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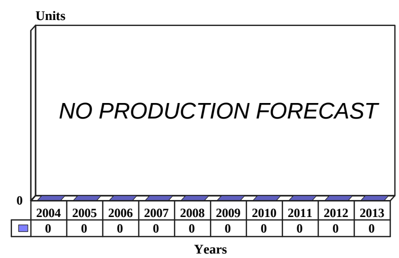
Rockwell/DASA X-31 - Archived 1/2005

Outlook

- The VECTOR program has been completed
- The sole existing X-31 is currently on display in a museum

10 Year Unit Production Forecast
2004 - 2013



Orientation

Description. Single-seat experimental aircraft developed under a joint U.S./Federal Republic of Germany program to explore technologies to expand maneuverability flight limits of high-performance combat aircraft.

Sponsors. U.S. Defense Advanced Research Projects Agency (DARPA) and the German Ministry of Defense. The U.S. Naval Air Systems Command, the U.S. Air Force, and the U.S. National Aeronautics and Space Administration (NASA) were also participants in the Enhanced Fighter Maneuverability (EFM) program.

Contractors. Rockwell International Corp, North American Aircraft, Palmdale, California, USA (now part of Boeing Company), and DaimlerChrysler Aerospace (DASA), Ottobrunn, Germany (later absorbed into EADS).

Status. The sole remaining X-31 is currently on display at the Deutsches Museum in Germany.

Total Produced. Two aircraft were assembled by the end of 1991.

Application. Research and testing.

Price Range. Unit cost not applicable. Total EFM program costs were approximately $270 million, with Germany providing roughly 25 percent.

Technical Data

Design Features. Cantilever low cranked-delta-wing monoplane with DASA (MBB)-designed and produced aluminum-structure wings with carbon-fiber skins, all-composite and all-flying canards, and single vertical stabilizer with powered two-section rudder. Wing moving surfaces include inboard and outboard elevons and inboard and outboard leading edge flaps. The forward fuselage employs a chin intake and is constructed with conventional aluminum alloy bulkheads and stringers under a skin of graphite epoxy. Mid-fuselage is skinned with aluminum, while the aft fuselage is skinned with titanium. A single GE F404 augmented turbofan is installed. Three MBB-designed thrust vectoring paddles control the direction of the engine exhaust flow.

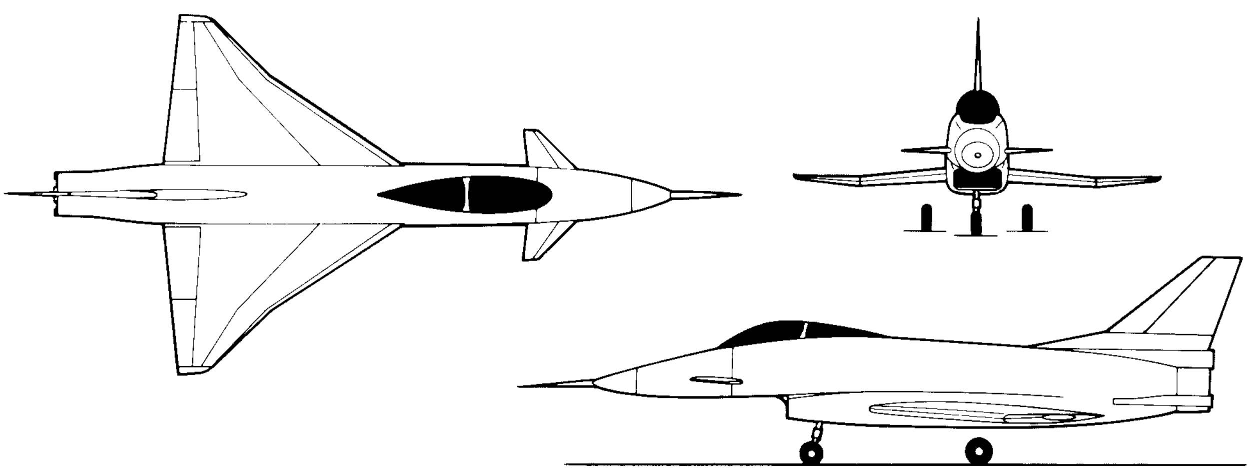
	Metric	U.S.
Dimensions		
Overall length[a]	13.21 m	43.33 ft
Height	4.44 m	14.58 ft

	Metric	U.S.
Wheel track	2.29 m	7.53 ft
Wingspan	7.26 m	23.83 ft
Weight		
Empty	5,248 kg	11,570 lb
Maximum take-off weight	7,101 kg	15,655 lb
Fuel weight	1,853 kg	4,085 lb
Performance[(b)]		
Max level speed[(c)]	Mach 1.3	Mach 1.3
Max climb rate, SL	13,106 m/m	43,000 ft/m
Max operating altitude	12,200 m	40,000 ft
T-O run	457 m	1,500 ft
Landing run	823 m	2,700 ft
Design G limits	+9/-4	+9/-4

Propulsion

X-31 (1) GE Aircraft Engines F404-GE-400 twin-spool, augmented turbofan engine rated 71.2 kN (16,000 lbst) with afterburning.

[(a)]Not including nose probe.
[(b)]Estimated; at maximum take-off weight.
[(c)]At 8,535-12,200 meters (28,000-40,000 ft).



ROCKWELL/DASA X-31A

Source: Forecast International

Variants/Upgrades

Not applicable.

Program Review

Background. The Enhanced Fighter Maneuverability (EFM) program was a joint United States-German effort aimed at breaking the "stall barrier" for future fighter aircraft. Breaking this barrier would allow close-in aerial combat beyond normal stall angles of attack. EFM was the first project resulting from the 1986

Nunn-Quayle Amendment that called for cooperative NATO research and development programs. The EFM project evolved from post-stall maneuvering studies conducted by MBB (since merged into DASA) beginning in 1977. Driving these studies was the developing all-aspect capability of short-range air-to-air missiles. Rockwell conducted supermaneuvering concept studies in 1983. MBB and Rockwell subsequently teamed in order to interest the U.S. Defense Advanced Research Projects Agency (DARPA) and the West German Defense Ministry in this concept.

A feasibility study of the EFM project began in 1984. In June 1986, the U.S. and West German governments signed a Memorandum of Understanding (MoU) on the EFM project. In September of that year, DARPA awarded the MBB/Rockwell team a 12-month preliminary design study (Phase II). The team subsequently moved into a 22-month Phase III stage and the design, fabrication, and assembly of two demonstrator vehicles, which were assigned the X-31A designation. Phase IV flight testing began in October 1990.

X-31A flight tests were carried out through December 1991 at Rockwell facilities in Palmdale, California. Testing was then moved to NASA's Ames-Dryden Flight Research Center at Edwards Air Force Base in California. In early 1993, flight testing moved to the Naval Air Test Center at Patuxent River, Maryland. Flight testing subsequently returned to Edwards AFB by early 1994.

Goals of the program were:

- Demonstration of post-stall controllability
- Determination of how enhanced maneuverability affects kill ratios (flight testing to involve a single X-31 on predetermined post-stall flight paths, one-on-one X-31 flight tests with post-stall capability disabled on one aircraft, and tests involving an X-31 versus a different aircraft)
- Creation of enhanced fighter maneuverability design requirements and database
- Development and evaluation of concepts for low-cost aircraft prototypes

Overall, the program was intended to yield data that should result in significant improvements in aircraft survivability through increased maneuverability during close-in aerial combat, as well as transonic and supersonic engagements and ground attack. Technologies integrated in this effort included vectored thrust, integrated digital control systems, and aircrew assistance. The program officially ended in May 1994, but it was kept alive for awhile with continued funding.

Off-the-Shelf Systems. To keep the cost of the program as low as possible, Rockwell and MBB employed as many off-the-shelf components and subsystems as they could. Among these were the General Electric F404 engine, the Martin-Baker SJU-5/6 ejection seat, the F/A-18 cockpit canopy and instrument panel, the F-16 tricycle-type landing gear, Cessna Citation III wheels and brakes, LTV A-7D Corsair II tires, the Garrett modified F-16 emergency power unit, and the Garrett F-20 hydrazine-fueled emergency air starter. The digital flight control system was provided by Honeywell and was derived from that used in the Lockheed C-130 HTTB testbed aircraft.

Responsibilities. Rockwell was responsible for the X-31 configuration, aerodynamics, and structure. Rockwell also performed final assembly of the aircraft and supervised early flight testing. The Rockwell division that was involved in the program, North American Aircraft, was acquired by Boeing in December 1996.

DASA (MBB) was responsible for design of the flight control system and development of the thrust vectoring system. The German manufacturer was also responsible for design and manufacture of the aircraft's wings. In 2000, DASA was merged into European Aeronautic Defence and Space Company (EADS).

Principal subcontractors included GE Aerospace (cockpit development), Menasco (landing gear), BFGoodrich (wheels), Swedlow (canopy), Sundstrand (electrical generating system), and AlliedSignal (integrated flight control actuation system).

Initial Flight. The first flight of the X-31 took place in October 1990, almost a year later than originally projected. The problems encountered during fabrication were considered minor, although MBB had to rebuild a wing that was accidentally dropped. Another cause for delay was additional time needed by Rockwell to work on the aircraft's flight control software.

Once in the air, the X-31 aircraft performed quite successfully. The aircraft achieved controlled, maneuvering flight at 70 degrees angle of attack. Other advanced U.S. fighter aircraft commonly do not exceed 20 to 45 degrees angle of attack. In April 1993, the aircraft performed a post-stall, minimal-radius 180-degree turn known as the Herbst maneuver. The turn was completed in a 475-foot radius. The Herbst maneuver demonstrates the ability of the aircraft to go into and out of post-stall quickly, yet still maneuver.

In March 1994, an X-31 successfully emulated flight without a tail at supersonic speeds. The test showed the possibility of replacing conventional aircraft tail surfaces with a vectored thrust capability, which could provide significant reductions in aircraft weight, aerodynamic drag, fuel consumption, and radar signature.

During a test flight in January 1995, the first X-31A crashed near Edwards AFB, California. The accident was caused by pitot icing that made the flight control gains excessive because of low indicated airspeed. The remaining X-31A was modified and resumed flying in April 1995. This aircraft conducted flight demonstrations at the June 1995 Paris Air Show. The costs of the aircraft's appearance at the air show were shared by Rockwell, DASA, and the U.S. and German governments. The aircraft was subsequently placed into storage.

VECTOR Program. The remaining X-31 resumed flying in February 2001 after a hiatus of nearly six years. The flight was part of a new effort called the Vectoring Extremely Short Take-Off and Landing Control and Tailless Operation Research (VECTOR) program.

In mid-1999, the U.S. and German governments had signed MoUs to begin work on the VECTOR program. In December 1999, the U.S. Navy awarded Boeing a $13.1 million contract to modify the surviving X-31 for use in the effort.

The VECTOR program lasted approximately three years. The United States and Germany shared the cost of the program. Government partners in the program were the U.S. Navy and the German Federal Office for Defense Technology and Procurement.

The main contractors on the program were Boeing and EADS. Boeing was responsible for program integration, flight control system hardware, and extremely short take-off and landing (ESTOL) activities. In partnership with EADS, the U.S. company led X-31 aircraft re-activation, modification, maintenance, and flight test technology.

EADS was responsible for the flight control law software, the aircraft wings, the thrust vectoring vanes, simulation build-up, and development of the Flush Air Data System (FADS). Major subcontractors included Honeywell, IntegriNautics, Moog, Nord-Micro, and RJK Technologies. IntegriNautics supplied the Integrity Beacon Landing System (IBLS), a GPS-based navigation system.

The U.S. Navy's goal for the VECTOR program was the reduction of ground approach and take-off speeds. Germany's interest in the program was in the X-31's integrated flight control system design and using the aircraft as a high angle-of-attack air data test platform.

Sweden had been expected to participate in the VECTOR program. However, in late 1999, Sweden notified the United States and Germany that it would not be able to participate because of fiscal constraints. Sweden's interest in the X-31 had been tied to potential improvements of the Saab JAS 39 Gripen combat aircraft. The X-31 and the Gripen are similar in configuration and use different versions of the same engine.

Funding

Total EFM program costs were approximately $270 million, with Germany providing roughly 25 percent. DASA spent approximately $6.0 million of its own funds to complete the manufacture of the two aircraft wing sets.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
Boeing	$13.1	Dec 99 - Contract from U.S. Navy for engineering development and modification of software and hardware, aircraft integration, and flight test evaluation and demonstration for the X-31 VECTOR program.

Timetable

Month	Year	Major Development
Nov	1984	Rockwell/MBB awarded DARPA feasibility study
Jun	1986	Government-to-government EFM MoU signed
Sep	1986	Preliminary design phase begun
Oct	1990	First flight of initial X-31A
Jan	1991	First flight of second X-31A
Feb	1991	First flight with thrust vectoring paddles
Sep	1992	X-31 successfully completed controlled, maneuvering flight at 70 degrees angle of attack

Month	Year	Major Development
	1993	Patuxent River flight testing program begun
Jan	1995	Crash of first X-31A
Jun	1995	Second X-31A conducted flight demonstrations at Paris Air Show
Feb	2001	First flight of X-31 VECTOR program
Apr	2003	Final flight of X-31 VECTOR program

Worldwide Distribution

Not applicable.

Forecast Rationale

The VECTOR flight test program was completed in April 2003. The effort was conducted in three phases. Phase I, which concluded in April 2001, involved functional flight testing. Phase II focused on ESTOL control law development using a virtual runway in the sky, validation of the IBLS, and data collection for the FADS. The X-31A made its first flight under Phase II in May 2002. Phase II ended in March 2003.

Phase III began in early April 2003, and included demonstrations of ESTOL landings on an actual runway. Phase III flight testing concluded in late April 2003, and was followed by data analysis and information recording.

Due to funding constraints, plans have been dropped that would have involved installation of the Eurojet EJ200 engine and an ITP Thrust Vectoring Control (TVC) nozzle on the X-31.

The VECTOR program pushed the X-31 to the end of its approved airframe service life. The aircraft is currently on display at the Deutsches Museum near Munich, Germany. It is to eventually be displayed at the National Air and Space Museum in Washington, DC.

Ten Year Outlook

No forecast.

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