NASA Facts

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X-31 Enhanced Fighter Maneuverability Demonstrator

Two X-31 Enhanced Fighter Maneuverability (EFM) demonstrators were flown at the NASA Dryden Flight Research Center, Edwards, CA, to obtain data that may apply to the design of highly-maneuverable next-generation fighters. The program ended in June 1995.

The X-31 program demonstrated the value of thrust vectoring (directing engine exhaust flow) coupled with advanced flight control systems, to provide controlled flight during close-in air combat at very high angles of attack. The result of this increased maneuverability is a significant advantage over conventional fighters.

Background

“Angle-of-attack” (alpha) is an engineering term to describe the angle of an aircraft’s body and wings relative to its actual flight path. During maneuvers, pilots often fly at extreme angles of attack -- with the nose pitched up while the aircraft continues in its original direction. This can lead to loss of control and result in the loss of the aircraft, pilot or both.

Three thrust vectoring paddles made of graphite epoxy mounted on the X-31’s exhaust nozzle direct the exhaust flow to provide control in pitch (up and down) and yaw (right and left) to improve control. The paddles can sustain up to 1,500 degrees centigrade for extended periods of time. In addition the X-31s are configured with movable forward canards and fixed aft strakes. The canards are small wing-like structures set on the wing line between the nose and the leading edge of the wing. The strakes are set on the same line between the trailing edge of the wing and the engine exhaust. Both supply additional control in tight maneuvering situations.

The X-31 research program produced technical data at high angles of attack. This information is giving engineers and aircraft designers a better understanding of aerodynamics, effectiveness of flight controls and thrust vectoring, and airflow phenomena at high angles of attack. This is expected to lead to design methods providing better maneuverability in future high performance aircraft and make them safer to fly.

Phase 1

Phase 1 was the conceptual design phase. During this phase the payoff expected from the application of EFM concepts in future air battles was outlined and the technical requirements for a demonstrator aircraft were defined.

Phase 2

Phase 2 carried out the preliminary design of the demonstrator and defined the manufacturing approach to be taken. Three governmental design reviews were held during this phase to thoroughly examine the proposed design. Technical experts from the U.S. Navy, German Federal Ministry of Defense and NASA all contributed to the careful examination of all aspects of the design.

Phase 3

Phase 3 initiated and completed the detailed design and fabrication of two aircraft, which were assembled at the Rockwell International facility at Air Force Plant 42, Palmdale, CA. This phase required that both aircraft fly a limited test flight program. The first aircraft was rolled out on Mar. 1, 1990, followed by a first flight on Oct. 11, 1990, piloted by Rockwell chief test pilot Ken Dyson. The aircraft reached a speed of 340 mph and an altitude of 10,000 feet during its initial 38-minute flight.

The second aircraft made its first flight on Jan. 19, 1991, with Deutsche Aerospace chief test pilot Dietrich Seeck at the controls.

Flight Summary

During the program’s initial phase of operations at Rockwell International’s Palmdale, CA, facility the aircraft were flown on 108 test missions. They achieved thrust vectoring in flight and expanded the post-stall envelope to 40 degrees angle of attack before flight operations were moved to Dryden in February 1992 at the request of the Advanced Research Projects Agency (ARPA).

At Dryden an international team of pilots and engineers (ITO: International Test Organization) expanded the aircraft’s flight envelope, including military utility evaluations that pitted the X-31 against comparable but non-thrust vectored aircraft to evaluate the maneuverability of the X-31 in simulated air combat. The ITO included participation by NASA, U.S. Navy, U.S. Air Force, Rockwell Aerospace, the Federal Republic of Germany, and Daimler-Benz (formerly Messerschmitt-Bolkow-Blohm and Deutsche Aerospace).

The first flight from Dryden under the ITO was in April 1992, and by July 1992 the X-31 program was continuing the initial stage of post-stall envelope expansion.

The X-31 achieved controlled flight at 70 degrees angle of attack at Dryden on Nov. 6, 1992. On that same day, a controlled roll around the aircraft's velocity vector was accomplished at 70 degrees angle of attack.

On April 29, 1993, the No. 2 X-31 successfully executed a minimum radius, 180-degree turn using a post-stall maneuver, flying well beyond the aerodynamic limits of any conventional aircraft. The revolutionary maneuver has been dubbed the “Herbst Maneuver,” after Wolfgang Herbst, a German proponent of using post-stall flight in air-to-air combat. The maneuver has also been described as a “J” turn when flown to an arbitrary heading change.

During the final phase of evaluation, with the X-31s engaged in simulated air combat scenarios against adversaries, the aircraft were superior and recorded the most simulated “kills” during most engagements when thrust vectoring was used for enhanced maneuverability. The first tactical maneuver with a cooperative adversary was in June 1993.

By December 1993, both aircraft had been flown at supersonic speeds (Mach 1.28).

A total of 160 flights were completed by the X-31 program in 1993, setting as 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.

Evaluation of the X-31's unique capabilities in close combat was completed on March 1, 1994, while evaluation of the aircraft as a fighter maneuverability demonstrator by the ITO concluded in May 1995.

The No. 1 X-31 aircraft was lost in an accident Jan. 19, 1995. The pilot, Karl Heinz-Lang, of the Federal Republic of Germany, ejected safely before the aircraft crashed in an unpopulated desert area just north of Edwards.

The X-31 program logged an X-plane record of 580 flights during the program, 559 research missions and 21 in Europe for the 1995 Paris Air Show. A total of 14 pilots representing all agencies of the ITO flew the aircraft.

Quasi-Tailless Demonstration

In 1994, software was installed in the X-31 to demonstrate the feasibility of stabilizing a tailless aircraft at supersonic speed using thrust vectoring. Tests also included subsonic speeds. During the flights the aircraft was destabilized with the rudder to stability levels that would be encountered if the aircraft had a reduced size vertical tail. The project has provided data to industry on the benefits of drag reduction, radar cross section, and weight reduction that could be used for future commercial and military designs and modifications.

1995 Paris Air Show

The X-31's enhanced maneuvering capabilities were demonstrated to the international aerospace industry during daily flights at the 1995 Paris (France) Air Show. The aircraft was flown to Europe aboard a U.S. military C-5 transport and was supported there by a small team of NASA and industry support personnel. The aircraft was flown 21 times in preparation for and during the show.

Program Management

An international test organization of about 110 people, managed by the Advanced Research Projects Agency (ARPA), conducted the flight tests at Dryden. In addition to ARPA and NASA, the International Test Organization (ITO) included the U.S. Navy, the U.S. Air Force, Rockwell International, the Federal Republic of Germany and Daimler-Benz Aerospace (formerly Messerschmitt-Bolkow-Blohm and Deutsche Aerospace). NASA was responsible for flight test operations, aircraft maintenance and research engineering.

The X-31 was the first international experimental aircraft development program administered by a U.S government agency, and was a key effort of the NATO Cooperative Research and Development Program.

The ITO director and NASA’s X-31 project manager at Dryden was Gary Trippensee.

Aircraft Specifications

Designed and constructed as a demonstrator aircraft by Rockwell International Corporation's North American Aircraft and Deutsche Aerospace.

The aircraft has a wing span of 23.83 feet (7.3 m). The fuselage length is 43.33 feet (12.8 m).

The X-31 is powered by a single General Electric F404-GE-400 turbofan engine, producing 16,000 pounds (71,168 N) of thrust in afterburner.

Typical takeoff weight of the X-31 is 16,100 pounds (7,303 kg).

The X-31 design speed is Mach 0.9 with an altitude capability of 40,000 feet (12,192 m). For specific tests to determine thrust vectoring effectiveness at supersonic speeds the aircraft was flown to Mach 1.28 at an altitude of 35,000 feet.

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