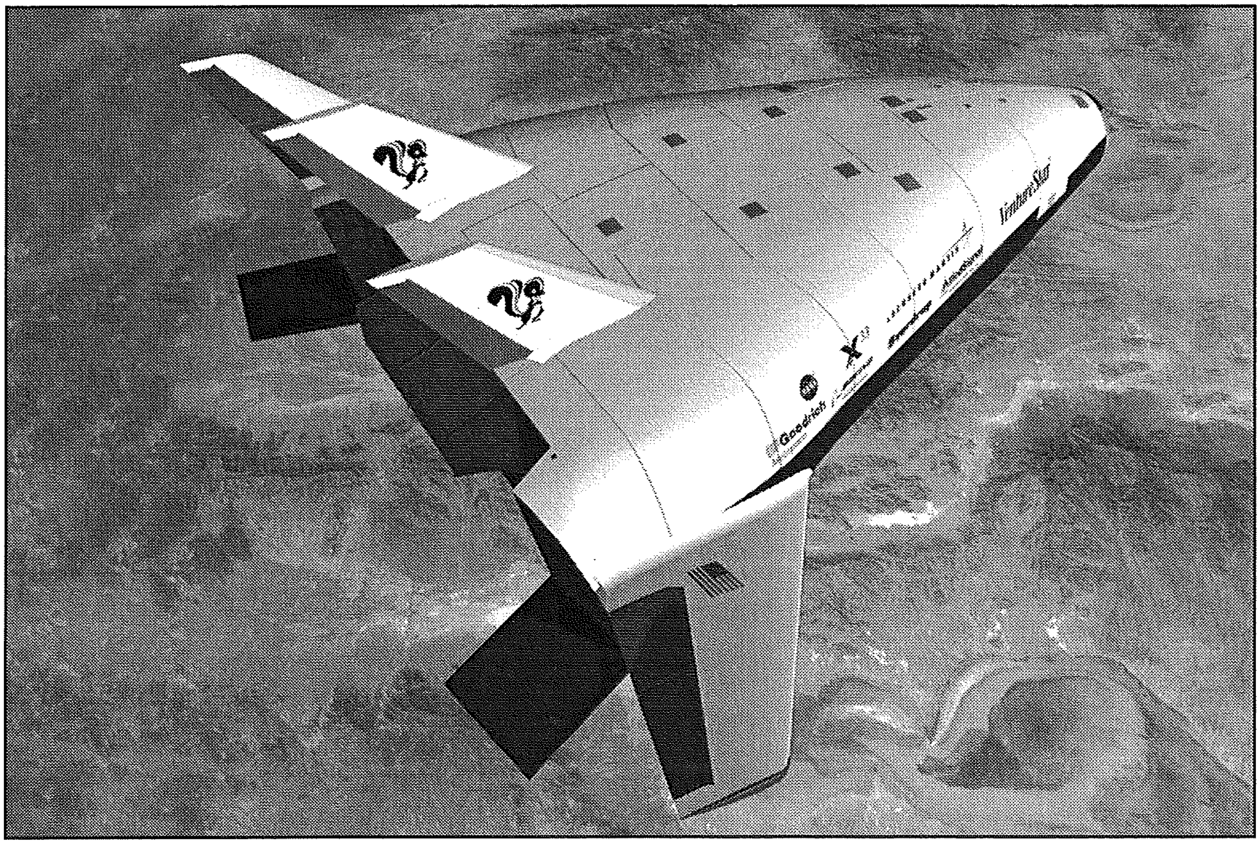
The X-32A completed low- and high-speed taxi tests at Palmdale on 23 May 2000 in preparation for its first flight sometime during the summer. (Boeing via the Dennis R. Jenkins Collection)

The X-32 is a prototype of Boeing's entry in the Joint Strike Fighter (JSF) program. The two X-32 concept demonstrators will demonstrate 1) commonality across the variants, including design/build processes, 2) the Boeing direct-lift propulsion concept for short takeoff/vertical landing (STOVL) hover and transition, and 3) low-speed carrier approach flying qualities. The X-32A is the conventional takeoff and landing variant for the U. S. Air Force and U. S. Navy, while the X-32B is the STOVL variant for the U. S. Marine Corps and the British Royal Air Force and Royal Navy. The Boeing X-32A employs a direct-lift system for short takeoffs and vertical landings instead of using vectored-thrust like the Harrier and the Lockheed martin JSF concept.

Boeing is competing with Lockheed Martin (see X-35) for what will most likely be the largest military aircraft contract of the early twenty-first century. With a planned purchase of up to 2,000 aircraft, the Air Force is the largest customer for JSF; the Marines plan to purchase more than 600 aircraft; and the U.S. Navy another 300. The British are looking to procure 60-90 JSFs to replace Harriers and Sea Harriers.

Lockheed Martin Corporation X-33

First Flight:	Pending	**Sponsors:**	NASA, Lockheed Martin
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



The first flight of the X-33 technology demonstrator has been delayed by test failures of its composite propellant tanks. The final design has evolved considerably from the early configuration studies. (Lockheed Martin via the Dennis R. Jenkins Collection)

The X-33 is a half-scale prototype of a Reusable Launch Vehicle (RLV) called VentureStar® being proposed by Lockheed Martin. Lockheed has resurrected a variation of the lifting-body concept for the vehicle, albeit one with small wings and vertical stabilizers. The X-33 itself is being designed and built as part of a "cooperative agreement" between NASA and an industry team led by Lockheed Martin that includes Boeing (Rocketdyne), B. F. Goodrich (formerly Rohr Industries), Honeywell (formerly AlliedSignal), and Sverdrup.

The X-33 is intended to demonstrate the key technology necessary to build VentureStar, including the unique aerospike engines, composite liquid hydrogen tanks, a metallic thermal protection system, and an austere launch site environment. Originally, 15 test flights from Edwards AFB to landing sites in Utah and Montana were to be completed by the end of 1999, but technical problems manufacturing the composite propellant tanks have pushed the flights back to 2001 at the earliest. The demonstrator was to have flown at Mach 15, but this has recently been scaled back to Mach 13 and may be further lowered to Mach 10-11 before the flight program gets underway.

X-34 Orbital Sciences Corporation

First Flight:	Pending	**Sponsors:**	NASA
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable

Unlike most earlier air-launched X-Planes that were carried aloft by converted B-29, B-50, or B-52 bombers, Orbital Sciences uses their specially modified Lockheed L1011 to carry the X-34. (NASA photo by Tony Landis via the Dennis R. Jenkins Collection)

The X-34 is a reusable test bed vehicle that is designed to demonstrate technologies that are essential to lowering the cost of access to space. Specific technologies to be demonstrated by the X-34 include advanced composite structures, a composite RP-1 fuel tank, an advanced thermal protection system, and autonomous flight operations. Three X-34 vehicles are being manufactured, and the first flight will take place in late 2000. The all-composite vehicle should be capable of speeds up to Mach 8 and altitudes of 250,000 feet.

The project will also demonstrate low cost flight operations, and has a goal of reaching a recurring cost of only $500,000 per flight and demonstrating a rate of 24 flights in 12 months while maintaining a small workforce. A typical X-34 flight will consist of dropping from the L1011, engine start and acceleration to the planned Mach number and altitude, a coast phase, followed by reentry and landing. Aircraft-type elevons, rudder, body flaps, and speed brake provide control and trim during unpowered flight, aided by reaction control during the high-altitude coast phase.

Lockheed Martin Corporation X-35

First Flight:	Pending	**Sponsors:**	USAF, USN, USMC, RAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable

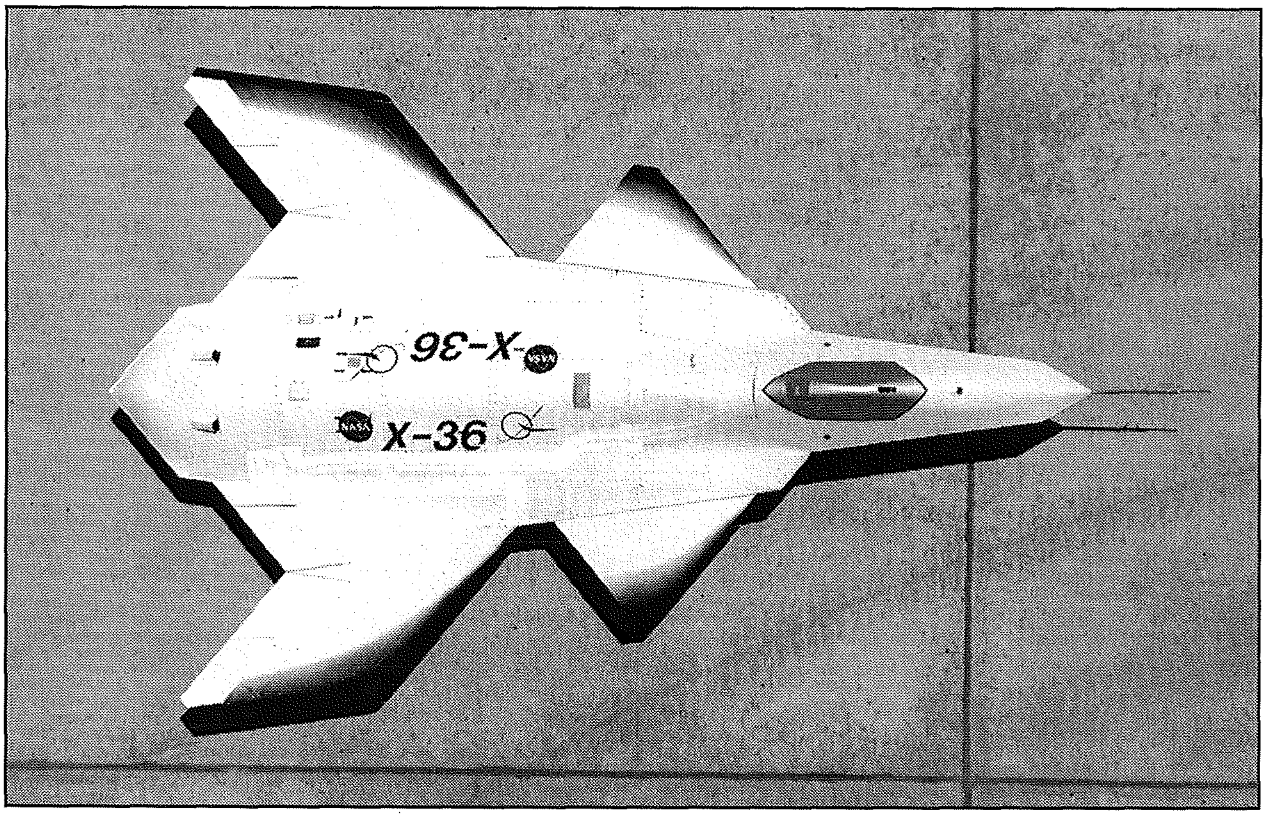
The first of the X-35 demonstrators taxies at Palmdale prior to its first flight. Note the faceted intakes on the side of the fuselage and the family resemblance to the F-22. (Lockheed Martin via the Dennis R. Jenkins Collection)

The Joint Strike Fighter (JSF) is a multirole fighter optimized for the air-to-ground role, designed to affordably meet the needs of the Air Force, Navy, Marine Corps, and allies, with improved survivability, precision engagement capability, the mobility necessary for future joint operations and the reduced life cycle costs associated with tomorrow's fiscal environment. The Lockheed Martin JSF will benefit from many of the same technologies developed for F-22 and will capitalize on commonality and modularity to maximize affordability. The JSF program likely will be the largest defense-procurement program in U.S. history.

The Lockheed Martin JSF concept for the Marine and Royal Navy variants uses a shaft-driven lift-fan system to achieve a STOVL capability. The aircraft will be configured with a Rolls-Royce/Allison shaft-driven lift-fan, roll ducts, and a three-bearing swivel main engine nozzle; all coupled to a modified Pratt & Whitney F119 main engine that powers all three variants. One of the X-35 prototypes will be configured as the STOVL variant while the other will demonstrate the conventional Air Force design.

X-36 The Boeing Company

First Flight:	17 May 1997	**Sponsors:**	NASA, Boeing
Last Flight:	24 September 1997	**Fastest Flight:**	204 mph
Total Flights:	22+	**Highest Flight:**	20,500 feet



The X-36 vehicle photographed in 1997. (NASA photo EC97-44165-151 via the Dennis R. Jenkins Collection)

The 28-percent scale, remotely piloted X-36 had no vertical or horizontal tails, yet proved to be more maneuverable and agile than most modern fighters. In addition, the tailless design reduced the weight, drag, and radar cross section typically associated with traditional fighter aircraft. The X-36 also explored advanced flight control technologies, such as split ailerons and thrust vectoring. The ailerons not only split to provide yaw (left and right) control, but also raise and lower asymmetrically to provide roll control.

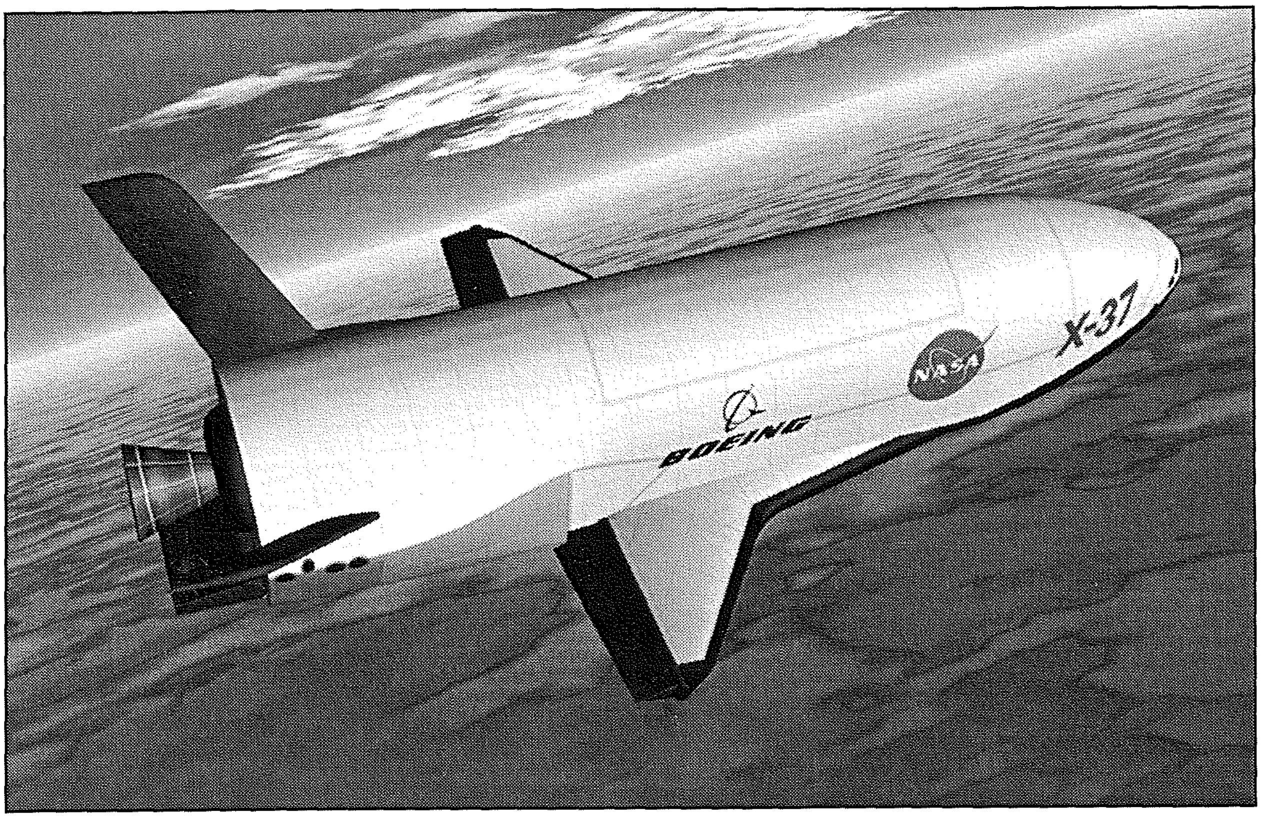
Boeing (formerly McDonnell Douglas) manufactured two X-36 vehicles, and the aircraft successfully completed all of its planned low- and high-g agility maneuvers, which demonstrated the aircraft's ability to quickly perform under a wide range of aerodynamic loads, and included 360-degree rolls at angles of attack (AoA) up to 15 degrees and rapid turning-rolling maneuvers at up to 35 degrees AoA.

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

The Boeing Company

X-37

First Flight:	Pending	**Sponsors:**	NASA, USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



An artist concept of the X-37 Future-X Pathfinder vehicle in orbit. (NASA via the Jay Miller Collection)

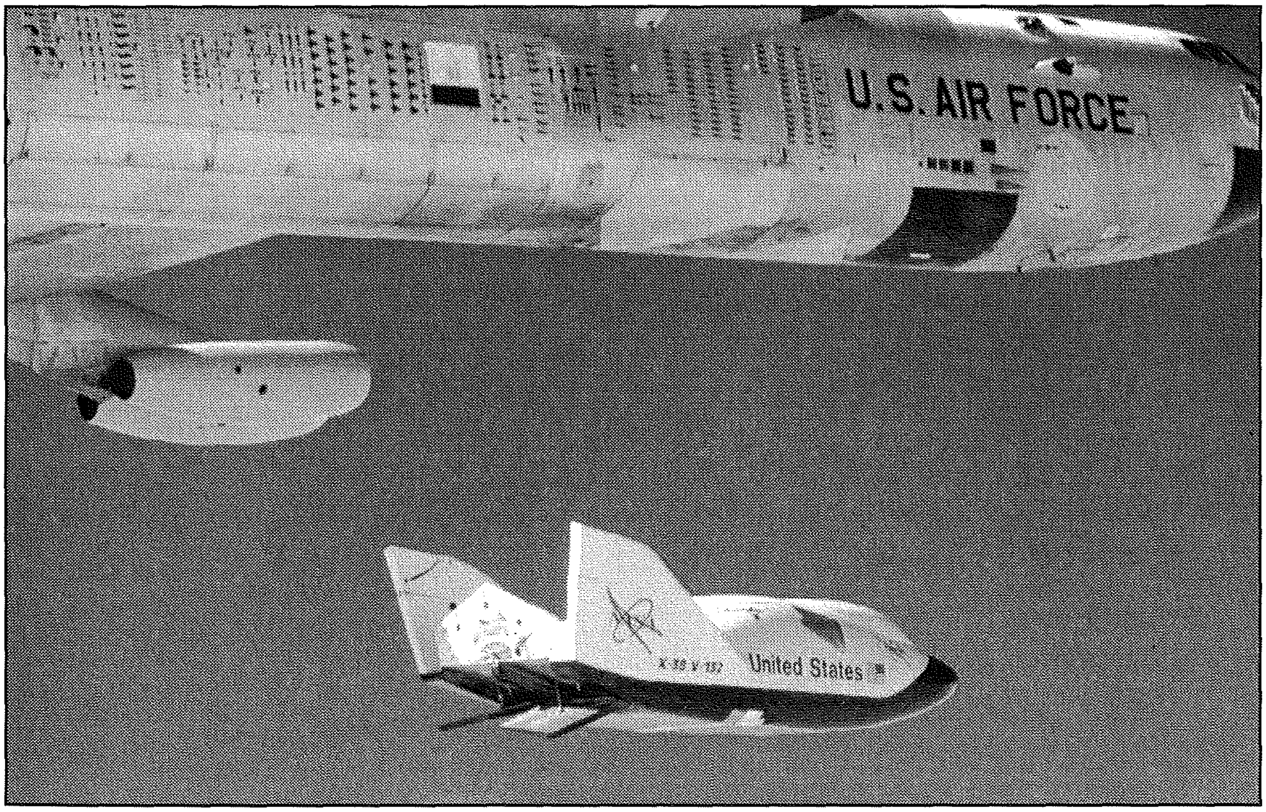
The X-37, formerly known as the Future-X Pathfinder, will make a series of atmospheric and orbital test flights to evaluate over 40 airframe, propulsion, and operations technologies designed to lower the cost of access to space. The X-37 will be launched aboard the Space Shuttle as a secondary payload—once on-orbit the Space Shuttle will deploy the X-37 from the Shuttle payload bay.

The X-37 is 27.5 feet long—about half the length of the Shuttle payload bay—and weighs about 12,000 pounds. It has a wing span of approximately 15 feet, and it contains an experiment bay 7 feet long and 4 feet in diameter that is designed to be modular to allow for rapid insertion of experiments. The X-37 vehicle is designed to be capable of at least 20 flights and landings.

The X-37 shape is identical to the X-40A developed for the Air Force, and recently the two programs have essentially been merged with the lone X-40A now serving as a prototype for the X-37. The X-37 was delivered to the Dryden Flight Research Center in May 2000.

X-38 NASA / Scaled Composites

First Flight:	12 March 1998	**Sponsors:**	NASA, ESA
Last Flight:	Continuing	**Fastest Flight:**	500 mph (approx)
Total Flights:	Continuing	**Highest Flight:**	39,000 feet



The X-38 atmospheric test vehicle (132) is released from the NB-52 at the Dryden Flight Research Center.
(NASA via the Jay Miller Collection)

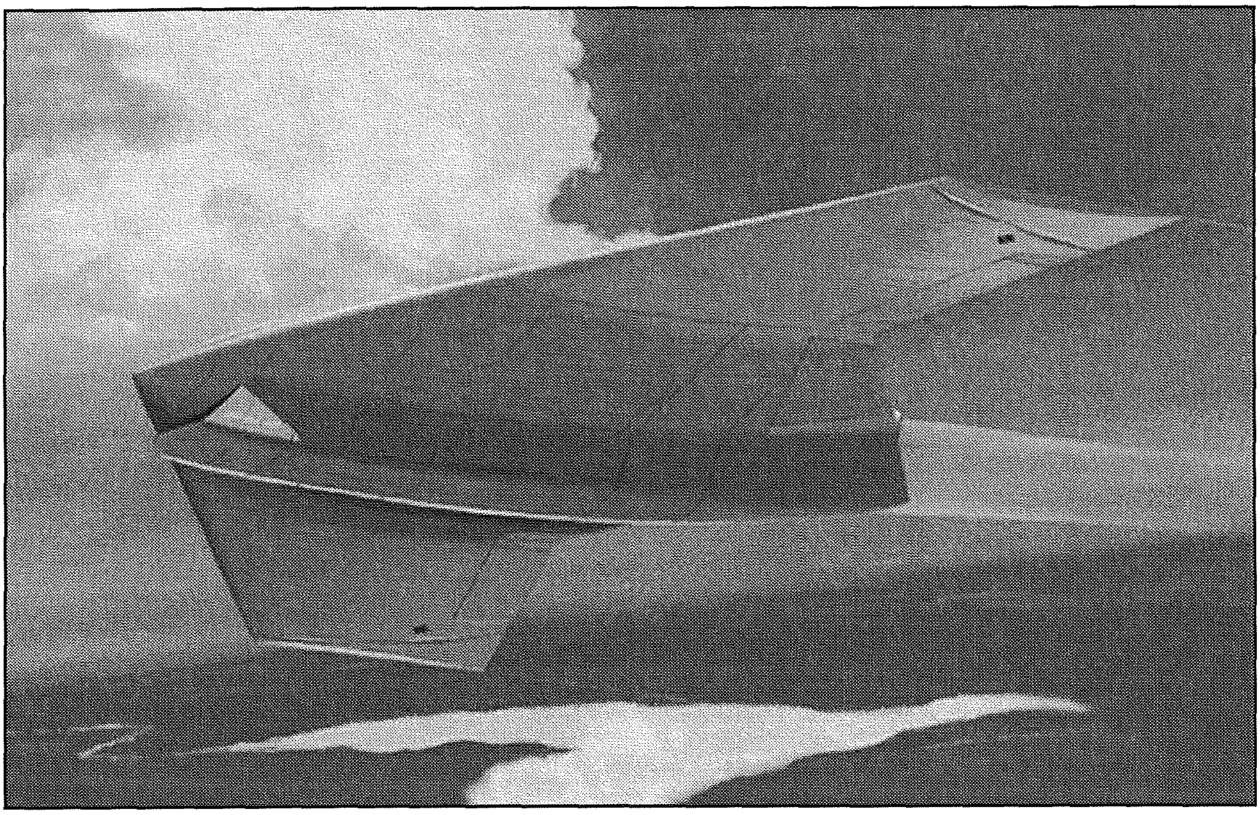
The X-38 is a conceptual demonstrator of a crew rescue vehicle (previously called an assured crew return vehicle—ACRV) for the International Space Station. The vehicles were designed in-house by the NASA Johnson Space Center with assistance from the Dryden Flight Research Center, and were manufactured by Scaled Composites.

The X-38 design uses a lifting body concept originally developed by the Air Force's X-24A in the mid-1960s. Following the jettison of a deorbit engine module, the X-38 will glide from orbit unpowered like the Space Shuttle and then use a steerable parafoil parachute, a technology developed by the Army, for its final descent to landing.

The first X-38, known as Vehicle 131, arrived at Dryden on 4 June 1997 aboard a C-17 transport aircraft and made its maiden flight in March 1998. The second aircraft, V132, was delivered to Dryden in September 1998 and has made four unpowered drop tests. V132 contains the full lifting body flight control system that allows the vehicle to fly autonomously prior to parafoil deployment. The first space flight vehicle, V201, has recently been delivered to Dryden, and the parafoils are undergoing continuous improvement tests at Yuma Proving Grounds.

Air Force Research Laboratory X-39

First Flight:	Pending	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



Speculative artist concept of a possible unmanned aerial vehicle that could be similar to the X-39.
(U.S. Air Force via the Dennis R. Jenkins Collection)

As of early 1999, the X-39 designator is apparently unassigned, but it is reportedly reserved for use by the Air Force Research Laboratory. The designation may be intended for sub-scale autonomous (no pilot) demonstrators planned under the Future Aircraft Technology Enhancements (FATE) program.

The FATE is intended to develop revolutionary technologies that will become the foundation for the next generation aerial vehicles and tactics. It will be these new systems that will provide the United States with air and space superiority in the 21st century. Examples of FATE technologies include affordable low-observable data systems, active aeroelastic wing, robust composite sandwich structures, advanced compact inlets, photonic vehicle management systems, self-adaptive flight controls and electric actuation. Each of the major aerospace contractors has performed a long-range study on next-generation aircraft using both company and government funding.

X-40A

The Boeing Company

First Flight:	11 August 1998	**Sponsors:**	USAF
Last Flight:	11 August 1998	**Fastest Flight:**	100 mph (approx)
Total Flights:	1	**Highest Flight:**	9,000 feet (approx)

The X-40A Space Maneuver Vehicle is displayed after its roll-out. (Boeing via the Jay Miller Collection)

The X-40A was a 90-percent scale model of a proposed Space Maneuver Vehicle (SMV) and had a wing span of 12 feet and an overall length of 22 feet. The SMV was designed to deliver small satellites, perform on-orbit reconnaissance, and other duties. The vehicle was designed to be launched into orbit aboard either an expendable launch vehicle or from the Space Shuttle payload bay, and would remain in orbit for over one year while waiting to perform tasks. The vehicle was designed to return to a gliding landing on Earth to be refurbished and reused.

The X-40A completed a successful autonomous approach and landing on its first flight test on 11 August 1998 after being dropped from an Army UH-60 Black Hawk helicopter at an altitude of 9,000 feet. The vehicle, which landed under its own power, used an integrated INS/GPS to touch down on a hard surface runway. For unexplained reasons, this was the vehicle's last flight.

The Air Force has given the X-40A to NASA for use as a prototype of their X-37 vehicle, and the X-40A arrived at the Dryden Flight Research Center on 26 May 2000. The X-40A is about 15 percent smaller than the X-37, and will be used in a series of ground tests and further drop tests in support of the X-37 program.

Unknown

X-41

First Flight:	Pending	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable

No Illustration Available

No photographs or artist concepts have been released of the X-41 to date.

The X-41 Common Aero Vehicle (CAV) involves an experimental maneuverable reentry vehicle carrying a variety of payloads through a suborbital trajectory, and reentering and dispersing the payload in the atmosphere.

The CAV program is slated for a flight demonstration in FY03. The CAV will provide both an expendable and future reusable Military Space Plane (MSP) system architecture with the ability to deploy multiple payload types from and through space to a terrestrial target. A CAV will be able to achieve high terminal accuracy, extended cross-range, and be highly maneuverable in a low-cost expendable or single use package supporting multiple military mission areas.

X-42

Unknown

First Flight:	Pending	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable

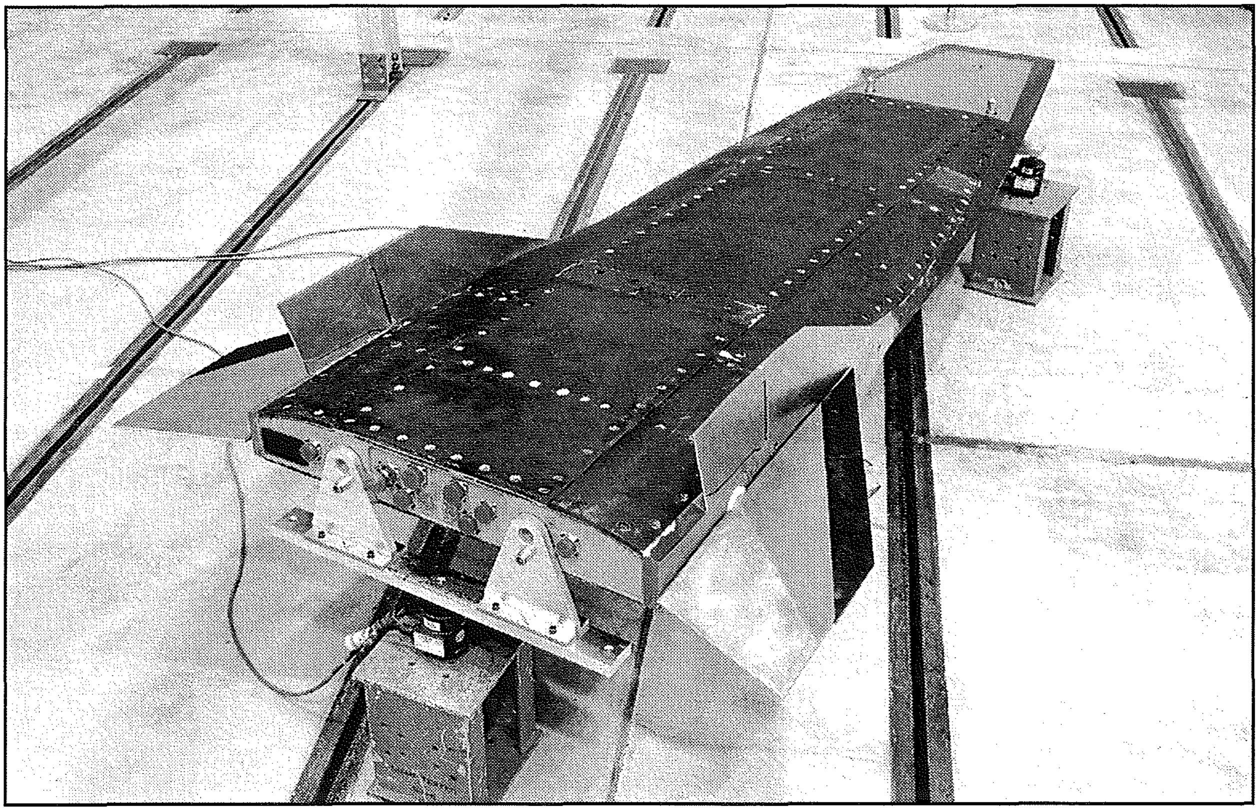
No Illustration Available

No photographs or artist concepts have been released of the X-42 to date.

The X-42 Pop-Up Upper Stage is an experimental expendable liquid-fueled upper stage designed to boost 2,000-4,000 pound payloads into orbit. Pop-Up Upper Stages can expand the utility of advanced military spacecraft, allowing for wider ranges of payload deployment. This project includes technologies which will improve pop-up upper stage technologies and/or stages themselves. The X-42 will demonstrate individual orbit transfer propulsion capabilities that significantly enhance low-cost, high-performance access to space via revolutionary propulsion techniques with improved designs, combustion and mixing technologies, and material advancements. It will also develop and demonstrate chemical propulsion systems for military, civil, and commercial orbit transfer applications. Future orbit transfer systems will require advanced materials, low-cost power processing developments, and increased thruster efficiency in order to maintain the United States' global presence capability through enhanced strategic agility.

Microcraft, Inc. X-43

First Flight:	Pending	**Sponsors:**	NASA
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



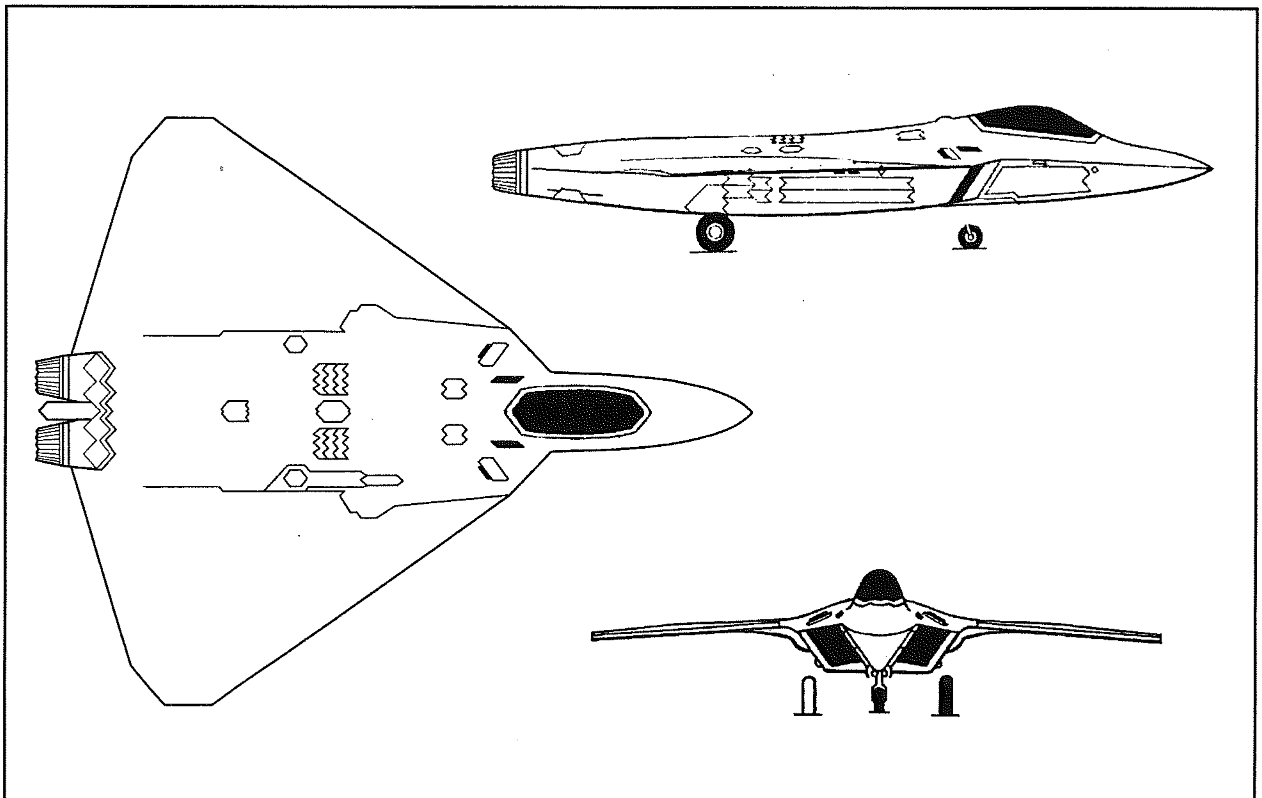
The first X-43 undergoes final checkout. (NASA photo by Tom Tschida via the Dennis R. Jenkins Collection)

The X-43A Hyper-X program seeks to overcome one of the greatest aeronautical research challenges—air-breathing hypersonic flight. Far outpacing contemporary aircraft of supersonic capability, three X-43A vehicles will fly at speeds of Mach 7 and 10. Ultimately, the revolutionary technologies exposed by the Hyper-X program promise to increase payload capacities and reduce costs for future air and space vehicles. The goal of the Hyper-X program is to validate key propulsion and related technologies for air-breathing hypersonic aircraft. The first X-43A is scheduled to fly during late 2000. Three flights are planned—two at Mach 7 and one at Mach 10. This is far faster than any air-breathing aircraft have ever flown. The world's fastest air-breathing aircraft, the SR-71, cruises slightly above Mach 3. The highest speed attained by the rocket-powered X-15 was Mach 6.7.

The flight tests will be conducted within the Western Range off the coast of southern California near Vandenberg AFB. The current flight profile calls for launching the X-43A vehicles on a westerly heading, and the flights will terminate in the Pacific Ocean. The ground track is completely over water and is nearly 400 miles in length. The vehicles will not be recovered, and all data will be telemetered to the ground during the flight.

X-44 Lockheed Martin Corporation

First Flight:	Pending	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable



A speculative three-view drawing of the Lockheed Martin X-44 tailless research aircraft. (Jay Miller Collection)

Very little data has been released on the X-44 program, other than the vehicle will use a shape derived from the Lockheed Martin F-22 and JSF designs and will not be equipped with vertical or horizontal stabilizers. It is most likely that the X-44 will be a subscale unpiloted demonstrator.

The Boeing Company

X-45

First Flight:	Pending	**Sponsors:**	USAF
Last Flight:	Not Applicable	**Fastest Flight:**	Not Applicable
Total Flights:	Not Applicable	**Highest Flight:**	Not Applicable

No Illustration Available

No photographs or artist concepts have been released of the X-45 to date.

Even less has been released on the X-45 program other than it has been awarded to Boeing, most probably to the Phantom Works at the former McDonnell Douglas in St. Louis, Missouri.

D-558 Douglas Aircraft Company

First Flight:	14 April 1947 (-I)	**Sponsors:**	USN, NACA
Last Flight:	12 December 1956 (-II)	**Fastest Flight:**	650.8 mph / 1,291 mph
Total Flights:	228 (-I) / 161 (-II)	**Highest Flight:**	40,000+ feet / 83,235 feet

The D-558-I used straight wings and a single turbojet engine—the D-558-II would use swept wings and the same Reaction Motors XLR-11 that powered the X-1 (and many others). This October 1949 photo shows the Skystreak in its later white paint scheme. (NASA photo E49-090 via the Dennis R. Jenkins Collection)

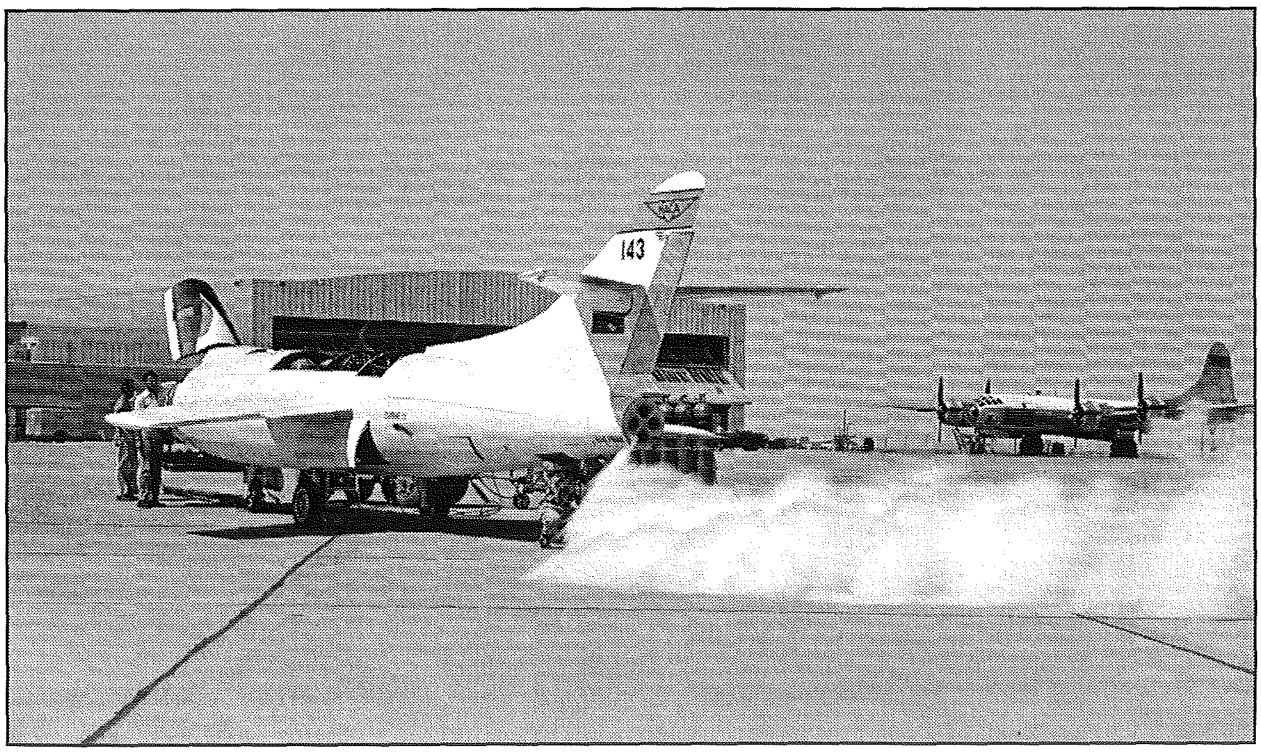
Usually overlooked when X-Planes are discussed, the two Navy-sponsored Douglas D558 designs did not use the Air Force "X" designation series, but nevertheless played an important role in advancing aeronautics during the late 1940s and early 1950s. In the public's mind, much of the research performed by the D-558-I Skystreaks was quickly overshadowed by Chuck Yeager and the X-1. Regardless, the Skystreak performed an important role in aeronautical research by flying for extended periods of time at transonic speeds, complementing the X-1 that flew for limited periods at supersonic speeds. The later D-558-IIs would follow the X-1's lead and use rocket propulsion.

The three D558-I Skystreaks were turbojet-powered aircraft that took off from the ground under their own power. The first aircraft is on display at the Naval Aviation Museum in Pensecola, Florida. The second D558-I crashed on 3 May 1948, killing NACA pilot Howard C. Lilly. The third Skystreak is owned by the Carolinas Historical Aviation Museum located at the Charlotte International Airport in North Carolina.

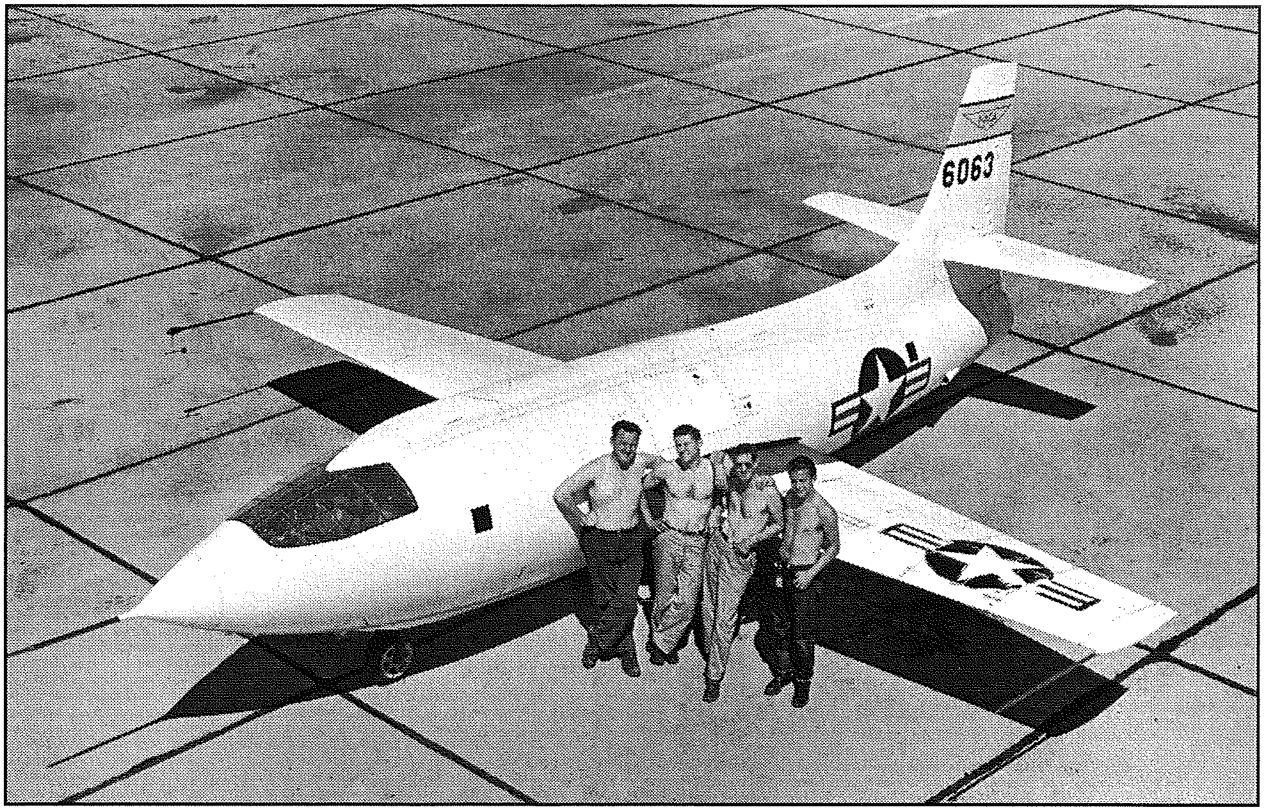
The rocket-powered air-launched D-558-II Skyrocket became the first aircraft to exceed Mach 2. The first D-558-II is on display at the Planes of Fame Museum in Chino, California. The number two Skyrocket, the aircraft used by Scott Crossfield to first break Mach 2, is on display at the National Air and Space Museum in Washington DC. The last D-558-II is displayed on a pedestal at Antelope Valley College, Lancaster, California.

Acronyms

AEC	Atomic Energy Commission
AFB	Air Force Base
AIAA	American Institute for Aeronautics and Astronautics
DARPA	Defense Advanced Research Projects Agency
ICBM	Intercontinental Ballistic Missile
JSF	Joint Strike Fighter
MBB	Messerschmitt-Bölkow-Blohm, Gmbh
MoD	Ministry of Defense (German)
NACA	National Advisory Committee on Aeronautics
NASA	National Aeronautics and Space Administration
RAF	Royal Air Force (U.K.)
RN	Royal Navy (U.K.)
STOVL	Short Take-Off and Vertical Landing
U.K.	United Kingdom
USAF	United States Air Force
USAF	United States Army
USMC	United States Marine Corps
USN	United States Navy
V/STOL	Vertical/Short Take-Off and Landing
VTOL	Vertical Take-Off and Landing



Research pilot A. Scott Crossfield used one of the D-558-IIs to become the first person to exceed twice the speed of sound—barely—he managed Mach 2.005 on 20 November 1953 after being dropped from an Boeing P2B-1S (the Navy designation for the B-29), similar to the one in the background. (NASA photo E-2499 via the Dennis R. Jenkins Collection)



The crew of the XS-1 in September 1949. Left to right: Eddie Edwards, Bud Rogers, Dick Payne (crew chief), and Henry Gaskins.
(NASA photo E49-0039 via the Dennis R. Jenkins Collection)

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