Canard Aeronautics & Aircrafts

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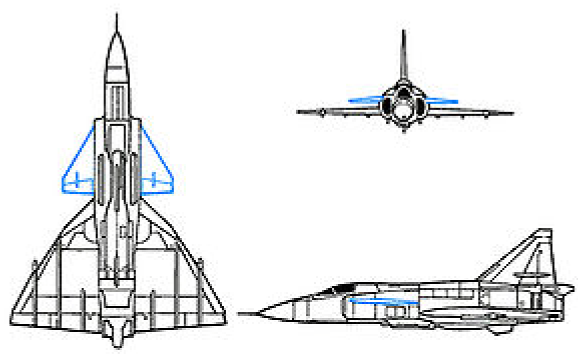
Canard (Aeronautics)

Canard



Canards (blue) on the Saab Viggen

In aeronautics, **canard** (French for duck) is an airframe configuration of fixed-wing aircraft in which the forward surface is smaller than the rearward, the former being known as the "canard", while the latter is the main wing. In contrast a conventional aircraft has a small horizontal stabilizer behind the main wing.

Some early fixed-wing aircraft such as the Brazilian Santos-Dumont 14-bis and French Canard Voisin had tail-first configuration which were seen by observers to resemble a flying duck — hence the name.

General characteristics

Unlike a conventional tailplane, in order to achieve longitudinal stability a canard surface is trimmed to increase lift as speed increases. This equates to a negative coefficient for trim drag.

A canard design tends to be less controllable than a conventional design because ailerons on the main wing may be subject to turbulence from the canards that varies widely at different Angle of attack, leading to conditions of deep stall. If the ailerons were located on the canards, the lever arm would be too short due to the narrow span, and also the twisting motion would be too far forwards of the center of mass.

Canards have poor stealth characteristics because they present large, angular surfaces that tend to reflect radar signals. The Eurofighter Typhoon uses software control of its canards in order to reduce its radar cross section.

Canard classes

Canard designs fall into two main classes: the lifting-canard and the control-canard.

Other classes include the close-coupled type and active vibration damping.

Rutan Long-EZ, with lifting-canard ahead of the cockpit.

A deflected control-canard on an RAF Typhoon F2

Canard (yellow) on a Mirage IIIS

Lifting-canard

The first airplane to fly, the Wright Flyer, was a lifting-canard. In this configuration, the weight of the aircraft is shared between the main wing and the canard wing. The pros and cons of the canard versus conventional configurations are numerous and complex, and it is impossible to say which is superior without considering a specific design application.

For example, a lifting-canard generates an upload, in contrast to a conventional aft-tail which typically generates a download that must be counteracted by extra lift on the main wing, which may appear to unambiguously favor the canard. However, the downwash interaction between the two surfaces is unfavorable for the canard, and favorable for the downloaded conventional tail, so the difference in overall induced drag is actually not obvious, and depends on the details of the configuration.

Another example is that the upward canard lift appears to increase the overall lift capability of the configuration. However, pitch stability flight safety requirements dictate that the canard must stall before the main wing, so the main wing can never reach its maximum lift capability. Hence, the main wing must then be larger than on the conventional configuration, which increases its weight and profile drag. Again, the relative merit depends on the details of the configuration and cannot be generalized.

In any case, pitch stability requires that the lift generated by the canard wing is significant, so in order to minimise induced drag on the canard, it is usually of higher aspect ratio and greater airfoil camber than a control-canard. To achieve stability, the change in lift coefficient with angle of attack should be less than that for the main plane.

One way in which this can be achieved is to use the same aerofoil for both planes, but to rig the canard at a higher angle of incidence. This tends to increase drag induced by the foreplane, which may be given a high aspect ratio in order to limit drag.

With a lifting-canard, the main wing must be located further aft of the center of gravity range than with a conventional aft tail, and this increases the pitching moment caused by trailing-edge flaps. Aircraft with lifting canards cannot readily be designed with sophisticated trailing-edge flaps.

Control-canard

In the later control-canard, most of the weight of the aircraft is carried by the main wing and the canard wing is used primarily for longitudinal control during maneuvering. A control-canard mostly operates at zero angle of attack. Combat aircraft of canard configuration typically have a control-canard. In combat aircraft, the canard is usually driven by a computerized flight control system.

One benefit obtainable from a control-canard is avoidance of pitch-up. An all-moving canard capable of a significant nose-down deflection will protect against pitch-up. As a result, the aspect ratio and wing-sweep of the main wing can be optimized without having to guard against pitchup.

Close-coupled canard

In the close-coupled canard, the foreplane is located just above and forward of the main wing. At high angles of attack the canard surface directs airflow downwards over the wing, reducing turbulence which results in reduced drag and increased lift.

The canard foreplane may be fixed as on the IAI Kfir, or have landing flaps as on the Saab Viggen, or it may be moveable and also act as a control-canard during normal flight as on the Dassault Rafale.

A close-coupled canard is very useful for a supersonic delta wing design which gains lift in both transonic flight (such as for supercruise) and also in low speed flight (such as take offs and landings).

A **moustache** is a small, high aspect ratio foreplane of close-coupled configuration. The surface is typically retractable at high speed and is deployed only for low-speed flight. First seen on the Dassault Milan, and later on the Tupolev Tu-144.

Active vibration damping

A large aircraft flying fast at low altitude can experience significant aerodynamic buffeting, leading to crew fatigue and reduced airframe life. Aircraft such as the B-1 Lancer incorporate small canard surfaces as part of an active vibration damping system that reduces these adverse effects.

Examples of canard aircraft

Some aircraft that have employed this configuration are listed below. A few types are listed twice, for example where the foreplane acts as a control-canard during normal flight and as a close-coupled type at high angles of attack.

Lifting-canard types

- AEA Silver Dart
- Beech Starship
- Berkut 360
- Chengdu J-9
- Cozy MK IV
- Freedom Aviation Phoenix
- Gyroflug Speed Canard
- Kyūshū J7W1 *Shinden*
- MacCready Gossamer Albatross
- MacCready Gossamer Condor
- MiG-8 *Utka*
- Miles Libellula
- North American SM-64 Navaho
- North American X-10
- OMAC Laser 300
- Peterson 260SE (a Cessna 182 with an added canard for STOL operations)
- Piaggio P180 Avanti (3 surfaces aircraft with flapped canard for pitch trim)
- Rutan Defiant
- Rutan Long-EZ
- Rutan VariEze
- Rutan VariViggen
- Rutan Voyager
- Rutan Quickie

- Santos-Dumont 14-bis
- Steve Wright Stagger-Ez
- Sukhoi T-4
- Tupolev Tu-144
- Velocity SE
- Velocity XL
- Wright Flyer
- XB-70 Valkyrie
- XP-55 Ascender

Control-canard types

- Atlas Cheetah
- Chengdu J-10
- Dassault Rafale
- Eurofighter Typhoon
- Grumman X-29A
- IAI Lavi
- McDonnell Douglas (now Boeing) F-15 S/MTD
- Pterodactyl Ascender
- Rockwell-MBB X-31
- Saab JAS 39 Gripen
- Sukhoi Su-30 MKI
- Sukhoi Su-33
- Sukhoi Su-34
- Sukhoi Su-27(27M variant)
- Sukhoi Su-37
- Sukhoi Su-47
- Chengdu J-20

Close-coupled canard types

- Atlas Cheetah
- Dassault Rafale
- IAI Kfir
- IAI Lavi
- Saab Viggen
- Tupolev Tu-144
- Novi Avion

Active vibration damping types

- B-1 Lancer

Concept aircraft

Lifting-canard types

- Lockheed L-133

Gallery

The first powered airplane, the Wright Flyer, used dual, vertically-stacked canards

Eurofighter Typhoon of the Royal Air Force displaying at the Farnborough Airshow, 2006

Dassault Rafale, in service with the French Navy (Marine Nationale) and the French Air Force (Armée de l'Air)

Canards visible on a JAS 39 Gripen at the Farnborough Airshow

Grumman X-29, an experimental aircraft for forward swept wing research

The Rockwell-MBB X-31 Enhanced Fighter Maneuverability Demonstrator Aircraft

Canards (just behind the flight deck) on the XB-70 Valkyrie experimental bomber aircraft

Closeup of a Piaggio P180 Avanti's canards

The Beechcraft Starship Executive Transport

A Pterodactyl Ascender II+2 showing its canard control surface

Saab 37 Viggen of the Swedish Air Force

Chapter 2

Beechcraft Starship

Model 2000 Starship

Role	Executive transport
Manufacturer	Beech Aircraft Corporation
Designed by	Burt Rutan
First flight	15 February 1986
Number built	53
Unit cost	US$ 3.9 million

The **Beechcraft Starship** was a twin-turboprop six- to eight-passenger pressurized business aircraft produced by Beech Aircraft Corporation (now Beechcraft Division of Hawker Beechcraft).

Development

Development of the Starship began in 1979 when Beech decided to explore designs for a successor to its King Air line of turboprops that would fly faster and carry more passengers. The design was originated by Beechcraft in January 1980 as Preliminary Design 330 (PD 330). On August 25, 1982 Beech contracted with Scaled Composites to refine the design and build an 85% scale proof-of-concept (POC) aircraft. One of the significant changes made to the design by Scaled Composites was the addition of variable geometry to the canard.

The POC aircraft first flew in August 1983. This aircraft had no pressurization system, no certified avionics, and a different airframe design and material specifications than the planned production Model 2000. Only one POC was built and it has since been scrapped.

Prototypes were produced even as development work was continuing—a system demanded by the use of composite materials, as the tooling required is very expensive and has to be built for production use from the outset. Beech built three airworthy full-scale prototypes. NC-1 was used for aerodynamic testing and was the only Starship equipped with conventional electro-mechanical avionics. NC-2 was used for avionics and systems testing and NC-3 was used for flight management system and powerplant testing. NC-1 first flew on February 15, 1986.

The program was delayed several times, at first due to underestimating the development complexity involved and later to overcome technical difficulties concerning the stall-warning system. By the end of development, the Starship had grown larger in cabin volume than the King Air 350 while having the same gross ramp weight of 15,010 lb (6,808 kg). Starship development cost $300 million. The first production Starship flew on April 25, 1989.

Design

The Starship is noteworthy for its carbon fiber composite airframe, canard design, lack of centrally located vertical tail, and pusher engine/propeller configuration.

Carbon fiber composite was used to varying degrees on military aircraft, but at the time the Starship was certified, no civilian aircraft certified by the US Federal Aviation Administration had ever used it so extensively. Beech chose carbon fiber composite for its durability and high strength-to-weight ratio. According to Beech the Starship weighs less than it would have if it were built from aluminum. Nonetheless, the empty weight of production aircraft exceeded the target by several thousand pounds.

Beech studied several configurations before settling on a canard configuration in early 1980. As configured, the Starship is difficult to stall—the forward surface stalls before the main lifting surface, which allows the nose to drop and more-normal flight to resume.

A traditionally located vertical tail would have transmitted propeller noise into the airframe. In its place, directional stability and control is provided by rudders mounted in the winglets (Beechcraft called them tipsails) at the tips of the wings.

Mounting the engines so that the propellers are facing rearward, pushing rather than pulling the aircraft, has the potential of a quieter ride since the propellers are further from the passengers and because vortices from the propeller tips do not strike the fuselage sides. However, the propellers are operating in a turbulent airflow in the pusher configuration (due to airflow past the wings moving aft in vortex sheets) and high-velocity exhaust gasses are discharged directly into the props, thus the resulting external propeller noise is more choppy and raucous than otherwise.

Flight instrumentation for the Starship included a 14-tube Proline 4 AMS-850 "glass cockpit" supplied by Rockwell Collins, the first application of an all-glass cockpit in a business aircraft.

Operational history

Sales

Beechcraft Starship

Beech sold only eleven Starships in the three years following its certification. Beech attributed the slow sales to the economic slowdown in the late-1980s, the novelty of the Starship, and the tax on luxury items that was in effect in the United States at the time. In an effort to stimulate demand, Beech began offering two-year leases on new Starships in 1991.

End of the program

The last Starship, NC-53, was produced in 1995. In 2003 Beechcraft determined that supporting such a small fleet of airplanes was cost-prohibitive and began scrapping and incinerating the aircraft under its control. The aircraft were sent to the Evergreen Air Center located at the Pinal Airpark in Arizona for destruction. Beech worked with owners of privately-owned Starships to replace their airplanes with other Beech aircraft such as the Premier I jet.

In 2004 Raytheon sold its entire inventory of Starship parts to a Starship owner for a fraction of its retail value.

Hawker Beechcraft continues to offer support by phone. Rockwell Collins has maintained full support for the AMS-850 avionics suite.

Variants

Model 2000

Initial production version. 20 produced including three pre-production airworthy prototypes.

Model 2000A

Beech did not serialize the 2000A as a distinct model and it was not issued a new FAA type certificate.

The final 2000A configuration had tuning-fork-type noise dampers and improved insulation to reduce cabin noise and redesigned exhaust stacks for more efficient engine airflow. Stall strips placed on the front wing to enhance stall behavior were removed. Elimination of the stall strips reduced stall speed by up to 9 knots (10 mph; 17 km/h), which allows the 2000A to takeoff from shorter runways. The 2000 had standpipes in the fuel tanks to artificially limit fuel capacity so the aircraft would meet a target payload weight. The standpipes were removed in the 2000A, increasing fuel capacity by 31 US gal (117 l). Both the maximum ramp weight and takeoff weight were increased by 500 lb (227 kg) and zero fuel weight was increased 400 lb (181 kg).

Beech produced a kit to upgrade serial numbers NC-4 through NC-28 to 2000A specifications.

Aircraft on display

Several Starships have been donated to museums since the decommissioning program began. The Kansas Aviation Museum received the first donated aircraft, NC-41, in August 2003 and the Beechcraft Heritage Museum in Tullahoma, TN, received the second donated aircraft, NC-49, in September 2003. NC-42 was donated to the Museum of Flight in Seattle, WA, and is currently on loan to the Future of Flight at Paine Field in Everett, WA. NC-27 was donated to Evergreen Aviation & Space Museumin McMinnville, Orgeon in late-2003 and is currently on static display. NC-23 is on Airline Row at the Pima Air & Space Museum.

Survivors

As of January 2010, nine Starships hold an active registration with the FAA. Three Starships are registered in Oklahoma (NC-29, NC-35 & NC-45), one in Washington (NC-

50), one in Colorado (NC-51), and four are registered to Hawker Beechcraft in Wichita, Kansas (NC-2, NC-8, NC-19 & NC-24). NC-51 was used as a chase plane during the re-entry phase of Burt Rutan's SpaceShipOne. In October 2008 NC-29 was the first of the five remaining privately-owned airworthy Starships to complete RVSM certification, returning the aircraft's service ceiling to the original FL410 limit.

Evergreen Air Center sold eight airframes back to private owners for $50,000 each. Most are being used for parts, however, one of these aircraft has since been made airworthy again. Some former Starship parts have been used on the Epic turboprop kitplane.

Queensland Institute for Aviation Engineering in Caloundra, Queensland, Australia, purchased NC-28 in November 2004 for use in various training programs. Salt Lake Community College uses a Starship in their Aviation Maintenance program.

Specifications (2000A)

A Beechcraft Starship chasing a Scaled Composites SpaceShipOne during a test flight
Data from Flying Magazine, NC-53 POH where noted

General characteristics

- **Crew:** One
- **Capacity:** Six
- **Length:** 46.1 ft (14.1 m)
- **Wingspan:** 54.5 ft (16.6 m)
- **Height:** 12.9 ft (3.9 m)

- **Wing area:** 281 sq ft (26.1 m^2)
- **Empty weight:** 10,085 lb (4,574 kg) standard empty weight
- **Gross weight:** 15,010 lb (6,808 kg) max ramp weight
- **Max takeoff weight:** 14,900 lb (6,759 kg)
- **Fuel capacity:** 3,785 lb
- **Powerplant:** 2 × Pratt & Whitney Canada PT6A-67A turboprop, 1,200 shp (890 kW) each
- **Propellers:** 5-bladed McCauley, 8 ft 8 in (2.64 m) diameter

Performance

- **Maximum speed:** 385 mph (620 km/h; 335 kn)
- **Cruise speed:** 353 mph (307 kn; 568 km/h)
- **Stall speed:** 112 mph; 180 km/h (97 kn) max weight with flaps retracted & idle power
- **Minimum control speed:** 108 mph; 174 km/h (94 kn) flaps retracted
- **Range:** 1,576 mi (1,370 nmi; 2,536 km)
- **Service ceiling:** 41,000 ft (12,497 m)
- **Rate of climb:** 2,748 ft/min (13.96 m/s)
- **Wing loading:** 53 lb/sq ft (260 kg/m^2)
- **Power/mass:** 6.2 lb/shp

Chapter 3

Berkut 360

Berkut 360

Role	Homebuilt aircraft
Manufacturer	Berkut Aircraft
Introduced	1989
Primary user	Private Users
Variants	Rutan Long-EZ and Rutan VariEze

Berkut 360

The **Berkut 360** is a tandem-seating two-seat homebuilt canard aircraft built primarily of carbon fiber and fiberglass.

Development

The prototype Berkut was designed and built by Dave H. Ronneberg and Kerry Beresford as part of a business partnership between Ronneberg and Donald S. Murphy (called Experimental Aviation) between 1989 and 1992.

In 1992 the partnership dissolved, and Ronneberg (incorporating as Experimental Aviation, Inc.) brought the aircraft to market as a kit, while Murphy wanted to shelve the project entirely. A subsequent series of lawsuits between the two resulted in bankruptcy for Ronneberg and Murphy as individuals, and for EAI as a corporation. The kit was resurrected by Renaissance Composites, in 1996, with Ronneberg working as a consultant.

In January 2001, under pressure from Ronneberg, Renaissance sold the assets to Vicki Cruse who then formed Berkut Engineering Inc. That company withdrew the aircraft from the market in 2002. Ronneberg continues with the project, which is now directed at UAV markets. In 2003 a deal was struck to sell the project to Republic Aerospace but the deal fell through. Cruse is no longer involved with day-to-day operations, but maintains ownership.

Through the various incarnations approximately 75 kits were sold, and 20 airplanes completed.

Configuration

The Berkut is descended from the Rutan Long-EZ, with the primary differences being retractable main landing gear, dual canopies, and molded fuselage, strakes, and spar. Like the Long EZ, the Berkut carries 2 people in tandem seats. The front seat occupant has access to all instrumentation and controls. The rear seat, normally holding the passenger, is equipped with a side stick and throttle, but no rudder pedals, brakes, or instruments. Aerodynamically only minor changes were made. The fuselage was stretched, and the nose, canard, instrument panel and pilot moved forward one foot, to allow a heavier engine to be used in the back. The main wing trailing edge was straightened, removing a small bend in the trailing edge of the Long EZ wing. The lower winglet was removed and the aileron size increased in both chord and span, increasing roll rate.

Early Berkuts used wings and canard that were structurally similar to the Long-EZ and used hot-wired solid blue 2 lb/cu. ft. density Dow STYROFOAM PI cores, but with carbon fiber skins instead of fiberglass. The fuselage and winglets remained fiberglass. Later versions (kits produced after spring 1999) used fully-molded carbon fiber canards and wings with high density, 5 lb/cu. ft. 1/4" thick PVC or SAN foam cores, leaving only minor fairings and tip surfaces to be carved from foam. The Berkut has always used the Roncz 1145MS canard airfoil, which is more tolerant of bug and rain contamination than the original GU 25-5(11)8 airfoil originally used on the Long-EZ.

Berkuts used a retractable main (rear) landing gear system designed by Shirl Dickey for his E-Racer homebuilt. Originally Berkut used gear parts produced by Dickey, but over time they were repeatedly re-engineered and strengthened. Later kits had gear components produced entirely in-house. Like the earlier Vari-Eze and Long EZ, the Berkut parks with its nose gear retracted to prevent the plane from tipping over backwards when parked without a pilot in the front seat. Some early Berkuts utilized hydraulic nose-gear extension systems, but most have used an electro-mechanical jack-screw. With the electric system the pilot can climb into the cockpit with the nose down, then extend the nose gear, raising the airplane with him inside.

While the Long-EZ was closer in the design of the Berkut it was originally designed for the Lycoming O-235 108-118 hp engine, the Berkut was designed from the outset for the larger Lycoming IO-360 180 hp engine. The aircraft was later adapted (with a different engine mount, cowls and battery location) to accept the 260-hp Lycoming IO-540, which most builders chose. With the 540, some have reportedly reached speeds of 300 mph in level flight.

Selected accidents

The Berkut has a poor safety record, with about a quarter of all completed airplanes crashing at some point. However, there is no single cause which has resulted in more than one crash. Each crash has been the result of construction error or pilot error.

N91DR. The original prototype, crashed by Rick Fessenden at an airshow at Santa Paula, California. Although the NTSB investigation concluded that an accelerated stall during Fessenden's "wind up turn" - a level 360-degree very high-G turn - caused the airplane to crash, examination of videotapes of the crash gave a strong indication that the pilot blacked out under 9+ Gs. Fessenden was killed.

N260DG. The first Berkut 540, built by Dan Gray, also crashed at Santa Paula. Gray started and finished his first flight at nearby Camirillo airport but on his second flight he chose to return to Santa Paula. On final approach his engine stopped and, in attempting to set down on a nearby freeway, he collided head-on with a Honda station wagon. The aircraft was extensively damaged but Gray was only bruised. The cause was found to be an incorrectly rebuilt fuel pump.

N600SE. Built by Michael Kasyan, this airplane served as the company demonstrator for several years. While being flown by another pilot, the plane encountered a dust devil on final approach. This flipped the airplane upside down and it tumbled down the runway. Both wings were broken, the right strake and spar were broken halfway between the fuselage and the end of the spar, the main gear was torn out, and the nose crushed back to the instrument panel. The pilot's legs were broken but the passenger suffered only a minor cut to the scalp. The airplane was rebuilt and is flying again.

N538AJ. This airplane, owned by John Daniels, has had several accidents, all involving the landing gear. The NTSB report concerns its first, a gear collapse at Jackson Hole, Wyoming. Later the airplane overran the runway at First Flight airport, tearing out its gear legs. There have been no injuries from any of the accidents.

N287CM. Built by Steve Drybread. During a test flight Drybread left out the main canard attach bolts. The canard separated in flight, Drybread was killed.

N5439N. Built by Steve Drybread. While being flown by its owner, Charles Bracken, the aircraft struck high tension power wires and crashed into the ground. The airplane was destroyed, the nose crushed back to the pilot's seat. Bracken's legs were broken.

Variants

- **Berkut 360** - Original configuration, retractable gear, Lycoming 4 cylinder 360 cubic inch, fuel injected, 180 hp engine.
- **Berkut FG360** - Fixed-gear version of the 360. (Offered but never built, except as a UAV by Geneva Aerospace)

- **Berkut 540** - Lycoming 6 cylinder, 540 cubic inch, 260 hp engine upgrade. Changes consisted of larger cowls, a different engine mount, custom engine mount ears, stiffer engine isolators, a custom sump modification and different cooling baffles.
- **Berkut FG540** - Fixed-gear version of the 540. (Offered but never built)
- **Mobius** - a modified Berkut with a single canopy and automated flight equipment located where the second seat would be located, for UAV research and development. Two aircraft have been built with a third one in development. N442LT is the first tail number. N497LT is the second.

- **Berkut Jet** - a Berkut using a modified GE T-58 turbine engine, built by Jerrold Jorritsma. Crashed in Loveland, CO on May 9, 2010

Specifications

General characteristics

- **Crew:** 2
- **Capacity:** 2
- **Length:** 5.67 m (18 ft 6 in)
- **Wingspan:** 8.25 m (26 ft 8 in)
- **Height:** 2.29 m (7 ft 6 in)
- **Wing area:** 33.53 m² (110 ft²)
- **Empty weight:** 521.6 kg (1150 lb)
- **Loaded weight:** 952.5 kg (2100 lb)
- **Useful load:** 433.6 kg (965 lb)
- **Powerplant:** 1× Lycoming IO-540 Light Speed Engineering Composite 67" diameter, 91/103" pitch, (260 hp)

Performance

- **Never exceed speed:** 563.3 km/h (350 mph)
- **Maximum speed:** 442 km/h (275 mph)
- **Cruise speed:** 370 km/h (230 mph)
- **Stall speed:** 104.6 km/h (65 mph)
- **Range:** 2433 km (1512 mi)
- **Rate of climb:** 610 m/min (2000 ft/min)

Chapter 4

Chengdu J-20

Chengdu J-20

Artist's impression of the Chengdu J-20

Role	Stealth air superiority fighter, multirole fighter Strike fighter
National origin	People's Republic of China
Manufacturer	Chengdu Aircraft Industry Group
First flight	11 January 2011
Introduced	2017–2019 (planned)
Status	In development/flight testing
Primary user	People's Liberation Army Air Force
Number built	2
Unit cost	US$110 million (est.)

The **Chengdu J-20** (simplified Chinese: 歼二十; traditional Chinese: 殲二十; pinyin: *Jiān èr shí*; literally "Annihilator Twenty") is a fifth generation stealth, twin-engine fighter aircraft prototype developed by Chengdu Aircraft Industry Group for the Chinese People's Liberation Army Air Force. In late 2010, the J-20 underwent high speed taxiing tests. The J-20 made its first flight on 11 January 2011. General He Weirong, Deputy

Commander of the People's Liberation Army Air Force said in November 2009 that he expected the J-20 to be operational in 2017–2019.

Development

The J-20 was one of the stealth fighter programs under the codename J-XX that was launched in the late 1990s. It has been also designated "Project 718". Two prototypes (#2001-01 & #2001–02) have been built as of the end of 2010.

On 22 December 2010, the J-20 was under-going high speed taxiing tests outside the Chengdu Aircraft Design Institute with no confirmed flight tests. The J-20 made its first flight, which lasted about 20 minutes, on 11 January 2011.

James R. Clapper has testified that the United States has known about the program for a "long time" and that the test flight was not a surprise.

Technology transfer

Globalsecurity.org states that China probably declined to participate in joint development and production of new fifth generation fighter with Russia given the belief that Russia stood to gain more from Chinese participation. Chinese leaders may have determined that their design was superior to the Russian PAK FA. United States House Committee on Armed Services chairman Howard McKeon said on the J-20 "my understanding is that they built it on information that they received from Russia, from a Russian plane, that they were able to copy". However Australian Aviation writer Steve Creedy has said that the Russians and Chinese are working on a similar aircraft, in addition to the Chengdu J-20.

Balkan military officials told the *Associated Press* that China and Russia may have adopted some stealth technology from a Lockheed F-117 Nighthawk, which was shot down by the Serbian military in 1999 during the Kosovo war. If Chinese experts used the F-117 stealth coatings, the result would be decades behind current American state-of-the-art. However, Chinese test pilot Xu Yongling said that the J-20 was a "masterpiece" of home-grown innovation, he also said the F-117 technology was already "outdated" even at the time it was shot down, and could not be applied to a next-generation stealth jet. *Janes* editor James Hardy agrees that it was unlikely China would have learned much from the wreckage.

Retired USAF general Thomas G. McInerney has suggested that the J-20 design may have been based on cyber-espionage of the Lockheed Martin FB-22 project.

Chief of the Air Staff of the Indian Air Force Pradeep Vasant Naik has suggested that the J-20 is entirely reverse engineered with no Chinese R&D involved, and questioned if the practice was ethical. The Deccan Chronicle has called Naik's comment a "unusual outburst of helplessness" as China surpasses Indian airpower.

Russian military commentator Ilya Kramnik conjectures that China is still 10 to 15 years behind the United States and Russia in fighter technology and may not be able to manufacture all the advanced composite materials, avionics and sensor packages needed for such aircraft, and could instead turn to foreign suppliers. However, he speculates that China may be able to produce the J-20 at a cost 50% to 80% lower than US and Russian fifth-generation jet fighters, and that potential customers may include Pakistan, the Middle East, Latin America, Southeast Asia and the richest countries in Africa. Konstantin Sivkov of the Academy for Geopolitical Issues argued that the US is correct to be alarmed at the progress of Chinese military technology.

Bill Sweetman speculates that China will have problems meeting its production requirements, as it has several other jet fighter projects in production. Aviation Week raised the question of whether the aircraft is a prototype, like the Sukhoi T-50, or a technology demonstrator similar to the Lockheed YF-22.

Despite the current arms embargo, China may use ongoing economic problems to pressure the European Union into selling advanced military technologies.

Design

Characteristics

The J-20 is a single-seat, twin-engine aircraft which appears to be somewhat larger and heavier than the comparable Sukhoi T-50 and Lockheed Martin F-22 Raptor. Bill Sweetman estimates that it is approximately 75 feet (23 m) in length, has a wingspan of 45 feet (14 m) or more, and is expected to have a takeoff weight of 75,000 to 80,000 pounds (34,000 to 36,000 kg) with internal stores only. The prototype could be powered by twin 32,000 pounds (15,000 kg) thrust Saturn 117S engines provided by Russia, a sign of problems in the development of the aircraft, according to Pentagon spokesman Col. David Lapan. Chinese sources have claimed that production aircraft will be powered by two 13,200 kilograms (29,000 lb)/WS-10 class high thrust turbofan engines fitted with Thrust Vector Controlled (TVC) nozzles, both made in China. However Richard Aboulafia has said that the WS-10 engine has suffered catastrophic failures in flight.

The J-20 may have lower supercruise speed (yet greater range) and less agility than a Lockheed Martin F-22 Raptor or PAK FA, but might also have larger weapons bays and carry more fuel. The J-20 has a long and wide fuselage and low jet engine intakes with a forward chine, a main delta wing, forward canards, a bubble canopy, conventional round engine exhausts and canted all-moving fins. The front section of the J-20 is similarly chiseled as the F-22 Raptor and the body and tail resemble those of the Sukhoi T-50 prototype. As early photographs of the prototype surfaced, Bill Sweetman commented that the design may suggest a large, long range ground attack aircraft, not unlike a "stealth version" of the General Dynamics F-111 Aardvark. Douglas Barrie has noted that the canard-delta configuration with canted vertical fins appears to resemble the MiG 1.42. Yet, Barrie notes that key differences include greater forward fuselage shaping as the basis for low observable characteristics, along with the different engine intake configuration. It is suspected that cyberespionage may have assisted the development of the J-20, with information used by subcontractors of Lockheed Martin for the F-35 project in particular having been significantly compromised during development of the J-20.

The J-20 has a pair of all-moving tailfins that are swept back in the F-35 style instead of being trapezoid like the F-22 and PAK-FA tails and ventral stabilizing fins. It also has an F-22 style nose section, but with F-35 style dropped nose, forward swept intake cowls with diverterless supersonic inlet (DSI) bumps and a one-piece canopy. It was reported in November 2006 that a T/W=10 17,000 kilograms (37,000 lb) class turbofan (WS-15/"large thrust") was being developed for the J-20. One (#2001-01) prototype is fitted with AL-31F, the other (#2001–02) is fitted with the improved WS-10G with a new "stealth" nozzle possibly to reduce RCS and IR emission.

The J-20 may become the first operational combat aircraft that carries sufficient fuel to supercruise throughout its missions, doubling its sortie rate.

Pentagon spokesman Geoff Morrell has said that it was premature to call the J-20 a stealth fighter or to judge if it had any other fifth generation characteristics.

Avionics

Displays which may be used in the Chendu J-20 cockpit.

The production J-20 may incorporate an advanced fly-by-wire (FBW) system fully integrated with the fire-control and the engine systems. Its fire-control radar is expected to be Active Electronically Scanned Array (AESA) (Type 1475/KLJ5?).

Cockpit

The aircraft features a "pure" glass cockpit (two large color liquid crystal display (LCD) and several smaller ones and a wide-angle holographic head-up display (HUD)). Many of these subsystems have been tested onboard J-10Bs to speed up the development.

Armament

The J-20 has a large belly weapon bay for short/long-range air-to-air missiles (AAM) (PL-10, PL-12C/D & PL-21) and two smaller lateral weapon bays behind the air inlets for short-range AAMs (PL-10).

Stealth

Carlo Kopp has suggested that the J-20's overall stealth shaping is "without doubt considerably better" than the F-35 and PAK FA, but he agrees with others, such as Shih Hiao-wei of Defense International monthly and Bill Sweetman of *Aviation Week*, that some parts on the J-20 will challenge its ability to remain stealthy from all directions: "The aft fuselage, tailbooms, fins/strakes and axi-symmetric nozzles are not compatible with high stealth performance, but may only be stop-gap measures to expedite flight testing of a prototype." As of January 2011 the engine nozzles were clearly non-stealthy; this may be due to the fact that the final "fifth generation" engines had not been completed yet. However, one of the prototypes uses WS-10G engines with stealthy jagged-edge nozzles and tiles.

Robert Gates has also questioned how stealthy the J-20 might be although he did say the development of the J-20 had the potential to "put some of our capabilities at risk, and we have to pay attention to them, we have to respond appropriately with our own programs." Kopp and Goon have further speculated that the J-20 is designed to operate as a heavy interceptor, destroying opposing AWACS and tanker aircraft. If true, this would make it more similar to a MiG-25 with stealth capability. Sweetman agrees that this is the most likely role for such a large aircraft with low thrust to weight ratio and limited agility that is optimized for range and speed. Lewis Page has said that it is unlikely that the Chinese will soon have an American style Low Probability of Intercept Radar and so the J-20 would be limited to attacking ground targets like previous generations of American stealth aircraft such as the Lockheed F-117 Nighthawk. In that case the J-20 would carry a radar, but using it would instantly give away its location. However, the J-20 is expected to use a AESA radar, which should have Low Probability of Intercept modes. Given that the F-35 can already track and jam even the F-22's radar, this might not be sufficient.

Loren B. Thompson has said that this combination of forward sector only stealth and long range will allow the J-20 to make attacks on surface targets while the United States lacks sufficient bases for F-22s in the area to counter these attacks and American allies have no comparable aircraft. Thompson has also said that a long-range maritime strike aircraft may cause the United States more trouble than a shorter range air-superiority fighter like the F-22.

A canard delta offers greater efficiency in both subsonic and supersonic flight (which may help supercruise range), but it is unknown if the Chinese have the same software used on the Eurofighter Typhoon to control the otherwise non-stealthy canards. Teal Group analyst Richard Aboulafia has also raised doubts about the use of canards on a design that is intended to be low-observable: "There's no better way of guaranteeing a radar reflection and compromise of stealth". Aboulafia has also called the J-20 a kludge made of mismatched parts and questioned if the Chinese have the skills or technology to produce a true fifth generation fighter. Nevertheless, canards greatly boost the aircraft's maneuverability over that of a pure delta wing without canards. Sweetman notes that the canard delta works with the Whitcomb area rule for a large-volume mid-body section supersonic aircraft. Also, while the DSI intakes are easier to maintain than more complex stealth-compatible intakes, such as on the F-22, their fixed form limits the aircraft to around Mach 2.0. J.D. McFarlan of Lockheed Martin has said that the J-20 DSI inlets resemble those of the F-35, but it is unclear if the Chinese have perfected their own design.

Operational history

On 22 December 2010, the J-20 was under-going high speed taxiing tests outside the Chengdu Aircraft Design Institute with no confirmed flight tests. Several Chinese military websites and photos revealed that on 10 January 2011 Chinese Vice President Xi Jinping and Chairman of the Standing Committee of the National People's Congress Wu Bangguo came to the Chengdu facility to witness the first flight test. The test flight was cancelled that day due to bad weather.

Flight testing

The J-20 made its first flight, which lasted about 15 minutes, on 11 January 2011. A Chengdu J-10S served as the escort aircraft. After successful first flight, an ceremony was held. J-20 first flight test pilot Li Gang, Chief designer Yang Wei and Gernal Li Andong(Deputy-Director of General Armaments Department, and Director of Science and Technology Commission of General Armaments Department of the PLA since 2000) attended the ceremony.

China thus became the third nation in the world to "develop and test-fly a full-size stealth combat aircraft demonstrator", after the United States and Russia. *The Guardian* reported that experts, on the one hand, expressed "surprise" at the speed with which the aircraft was developed, but on the other hand "said the country's military prowess was still relatively backward and way behind that of the US" and that its military interests were limited to its region.

The first test flight coincided with a visit of United States Secretary of Defense Robert Gates to China, and was initially interpreted by Pentagon officials and media pundits as a possible signal to the visiting delegation from the U.S. However, after meeting with senior Chinese officials including Chinese President Hu Jintao, Secretary Gates remarked, "The civilian leadership seemed surprised by the test and assured me it had nothing to do with my visit." Jin Canrong, a professor at Renmin University in Beijing who specializes in China-U.S. relations, suggested that President Hu's ignorance of the test raises questions about the nature of civilian control of the Chinese military. However, as Michael Swaine, an expert on the PLA and United States – China military relations, explained, although it's possible and even likely that "senior officials in the [Chinese] leadership did not know that this flight test would occur on this precise day," this is not necessarily evidence of a military-backed effort to insult Secretary Gates' delegation or embarrass President Hu. Rather, decisions regarding the production, development and testing of such military aircraft are routinely managed by engineers and low-level officials more than by senior civilian or military leadership. Coupled with the fact that there was relatively limited coverage of the event in Chinese media initially, it is likely that the test may not have been considered a significant enough event to warrant notification to President Hu. Moreover, the Chinese military has conducted important tests (including the 2007 anti-satellite missile test) on 11 January in the past; thus, the test may have been related to this.

The U.S. China Economic and Security Review Commission took testimony on the implications for PRC civilian control of the PLA.

Role in future conflicts

Pacific Air Forces commander Gary L. North has said that the Next-Generation Bomber may prove the key to defeating the J-20 in future conflicts by knocking the Chinese airbases out of action.

Specifications

Because the aircraft is in development, these specifications are preliminary and are taken as estimates from the available images.

General characteristics

- **Crew:** 1
- **Length:** 62 ft (19 m)
- **Wingspan:** 41 ft (12.5 m)
- **Height:** ()
- **Wing area:** 630 ft^2 ()
- **Max takeoff weight:** 66,000–80,000 lb (34,000 - 37,000 kg)
- **Powerplant:** 2× WS-10G thrust-vectoring turbofan (155 kN) on production aircraft. Possible WS-15 on production aircraft.

Performance

Armament

- **Guns:** None on prototype.
  Expected to have internal and external hardpoints for missiles, bombs and fuel tanks.

Avionics

Anticipated AESA radar with LPI modes for use against air and surface targets, and low observable data links, infrared missile warning and radar warning sensors.

Chapter 5

Chengdu J-10

J-10 Vigorous Dragon
F-10 Vanguard

J-10A seen at Zhuhai airshow.

Role	Multi-role combat aircraft
National origin	People's Republic of China
Manufacturer	Chengdu Aircraft Industry Corporation
Designed by	Chengdu Aircraft Design Institute
First flight	23 March 1998
Introduced	2005
Status	In service
Primary user	People's Liberation Army Air Force
Produced	2002-Present
Number built	168-196
Program cost	500 million RMB allocated in 1982 (Project #10)
Unit cost	190 million RMB (27.84 million USD; 2010)
Developed from	Chengdu J-9

The **Chengdu J-10** (simplified Chinese: 歼十; traditional Chinese: 殲十; pinyin: *Jiān Shí*; literally "Annihilator Ten") is a multirole fighter aircraft designed and produced by the People's Republic of China's Chengdu Aircraft Industry Corporation (CAC) for the People's Liberation Army Air Force (PLAAF). Known in the West as the "Vigorous Dragon", the J-10 is a multi-role combat aircraft capable of all-weather day/night operation.

Development

The program was originally backed by the Chinese leader, Deng Xiaoping, who authorized spending of half a billion Renminbi to develop an indigenous aircraft, but the program did not start until several years later, in January 1988, when the Chinese government began initial development of the Project #10 to develop a fighter to counter new fourth generation fighters then being introduced by the USSR The 611th Institute, also known as the Chengdu Aircraft Design Institute, was tasked as the main developer, with Song Wencong (宋文骢), the chief designer of the J-7III, assigned as the chief designer and Xue Chishou (薛炽寿) as the chief engineer. The deputy general designer was Mr. Su Longqing (苏隆清). Initially designed as a specialized fighter, it was later recast as a multirole aircraft capable of both air to air combat and ground attack missions.

Although the existence of the J-10 was long reported both inside and outside of China, the Chinese government did not officially admit the existence of the aircraft until January 2007, when the first photographs of the J-10 were allowed to be published to the public by the Xinhua News Agency. Having been designed under such secrecy, before its official disclosure many details of the J-10 were subject to much speculation. Rumors of a crash during flight testing, however, have been openly denied by the government. During the official announcement of the J-10, on 1 January 2007, both the Xinhua News Agency and the PLA Daily listed no crashes since the start of the project as one of the accomplishments of the test pilots. However, later reports reveal that one of the prototype J-10s did crash and the Chinese government tried to cover up the details regarding the crash.

According to Chinese media reports, the first plane, "J-10 01", was rolled out in November 1997, and the aircraft made its successful maiden flight on 23 March 1998, flown by test pilot Lei Qiang (雷強) and lasting for twenty minutes. Another test pilot, Li Zhonghua (李中华), test flew the prototype on aerodynamic performance trials that lasted till early December, 2003, during which time aerial refueling tests were also successfully completed. In these aerodynamic tests, the aircraft was pushed beyond its parameters of the original design and it was discovered that the aircraft could easily withstand the greater requirements. The last part of the test flight programme was the live firing of air-to-air missiles by test pilot Xu Yongling (徐勇凌), which lasted from 21 December 2003 to 25 December 2003.

The aircraft were first delivered to the 13th Test Regiment on 23 February 2003. The aircraft was given the status 'operational' in December of the same year, after 18 years in development. The first operational regiment was the 131st Regiment of the 44th Division. It is rumored that a regiment of the 3rd Division has also J-10s.

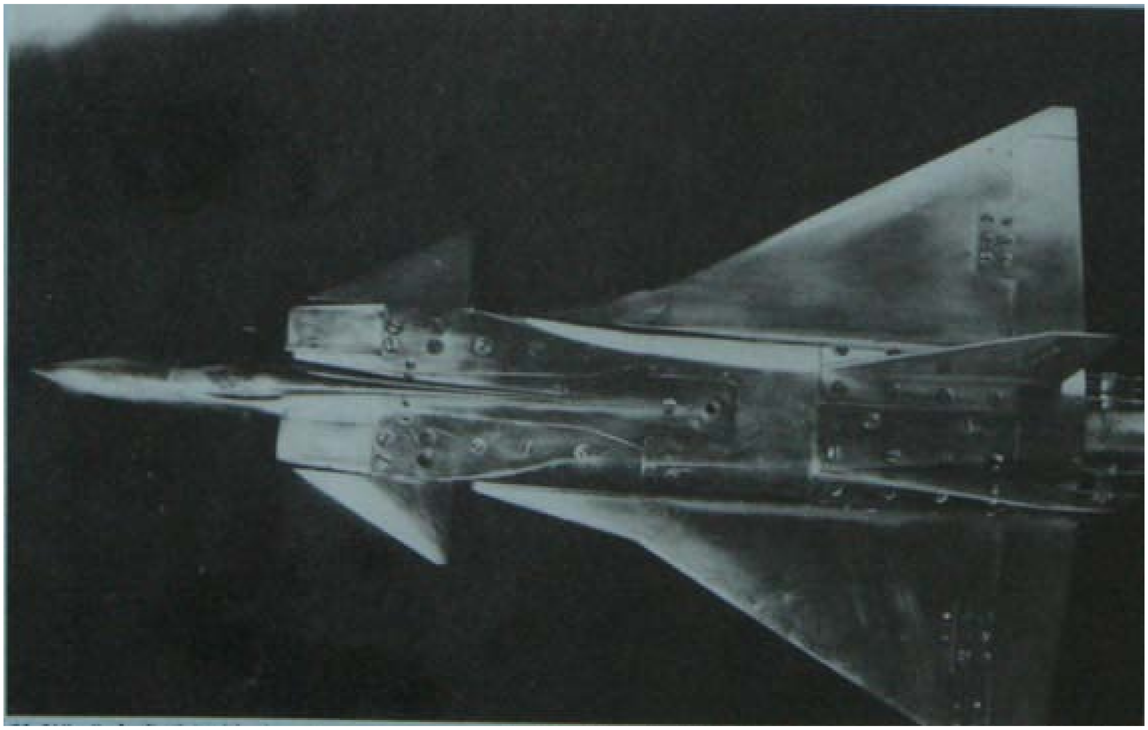
Export

Plans are in place for AVIC to aggressively market an upgraded J-10 variant, most likely the J-10B, once its development is complete. Several countries have shown interest and Pakistan is likely to be the first export customer, with deliveries taking place in 2014-2015.

In late February 2006 the then President of Pakistan, Pervez Musharraf, was shown the J-10 and JF-17 production facilities, also taking the opportunity to sit in the cockpits of both aircraft. He later said the Chinese had offered to sell the J-10 to Pakistan and the offer would be considered by the government and Pakistan Air Force (PAF). On 12 April 2006 the Pakistani cabinet approved the purchase of at least 36 J-10. On 7 March 2009 Air Chief Marshal Tanvir Mehmood Ahmed, then Chief of the Air Staff of the PAF, stated that the high-tech fighters would be designated FC-20 and two squadrons (36 aircraft) would be delivered to the PAF in 2014–2015, after some improvements in accordance with PAF requirements.

Foreign participation

Drawing of the canceled Chengdu J-9



Wind tunnel model of the canceled Chengdu J-9

The canceled Israeli IAI Lavi

According to official Chinese sources, the J-10 is said to have been developed from the now canceled Chengdu J-9. However, there have been conflicting reports about a possible relationship between the J-10 and the Israeli IAI Lavi fighter program, the latter having a similar canard-configuration. The J-9 program predated both of the other aircraft. In an interview, the general designer of J-10, Mr. Song Wencong (宋文骢) said, "Our nation's new fighter's external design and aerodynamics configuration are completely made by us and did not receive foreign assistance, this made me very proud. Our nation developed J-9 in the 1960s, this adopted the canard configuration. So, those statements that said J-10 is a copy of Israeli Lavi are just laughable."

The strongest admission of Israeli involvement in the J-10's development by Israeli authorities appeared in a statement made by an official as American authorities investigated alleged Lavi technology transfers to China. Without mentioning either Lavi or J-10, the Director General of Israel's Ministry of Defense David Lari "acknowledged in an Associated Press interview that 'some technology on aircraft' had been sold to China and that some Israeli companies may not have 'clean hands'".

In May 2008, Jane's Information Group reported several interviews with Russian sources claiming to be involved with various Chengdu military projects. A number of engineers, designers and technical specialists described their visits to Chengdu and other areas of China in the 1980s. A source alleged that high-level Chengdu officials described the possession of a single Lavi prototype at one of Chengdu's facilities. They also claim that in 2000, two years after the J-10's maiden flight, aerodynamic models were sent to Russian wind tunnel testing facilities to study the J-10's aerodynamics.

During the 2006 Farnborough Airshow, the Russian Siberian Aeronautical Research Institute (SibNIA) confirmed its participation in the J-10 program. According to the article, this participation was limited to observation and instruction as "scientific guides." The sources also called the J-10 "more or less a version of the [Israel Aircraft Industries] Lavi", but also a "a melting pot of foreign technology and acquired design methods" Left unelaborated is the degree of Israeli participation - if any - in J-10 development.

Kommersant's reporter Kostantin Lantratov affirmed that Russian consent was required to export the J-10, given its Russian AL-31 engine.

It has been reported that composite materials tested in the Delsen Testing Laboratories in Glendale, California during the year 1990 were related to the J-10 project.

Design

J-10 was designed by the Chengdu Aircraft Design Institute (CADI), a subordinate research institute of Chengdu Aircraft Industry Corporation (CAIC). Some of the designers and their roles are identified as follows; Xue Chishou (薛炽寿, chief engineer, also deputy general manager of CAIC), Zhou Ziquan (周自全, chief test engineer, also deputy director of CADI). In a rather unusual agreement, the single seat version of the J-10 and the twin seat version of J-10 were designed by two different general designers; Song Wencong for the single seat version and Yang Wei (杨伟) for the twin seat version, also the general designer of the JF-17 light-weight fighter. Sang Jianhua (桑建华) of CADI was responsible for airframe design features that reduce radar signature.

Airframe and cockpit

Constructed from metal alloys and composite materials for high strength and low weight, the airframe's aerodynamic layout adopts a "tail-less canard delta" wing configuration. A large delta wing is mid-mounted towards the rear of the fuselage, while a pair of canards (or foreplanes) are mounted higher up and towards the front of the fuselage, behind and below the cockpit. This configuration provides very high agility, especially at high speed. A large vertical tail is present on top of the fuselage and small ventral fins underneath the fuselage provide further stability.

A rectangular air intake is located underneath the fuselage, providing the air supply to the engine. Also under the fuselage and wings are 11 hardpoints, used for carrying various types of weaponry and drop-tanks containing extra fuel.

The retractable undercarriage comprises a steerable pair of nose-wheels underneath the air intake and two main gear wheels towards the rear of the fuselage.

The cockpit is covered by a two-piece bubble canopy providing 360 degrees of visual coverage for the pilot. The canopy lifts upwards to permit cockpit entry and exit. The Controls take the form of a conventional centre stick and a throttle stick located to the left of the pilot. These also incorporate "hands on throttle and stick" (HOTAS) controls. A zero-zero ejection seat is provided for the pilot, permitting safe ejection in an emergency even at zero altitude and zero speed.

Avionics (aircraft related)

Flight control system

Due to the J-10's aerodynamically unstable design, a digital quadruplex-redundant fly-by-wire flight control system aids the pilot in flying the aircraft. Chinese aircraft designer Yang Wei is claimed to be the chief designer of the fly-by-wire flight control system, although this is disputed by analyst Richard Fisher who credits Israeli consultants for developing the system. The flight control computer provides automatic flight coordination and keeps the aircraft from entering potentially dangerous situations such as unintentional slops or skids. This therefore frees the pilot to concentrate on his intended tasks during the combat.

Flight instrumentation

Information is provided visually to the pilot via three liquid crystal (LCD) Multi-function displays (MFD) in the cockpit. Chief designer of the flight instrumentation panel was Zhou Han (周寒, unrelated to the chief test engineer), who was in charge of both the CRT display design at the early stages of development and the later LCD design that is currently adopted by J-10 in service.

The LCD display panel entered service shortly after 2000. The LCD displays and earlier CRT displays for J-10 (and that of WZ-10, J-11 and JH-7) are manufactured by the Suzhou Long Wind Machinery Plant (苏州长风机械总厂), later reorganized as AVIC Radar and Avionics Equipment Research Institute (中航雷达与电子设备研究院).

In addition to the flight instrumentation, a Chinese holographic head-up display (HUD) is also present. The HUD shows important flight and combat related information such as targeting cues. It can also be used as a radar scope, a feature believed to be inspired by the HUDs of Russian aircraft, that allows the pilot to keep his eyes focused at infinity while working with his radar. Monochrome images from electro-optical avionics pods (FLIR and targeting pods) can also be displayed on the HUD. The HUD was designed to overcome issues with the HUDs of Russian fighters, which experienced significant fogging problems when deployed in humid and tropical zones of China, as they were originally designed for deployment in arid Arctic/sub-Arctic zones. The modular design of the HUD system and use of the MIL-STD-1553B databus architecture allows HUDs of Western origin to be integrated if desired by the user.

Avionics (mission related)

Electronic warfare

A comprehensive internal electronic counter-measures (ECM) suite is likely to be present, which can be supplemented by active jammer pods such as the BM/KG300G carried externally on the aircraft's hardpoints. Additionally, the KZ900 signals intelligence (SIGINT) pod can be carried for reconnaissance missions.

Infra-Red Search and Track

A Chinese infra-red search and track (IRST) system developed by the Sichuan Changhong Electric Appliance Corporation, the Type Hongguang-I (Rainbow Light-I) Electro-Optical Radar (虹光-Ⅰ型光电雷达), is integrated with the J-10. It is a third generation optronics system utilising a HgCdTe focal array with imaging infra-red (ImIR) capability. Receiving its certification on 3 March 2005 and subsequently entering service with the PLAAF, the system was revealed to the public one year later at a conference on the Sichuan province of China, during which the system was demonstrated to visiting officials. Based on the limited information released, Type Hongguang-I has a maximum range of 75 km.

Although the Type Hongguang-I was designed to be lighter and more compact than similar Russian systems so that it could be fitted in the nose of J-10 while leaving enough space for a suitable radar, the current production model J-10 does not have enough space and must carry a podded version externally on one of the aircraft's hardpoints. However, recently released images show a modified variant of the J-10 with what is believed to be an IRST device fitted to the upper starboard side of the nose. Type Hongguang-I is also designed to be compatible with China's Shenyang J-11, Shenyang J-8 and Xian JH-7 combat aircraft, as well as the Xian H-6 bomber and Sino-Pakistani JF-17 light-weight fighter.

Radar and targeting

According to Chengdu Aircraft Industry Corporation officials the J-10 uses a multi-mode fire-control radar designed in China. The radar has a mechanically scanned planar array antenna and is capable of tracking 10 targets. Of the 10 targets tracked, 2 can be engaged simultaneously with semi-active radar homing missiles or 4 can be engaged with active radar homing missiles.

The radar is believed to be designed by the Nanjing Research Institute of Electronic Technology (NRIET), designated KLJ-10 and a smaller variant is claimed to be installed on the JF-17 light-weight fighter. Believed to be based on technologies from Russia, Israel or a combination of both, the radar should be comparable to Western fighter radar designs of the 1990s. It may also be replaced by more advanced radars of other origin on export versions of the J-10. The Italian FIAR (now SELEX Galileo) Grifo 2000/16, has been offered to the Pakistan Air Force for installation on the J-10, should the PAF induct the aircraft. On June 14, it was announced by Chinese state media that a version of J-10 has been equipped with a phased array radar.

In Chinese military technology related exhibitions, various helmet-mounted display (HMD) systems developed by Chinese organisations have been shown. It is believed that the J-10 is integrated with such a system to assist the pilot in targeting enemy aircraft. The J-10 has also been featured in photos and models carrying the FILAT (Forward-looking Infra-red Laser Attack Targeting) pod for laser designation of targets and the Blue Sky forward looking infra-red (FLIR) pod for low visibility, low altitude flights.

Propulsion

The J-10 is powered by a single Russian Lyulka-Saturn AL-31FN turbofan engine giving a maximum static power output of 12,500 kgf (123 kN, 27,600 lbf)). The most significant difference between the AL-31FN and the AL-31F is the arrangement of certain parts and mechanisms due to spacial limitations of the engine bay in the J-10. The AL-31F is designed for a twin engine aircraft such as the Su-27. For the J-10's AL-31FN variant, protruding parts of the engine such as the gearbox and pump are mounted opposite to that of AL-31F.

The AL-31FN was initially expected to be replaced by a domestic powerplant developed and manufactured in China, the WS-10A (WoShan-10A) Taihang turbofan, giving a thrust of 129 kN (13,200 kgf or 29,101 lbf); however, the PLAAF delayed integration of the WS-10 onto the aircraft given development difficulties with the engine.

Weaponry and external loads

The aircraft's internal armament consists of a 23 mm twin-barrel cannon, located underneath the port side of the intake. Other weaponry and equipment is mounted externally on 11 hardpoints, to which 6,000 kg (13,228 lb) of weaponry such as missiles and bombs, drop-tanks containing fuel and other equipment such as avionics pods can be attached.

Air-to-air missiles deployed may include short range air-to-air missiles such as the PL-8 and PL-9, medium-range radar-guided air-to-air missiles such as the PL-11 and PL-12, unguided and precision guided munitions such as laser-guided bombs, anti-ship missiles such as the YJ-9K and anti-radiation missiles such as the PJ-9.

Variants

- **J-10A**: Single seat multi-role variant. The export designation is **F-10A**.
- **J-10S**: Twin-seat fighter-trainer variant of the J-10A. The forward fuselage of the aircraft is stretched to accommodate an additional pilot seat, two pilots sit in tandem with a single large bubble canopy. Also incorporates an enlarged dorsal spine which may accommodate additional avionics equipment or fuel. As well as serving as training aircraft, the J-10S may also be used for the ground attack role where the rear seat pilot would act as the weapon systems operator.
- **J-10B**: An upgraded variant of the J-10, also known as the "Super-10." The existence of the J-10B is not confirmed by official Chinese sources, but numerous images of a new J-10 variant have surfaced, showing a prototype J-10 modified with a diverterless supersonic inlet (DSI), an infra-red search and track (IRST) sensor, modified vertical stabiliser, ventral fins, housings fitted under the wings, and a modified nose that could indicate an AESA radar. It had its first flight in December 2008.
- **FC-20**: An export variant of the J-10B designed for the Pakistan Air Force. First flight stated to take place in 2009.
- **J-10C**: A carrier-based (possibly twin-engined) variant of the J-10B with more powerful engines, developed for future Chinese aircraft carrier.

Operators

People's Republic of China

- People's Liberation Army Air Force - 120+ J-10A and AS in service according to 2010 IISS Military Balance, page 404

Incidents

Notable accidents

There have been four known crashes of the J-10 to date. The first crash was of a prototype combat aircraft during testing in 1998 with the most likely cause cited as failure of the fly-by-wire flight control system.

In 2007, a second crash occurred near Guilin involving a J-10 of the PLAAF's 2nd Division.

A third crash occurred in August 2009 when pilot Meng Fansheng was forced to eject from his aircraft when the aircraft suffered an abrupt loss of engine power. An official investigation by the PLAAF also echoed that the crash was the result of the failure of the AL-31F engine on the aircraft.

A fourth crash involving the aircraft occurred on April 22, 2010 when an active duty J-10 of the PLAAF crashed killing a Senior Colonel. A report that the Chinese government tried to cover up the crash but was unable to do so when the funeral for the dead pilot gained prominence was published by the German based Defense Professionals website.

In addition, it was reported that on March 7, 2009 that an active duty J-10 suffered a loss of all onboard avionics during a tactical training exercise. However, the pilot of the aircraft, Lieutenant Colonel Li Feng was able to land the aircraft safely. The pilot cited the cause of the avionics failure as smoke in the cockpit presumably generated by the engine which had leaked in from the environmental control system.

J-10 footage controversy

On January 23, 2011 the CCTV news program Xinwen Lianbo showcased the J-10 in the air by firing a missile at a plane. The target then exploded. This footage lasted half a second. The footage shown was that of a F-5, US fighter jet. It turns out the clip was taken from the 1986 US movie Topgun.

Specifications (J-10A)

General characteristics

- **Crew:** 1 (basic), 2 (trainer variant)
- **Length:** 16.43 m (53 ft 10 in)
- **Wingspan:** 9.75 m (31 ft 11 in)
- **Height:** 4.78 m (15.7 ft)
- **Wing area:** 39 m² (419.8 ft²)
- **Empty weight:** 9,750 kg (21,495 lb)
- **Loaded weight:** 14,876 kg (32,797 lb)
- **Useful load:** 4,500 kg (9,920 lb)

- **Max takeoff weight:** 19,277 kg (42,500 lb)
- **Powerplant:** 1× Saturn-Lyulka AL-31FN or WS-10A Taihang turbofan
    - **Dry thrust:** 79.43 kN / 89.17 kN (17,860 lbf / 20,050 lbf)
    - **Thrust with afterburner:** 122.5 kN / 132 kN (27,557 lbf / 29,101 lbf)

Performance

- **Maximum speed:** Mach 2.0 at altitude, Mach 1.2 at sea level
- ***g*-limits:** +9/-3 *g* (+88/-29 m/s², +290/-97 ft/s²)
- **Combat radius:** 1100 km (688 mi)
- **Service ceiling:** 18,000 m (59,055 ft)
- **Wing loading:** 335 kg/m² (69 lb/ft²)
- **Thrust/weight:** .98

Armament

- **Guns:** 1× 23mm twin-barrel cannon
- **Hardpoints:** 11 in total (6× under-wing, 5× under-fuselage) with a capacity of 6,000 kg (13,228 lb) external fuel and ordnance
- **Rockets:** 90 mm unguided rocket pods
- **Missiles:**
    - **Air-to-air missiles**: PL-8, PL-9, PL-11, PL-12
    - **Air-to-surface missiles**: PJ-9, YJ-9K
- **Bombs:** laser-guided bombs (LT-2), glide bombs (LS-6) and unguided bombs
- **Others:**
    - Up to 3 external fuel drop-tanks (1× under-fuselage, 2× under-wing) for extended range and loitering time

Avionics

- NRIET KLJ-10 multi-mode fire-control radar
- Externally-mounted avionics pods:
    - Type Hongguang-I infra-red search and track pod
    - BM/KG300G self-protection jamming pod
    - KZ900 electronic reconnaissance pod
    - Blue Sky navigation/attack pod
    - FILAT (Forward-looking Infra-red Laser Attack Targeting) pod

Chapter 6

Dassault Rafale

Rafale

A Rafale B (foreground), and a Rafale C (background) of the French Air Force

Role	Multirole fighter aircraft
National origin	France
Manufacturer	Dassault Aviation
First flight	4 July 1986
Introduced	4 December 2000
Status	Active
Primary users	French Air Force French Navy
Program cost	€39.6 billion (1 January 2008)
Unit cost	Rafale C: €64 million, US$82.3 million (flyaway cost, 2008) Rafale M: €70 million, US$90.5 million (flyaway cost, 2008)

The **Dassault Rafale** is a French twin-engined delta-wing multi-role jet fighter aircraft designed and built by Dassault Aviation. Introduced in 2000, the Rafale is being produced both for land-based use with the French Air Force and for carrier-based operations with the French Navy. It has also been marketed for export to several countries but has not yet received orders.

Development

The logo of the Dassault Rafale programme.

In the mid-1970s, both the French Air Force (*Armée de l'Air*) and Navy (*Aéronavale*) had requirements (the Navy's being rather more pressing) to find a new generation of fighters (principally to replace Air Force SEPECAT Jaguars and Navy F-8 Crusaders), and their requirements were similar enough to be merged into one project. In 1983, France awarded Dassault a contract for two *Avion de Combat eXpérimental* (ACX) demonstrators. European nations, Germany, France, Italy, Spain and the United Kingdom agreed to jointly develop a new fighter in the early 1980s. Disagreement over the fighter's size and project leadership led France and the other nations to split in 1985. France developed the smaller Rafale, while the other nations developed what would later be named the Eurofighter Typhoon.

Prototype Dassault Rafale A

The **Rafale A** technology demonstrator was rolled out in late 1985 and made its maiden flight on 4 July 1986. The SNECMA M88 engine was being developed and was not considered sufficiently mature for the initial trials programme, so the demonstrator flew with General Electric F404-GE-400 afterburning turbofans as used on the F/A-18 Hornet. Production orders were placed in 1988.

Further testing continued, including carrier touch-and-go landings and test-flying early M88 engines, before the Rafale A was retired in 1994. Though the Rafale A and British

Aerospace EAP were broadly comparable, when the first Eurofighter made its maiden flight in March 1994, pre-series Rafales had been flight-testing for three years, including carrier trials; Rafale C01, Rafale M01, and Rafale B01 first flew in May 1991, December 1991, and April 1993 respectively.

Three versions of Rafale were in the initial production order:

- **Rafale C** (Chasseur) Single-seat fighter for the *AdA* (*Armée de l'Air*, French Air Force)
- **Rafale B** (Biplace) Two-seat fighter for the *AdA*
- **Rafale M** (Marine) Single-seat carrier fighter for the *Aéronavale*

The prototype Rafale C flew in 1991, the first of two Rafale M prototypes flew later that year. The prototype Rafale B flew in early 1993, and the second Rafale M prototype flew later that year. Catapult trials were initially carried out between 13 July and 23 August 1992 at NAS Lakehurst in New Jersey, USA and NAS Patuxent River, Maryland, USA, as France had no land-based catapult test facility. The aircraft then undertook trials aboard the carrier FS *Foch*.

A French Navy Rafale M performing a touch and go on the deck of the carrier USS John C. Stennis (CVN-74).

Initially, the Rafale B was to be just a trainer, but Gulf War and Kosovo experience showed that a second crew member is invaluable on strike and reconnaissance missions, and therefore more Rafale Bs were ordered, replacing some Rafale Cs. 60% of the aircraft will be two seaters. The navy investigated a naval version of the two-seat version. No production aircraft or prototypes were built.

Political and economic uncertainty meant that it was not until 1999 that a production Rafale M flew.

The French forces were expected to order 294 Rafales: 234 for the Air Force and 60 for the Navy. To date, 120 Rafales have been officially ordered. These are being delivered in three separate batches, the most recent being the December 2004 order for 59 Rafales.

The marine version has priority since the aircraft it is replacing are much older F-8E(FN) Crusader fighters. Service deliveries began in 2001 and the type "entered service" on 4 December 2000, though the first squadron, Flotille 12, did not actually reform until 18 May 2001. The unit embarked on the *Charles de Gaulle* in 2002, becoming fully operational on 25 June 2004, following an extended operational evaluation that included flying limited escort and tanker missions in support of Operation Enduring Freedom over Afghanistan.

The *Armee de l'Air* received its first three Rafale Bs (to F2 standards) in late December 2004. They went to the *Centre d'Expériences Aériennes Militaires* (CEAM) at Mont-de-Marsan for operational evaluation and associated pilot conversion training.

Costs

The total programme cost, as of 2008, is around €39.6 billion, which translates to a unit programme cost of approximately €138.5 million. The unit flyaway price as of 2008 is €64 million for C version (Air Force), and €70 million for the Navy version.

Total costs, as of 2011, have been estimated to have escalated to €53 billion.

Programme milestones

Important dates from the Rafale programme include:

- **1985** France formally withdraws from Eurofighter programme, committing to Rafale project.
- **1986** July 4: First flight of Rafale A; December: Development of SNECMA M88 engines commences
- **1988** April: First order signed (for Rafale C prototype).
- **1990** February: Flight tests of M88 begin
- **1991** May 19: First flight of Armée de l'Air single seat prototype (Rafale C); December 12: First flight of *Aéronavale* prototype (Rafale M)
- **1992** Rafale M carrier trials programme begins

- **1993** March: First contract for production aircraft signed. April: Start of carrier compatibility trials with *Foch*. 30 April: First flight of *Armée de l'Air* twin seat prototype (Rafale B)
- **1995** June: First MICA fired from Rafale in self guided mode. July: OSF system and helmet-mounted sight/display installed and tested. September: Rafale M tested on board carrier (4th series). November: First non-stop long-range flight by Rafale B01 (3,020 nm in under 6 hours 30 minutes). October: Final land-based carrier test series of Rafale M in the USA. December: First production model fuselage assembly.
- **1996** March: M88 engine "flightworthiness" qualified. April: Production suspended, restarted in January 1997 following cost reductions. May: Low level tests with digital terrain database. July: Spectra electronic warfare system integration tests in anechoic chamber. November: Spectra flight tested. December: First deliveries of production standard engines.
- **1997** February: Rafale B01 flight tested in heavyweight configuration (2 Apache ASMs, three 2,000 l drop tanks, two Magic and two MICA AAMs). May: First inertially-guided MICA firing. June: Flight testing of Spectra countermeasures system. October: First production RBE2 radar flown for the first time. November: Inertially-guided firing of missiles against two targets, with aircraft-to-missile link, with countermeasures.
- **1998** June: Qualification of MICA fire control system. Proposed initial operational capability evaluated by Navy and Air Force pilots flying Rafale B01 and M02 development aircraft. 24 November: First flight of production Rafale (a Rafale B)
- **1999** May: First test launch of SCALP EG cruise missile. 6 July: First deck landing on *Charles de Gaulle*. 7 July: First flight of production Rafale M
- **2000** 20 July: First Rafale M delivered to *Flotille* 12F
- **2002** Rafale M entered service with 12F (*Aéronavale*, evaluation)
- **2004** Full service entry with 12F (Navy); 9 September: First Meteor GHTM (General Handling Training Missiles) carriage trials by Rafale M from CEV Istres; June:December: Three Rafale Bs delivered to CEAM, Mont de Marsan
- **2005** September 11: First Meteor GHTM carriage trials by Rafale M from the carrier *Charles de Gaulle*.
- **2006** Summer: Formation of EC 1/7 with 8–10 aircraft
- **2007** Full service entry (Air Force) expected with EC7; First landing of Rafale M on US Navy carrier USS *Enterprise*
- **2008** Rafale qualified to full F3 standard

Design

Aerodynamics

The Rafale features a delta wing combined with active integrated (Close-coupled) canard to maximize maneuverability (withstanding +9 g or -3 g) while maintaining stability in flight, a maximum of 11 g can be reached in case of emergency. The canard also reduces landing speed to 115 knots. According to internal sources (Les essais en vol du Rafale) low speed limit is 100 kt but 80 kt is sometimes demonstrated during airshows by pilots willing to underline low speed qualities of the aircraft." "A minimum of 15 kt have been reached during simulated combat vs a Mirage 2000 by an aggressive pilot." The aircraft can operate from 400 meter runways.

Combat systems

Weapon complement of the Rafale.

The Rafale carries an integrated electronic survival system named SPECTRA which features a software-based virtual stealth technology. The most important sensor is the Thales RBE2 passive electronically scanned multi-mode radar. Thales claims to have achieved unprecedented levels of situational awareness through the earlier detection and tracking of multiple air targets for close combat and long-range interception, as well as real time generation of three-dimensional maps for terrain-following and the real time generation of high resolution ground maps for navigation and targeting.

In circumstances when signature management is required, the Rafale can use several passive sensor systems. The front-sector electro-optical system or Optronique Secteur Frontal (OSF), developed by Thales, is completely integrated within the aircraft and can operate both in the visible and infrared wavelengths.

The SPECTRA electronic warfare system, jointly developed by Thales and EADS France, provides the aircraft with the highest survivability assets against airborne and ground threats. The real-time data link allows communication not only with other aircraft, but also with fixed and mobile command and control centres. For those missions requiring it, the Rafale will also eventually use the Damoclès electro-optical/laser designation pod that brings full day and night LGB capability, though the Armée de l'Air's current plans call for Rafale to use stand off weapons, and for the LGB role to be handled by Dassault Mirage 2000s.

The Rafale core systems employ an Integrated Modular Avionics (IMA), called MDPU (Modular Data Processing Unit). This architecture hosts all the core functions of the aircraft as Flight management system, Data Fusion, Fire Control, Man-Machine Interface, etc.

The total value of the radar, electronic communications and self-protection equipment is about 30% of the cost of the entire plane.

The Rafale's ground attack capability is limited by the lack of an advanced targeting pod, but this will be rectified with the addition of Thales Optronique's Reco NG/Areos reconnaissance and Damocles targeting pods on the F-3 standard.

Rafale B/C

AESA Radar

The new Thales RBE2 AA Active Electronically Scanned Array (AESA) radar is planned to replace the existing passively scanned array of the RBE2. Thales will begin deliveries of the new radar in August 2010 for use on the fourth tranche of Rafale aircraft. A total of 60 tranche four aircraft have been ordered to date. The first AESA-equipped squadron of aircraft is expected to become operational in 2012. Thales also claims that the AESA radar will improve the operational capabilities of the aircraft in terms of range, interception, tracking ability and countermeasures. Rafale's attempts at export sales have been hindered by a lack of AESA capability, "a baseline requirement for a 21st-century aircraft.”

Cockpit

The cockpit uses a Martin-Baker Mark 16F "zero-zero” ejection seat, i.e., capable of being used at zero speed and zero altitude. The seat is inclined 29 degrees backwards to improve G force tolerance. The canopy hinges open to the right. An on-board oxygen generating system is provided to eliminate the need for multiple oxygen canisters.

The cockpit includes a wide-angle holographic head-up display (HUD), two head-down flat-panel colour multi-function displays (MFDs) and a center collimated display. Display interaction is by means of touch input for which the pilot wears silk-lined leather gloves. In addition, in full development, the pilot will have a head-mounted display (HMD).

The pilot flies the aircraft with a side-stick controller mounted on his right and a throttle on his left. These incorporate multiple hands on throttle and stick (HOTAS) controls. The Rafale cockpit is also planned to include Direct Voice Input (DVI), allowing for pilot action by voice commands.

Radar signature reduction features

Although not a true stealth aircraft, the Rafale has reduced radar signature according to Dassault, while most of the stealth design features are classified, extensive use of composite materials and serrated patterns on the trailing edges of the wings and canards help to reduce the radar cross section.

Standards

Initial deliveries of the Rafale M were to the *F1* ("France 1") standard. This meant that the aircraft was suitable for air-to-air combat, replacing the obsolescent F-8 Crusader as the Aviation Navale's carrier-based fighter, but not equipped or armed for air-to-ground operations. Actual deliveries (to *Flotille 11* some time after 2007) are to the "F2" standard, giving air-to-ground capability, and replacing the Dassault-Breguet Super Étendard in the ground attack role and the Dassault Étendard IVP in the reconnaissance role. This will leave the Rafale M as the only fixed-wing combat aircraft flown by the Aviation Navale, and plans are to upgrade all airframes to the "F3" standard, with terrain-following 3D radar and nuclear capability, from early in the decade following 2010. This upgrade has been brought forwards to 2010 for the first 10 French Navy Rafale F-1’s.

The first Rafale C delivered to the *Armée de l'Air*, in June 2005, was to the "F2" standard, and it is anticipated that upgrades similar to those of the navy will take place in the future. The Rafale replaces the SEPECAT Jaguar, Mirage F1 and the Mirage 2000 in the Armée de l'Air.

Operational history

France

A Rafale M landing on an aircraft carrier.

The Rafale is now in service in the trials and training role with the French Air Force (CEAM/EC 5/330) and EC 1/7 at Saint-Dizier is expected to receive a nucleus of 8–10 Rafale F2s during the Summer of 2006, and it looks set to enter full operational service (with robust air-to-air and stand off air-to-ground precision attack capabilities) during mid-2007 (when EC 1/7 will have about 20 aircraft, 15 two-seaters and 5 single-seaters). The aircraft is already in limited operational service with the French Navy (*Flotille 12F*) in the air-to-air role, and has undertaken a great deal of air-to-ground trials and evaluation work.

The Rafale M is fully compatible with US Navy aircraft carriers and some French Navy pilots have qualified to fly the aircraft from US Navy flight decks.

The first Rafale deployed in a combat zone were those of the French Navy during *Opération Héraclès*, the French participation in "Operation Enduring Freedom". They flew from the *Charles de Gaulle* over Afghanistan as early as 2002, but the F1 standard precluded air-to-ground missions and the Rafale did not see any action.

In June 2002, while *Charles de Gaulle* was in the Arabian Sea, armed Rafale fighters participated in interposition patrols near the India-Pakistan border, marking a significant point in the Rafale M's operational career and its integration with the carrier.

In 2007, after a "crash program" enhancement six Rafales were given the ability to drop laser-guided bombs, in view of engaging them in Afghanistan. Three of these aircraft belonging to the Air Force were deployed to Dushanbe in Tajikistan, while the three others were *Rafale Marines* of the Navy on board the *Charles De Gaulle*. The first mission occurred on 12 March 2007, and the first GBU-12 was launched on 28 March in support of embattled Dutch troops in Southern Afghanistan, marking the operational début of the Rafale. They still have to rely on Mirage 2000Ds and Super Étendards carrying laser designation pods to designate their targets.

The Rafale is planned to be the French Air Force's primary combat aircraft until 2040 or later.

In November 2009 the French government ordered an additional 60 aircraft to take the total order for the French Air Force and Navy to 180.

On 4 June 2010, a French Rafale became the first jet fighter of a foreign navy to have its jet engine changed on board an American aircraft carrier, during an exercise on the USS Harry S. Truman (CVN-75).

Export

Several countries have shown interest in purchasing the Rafale. The Rafale is one of the six fighter jets competing for India's tender for 126 multi-role fighters. In April 2009, news reports stated the Rafale had been disqualified from the competition for not meeting minimum performance requirements of the Indian Air Force and that other competing aircraft, namely Mikoyan MiG-35, General Dynamics F-16 Fighting Falcon, Boeing F/A-18E/F Super Hornet, JAS 39 Gripen and Eurofighter Typhoon, qualified for the next round of evaluation. The Indian Defence Ministry denied this report; an IAF spokesman stated, "we have not ruled anyone out yet in the MMRCA competition". Reports suggested Rafale and Typhoon have entered the final stage of the contest.

In January 2006, the French newspaper *Journal du Dimanche* reported that Libya wanted to order 13–18 Rafales "in a deal worth as much as $3.24 billion". In December 2007, Saif al-Islam Gaddafi openly declared the Libyan interest in the Rafale. Greece has also expressed an interest in the French fighter, possibly in exchange for its fleet of Mirages.

In 2006 the British Royal Navy considered the Rafale as an alternative to the F-35 JSF but decided to proceed with the F-35. However the British aircraft carriers will be modified in order to operate French Rafales.

In February 2007, it was reported that Switzerland was considering the Rafale and other fighters to replace its F-5 Tiger IIs. The one month evaluation started in October 2008 at

Emmen Airforce Base consisting of approx. 30 evaluation flights. The Rafale along with the Gripen and the Eurofighter were to be evaluated.

In September 2007, *La Tribune* reported that a sale to Morocco had fallen through, the government selecting Lockheed Martin's F-16 instead. In October 2007, *La Tribune*'s earlier report appeared to have been confirmed that the Rafale would not be bought.

In January 2008, *O Estado de São Paulo* reported that the Brazilian Defence Minister visited France to discuss the possibility of acquiring Rafale fighters for the F-X2 program. In June 2008, the Brazilian Air Force divulged a Request For Information to the following companies and their aircraft: Boeing F/A-18E/F Super Hornet and Lockheed Martin F-35 Lightning II, Dassault Rafale, Sukhoi Su-35, Saab Gripen NG and Eurofighter Typhoon. In October 2008, it was reported that Brazilian Air Force had selected three finalists for F-X2; Dassault Rafale, Saab Gripen NG and Boeing F/A-18E/F. On 7 September 2009, during a visit by French President Nicolas Sarkozy, Brazil announced a pact with France and that the nations are in contract negotiations to buy 36 Rafales. The crash of two Rafales in the Mediterranean off Perpignan on 24 September 2009 after a midair collision, comes at a delicate time for the Brazil-France negotiations. On 5 January 2010, media reports stated that the final evaluation report by the Brazilian Air Force placed the Gripen ahead of the other two contenders. The decisive factor was apparently the overall cost of the new fighters, both in terms of unit cost, and operating and maintenance costs. Some sources say that Rafale was chosen by the Defense Ministry, but there has been no confirmation on this. In February, 2011, the press announced that the new president of Brazil, Dilma Roussef, had decided in favor of the American F-18 fighter. On February 28, 2011, the Minister of Finance, Guido Mantega, said the issue would not be resolved in the current year, citing "lack of resources", due to budgetary constraints for the new fiscal year.

In February 2009, French President Nicolas Sarkozy announced that Kuwait was considering buying up to 28 Rafales, but with no firm order then. The same month, France offered Rafales to Oman to replace its ageing fleet of SEPECAT Jaguars. But in 2010, Oman prefers to order the Typhoon.

The UAE was interested in a version of the Rafale that would be upgraded with more powerful engines and radar and advanced air to air missiles. They have now started to explore a purchase of the Boeing F/A-18E/F Super Hornet. This is reported to be because France's Defense Minister Hervé Morin has asked the UAE to pay 2 billion euros of the total cost to upgrade the Rafale to match the Super Hornet's advancements.

Leaked United States State Department cables have said that "French representatives have tried to spin the Rafale's dismal performance in the global market to be the result of U.S. government political pressure rather than the aircraft's shortcomings".

Variants

Dassault Rafale M.

Rafale B at the Paris Air Show 2007

Rafale A

A technology demonstrator that first flew in 1986. It has now been retired.

Rafale D

Dassault used this designation (D for *discret* or stealthy) in the early 1990s for the production versions for the *Armée de l'Air*, to emphasise the new semi-stealthy features they had added to the design.

Rafale B

This is the two-seater version for the *Armée de l'Air*; delivered to EC 330 in 2004.

Rafale C

This is the single-seat version for the *Armée de l'Air*; delivered to EC 330 in June 2004.

Rafale M

This is the carrier-borne version for the *Aéronavale*, which entered service in 2002. The Rafale M weighs about 500 kg (1,100 lb) more than the Rafale C. Very similar to the Rafale C in appearance, the M differs in the following respects:

- Strengthened to withstand the rigors of carrier-based aviation
- Stronger landing gear
- Longer nose gear leg to provide a more nose-up attitude for catapult launches
- Deleted front centre pylon (to give space for the longer gear)
- Large stinger-type tailhook between the engines
- Built-in power operated boarding ladder
- Carrier microwave landing system
- "Telemir" inertial reference platform that can receive updates from the carrier systems.

Rafale N

The Rafale N, originally called the Rafale BM, was planned to be a two-seater version for the *Aéronavale*. Budget constraints and the cost of training extra crew members have been cited as the grounds for its cancellation.

Operators

France

180 ordered, 82 delivered as of December 2009

- French Air Force - 54
- French Navy - 28

Accidents

- On 6 December 2007, a French Air Force twin-seat Rafale crashed during a training flight. The pilot, who was the only person on board the fighter, was killed in the accident.
- On 24 September 2009, two French Navy Rafales collided in mid-air off Perpignan during exercises on the *Charles de Gaulle*.

- On 28 November 2010, a Rafale from carrier "Charles de Gaulle" crashed in the Arabian Sea. This aircraft was supporting Allied operations in Afghanistan. The pilot ejected safely and was recovered by a SAR helicopter from the carrier. Later reports said the engine stopped after being starved of fuel due to confusion by the pilot over the operation of valves in the fuel tanks.

Specifications

A Rafale M flies above the aircraft carrier USS *John C. Stennis*.
Data from Dassault Rafale characteristics, *Superfighters* French Navy page

General characteristics

- **Crew:** 1–2
- **Length:** 15.27 m (50.1 ft)
- **Wingspan:** 10.80 m (35.4 ft)
- **Height:** 5.34 m (17.5 ft)
- **Wing area:** 45.7 m² (492 ft²)
- **Empty weight:** 9,500 kg (C), 9,770 kg (B), 10,196 kg (M) ()
- **Loaded weight:** 14,016 kg (30,900 lb)
- **Max takeoff weight:** 24,500 kg (C/D), 22,200 kg (M) (54,000 lb)
- **Powerplant:** 2× Snecma M88-2 turbofans
  - **Dry thrust:** 50.04 kN (11,250 lbf) each
  - **Thrust with afterburner:** 75.62 kN (17,000 lbf) each

Performance

- **Maximum speed:**
  - **High altitude:** Mach 2 (2,390 km/h, 1,290 knots)
  - **Low altitude:** 1,390 km/h, 750 knots
- **Range:** 3,700+ km (2,000+ nmi)
- **Combat radius:** 1,852+ km (1,000+ nmi) on penetration mission .
- **Service ceiling:** 16,800 m (55,000 ft)
- **Rate of climb:** 304.8+ m/s (1,000+ ft/s)
- **Wing loading:** 306 kg/m² (62.8 lb/ft²)
- **Thrust/weight:** 1.10 (100% fuel, 2 EM A2A missile, 2 IR A2A missile)

Armament

- **Guns:** 1× 30 mm (1.18 in) GIAT 30/719B cannon with 125 rounds
- **Hardpoints:** 14 For Armée de l'Air version (Rafale B,C), 13 for Aéronavale version (Rafale M) with a capacity of 9,500 kg (21,000 lb) external fuel and ordnance
- **Missiles:**
  - **Air-to-air:**
    - MICA IR/EM *or*
    - Magic II and in the future
    - MBDA Meteor
  - **Air-to-ground:**
    - MBDA Apache *or*
    - SCALP EG *or*
    - AASM *or*
    - GBU-12 Paveway II *or*
    - AM 39 Exocet *or*
    - ASMP-A nuclear missile
- **Others:**

    - Thales Damocles targeting pod
    - RECO NG reconnaissance pod
    - up to 5 drop tanks
    - The Rafale can also carry a buddy-buddy refuelling pod

Avionics

- Thales RBE2 radar
- Thales SPECTRA electronic warfare system.
- Thales/SAGEM OSF (*Optronique Secteur Frontal*) infrared search and track system.

Chapter 7

Eurofighter Typhoon

Eurofighter Typhoon

A Eurofighter Typhoon of the Italian Air Force

Role	Multirole fighter
Manufacturer	Eurofighter GmbH
First flight	27 March 1994
Introduced	4 August 2003
Status	Operational
Primary users	Royal Air Force Luftwaffe Italian Air Force Spanish Air Force
Number built	>260 as of January 2011 471 ordered (as of January 2009)
Unit cost	€90 Million (system cost Tranche 3A)
Developed from	British Aerospace EAP
Variants	Eurofighter Typhoon variants

The **Eurofighter Typhoon** is a twin-engine, canard-delta wing, multirole combat aircraft, designed and built by a consortium of three companies: Alenia Aeronautica, BAE Systems, and EADS; working through a holding company, Eurofighter GmbH, which was formed in 1986. The project is managed by the NATO Eurofighter and Tornado Management Agency, which acts as the prime customer.

The series production of the Eurofighter Typhoon is underway, and the aircraft is being procured under three separate contracts (named "tranches"), each for aircraft with generally improved capabilities. The aircraft has entered service with the British Royal Air Force, the German Luftwaffe, the Italian Air Force, the Spanish Air Force, the Austrian Air Force and the Royal Saudi Air Force.

Development

Official Eurofighter logo

The UK had identified a requirement for a new fighter as early as 1971. A specification, AST 403, issued by the Air Staff in 1972, resulted in a conventional "tailed" design known as P.96, which was presented in the late 1970s. While the design would have met the Air Staff's requirements, the UK air industry had reservations as it appeared to be very similar to the McDonnell Douglas F/A-18 Hornet, which was then well advanced in its development. The design had little potential for future growth, and when it entered production it would secure few exports in a market in which the Hornet would be well established. Simultaneously, by 1979 the West German requirement for a new fighter had led to the development of the TKF-90 concept. This was a cranked delta wing design with forward canard controls and artificial stability. Although the British Aerospace designers rejected some of its advanced features such as vectoring engine nozzles and vented trailing-edge controls, they agreed with the overall configuration.

In 1979 British Aerospace and Messerschmitt-Bölkow-Blohm presented a formal proposal to their respective governments for the ECF, the **European Collaborative Fighter** or **European Combat Fighter**. In October 1979 Dassault joined the ECF team for a tri-national study, which became known as the **European Combat Aircraft**. It was at this stage of development that the Eurofighter name was first attached to the aircraft. The development of different national prototypes continued. France produced the ACX.

The UK produced two designs; the P.106 was a single-engined "lightweight" fighter, superficially resembling the JAS 39 Gripen, the P.110 was a twin-engined fighter. The P.106 concept was rejected by the RAF, on the grounds that it had "half the effectiveness of the two-engined aircraft at two thirds of the cost". West Germany continued to refine the TFK-90 concept. The ECA project collapsed in 1981 for several reasons including differing requirements, Dassault's insistence on "design leadership" and the British preference for a new version of the RB199 to power the aircraft versus the French preference for the new SNECMA M88.

As a result the Panavia partners (BAe, MBB and Aeritalia) launched the **Agile Combat Aircraft** (ACA) programme in April 1982. The ACA was very similar to the BAe P.110, having a cranked delta wing, canards and a twin tail. One major external difference was the replacement of the side mounted engine intakes with a chin intake. The ACA was to be powered by a modified version of the RB199. The German and Italian governments withdrew funding, and the UK Ministry of Defence agreed to fund 50% of the cost with the remaining 50% to be provided by industry. MBB and Aeritalia signed up with the aim of producing two aircraft, one at Warton and one by MBB. In May 1983 BAe announced a contract with the MoD for the development and production of an ACA demonstrator, the **Experimental Aircraft Programme**.

In 1983 the UK, France, Germany, Italy and Spain launched the **Future European Fighter Aircraft** (FEFA) programme. The aircraft was to have Short Take Off and Landing (STOL) and Beyond Visual Range (BVR) capabilities. In 1984 France reiterated its requirement for a carrier-capable version and demanded a leading role. The UK, West Germany and Italy opted out and established a new EFA programme.

In Turin on 2 August 1985 Italy, West Germany and the UK agreed to go ahead with the Eurofighter. The announcement of this agreement confirmed that France, along with Spain, had chosen not to proceed as a member of the project. Despite pressure from France, Spain rejoined the Eurofighter project in early September 1985. France officially withdrew from the project to pursue its own ACX project, which was to become the Dassault Rafale.

Close up view of an RAF Typhoon F2, showing the deflected canard control surface immediately below the pilot

By 1986, the cost of the program had reached £180 million. When the EAP program had started, the cost was supposed to be equally shared by both government and industry, but the West German and Italian government wavered on the agreement and the three main industrial partners had to provide £100 million to keep the program from ending. In April 1986 the BAe EAP was rolled out at BAe Warton, by this time also partially funded by MBB, BAe and Aeritalia. The EAP first flew on 6 August 1986. The Eurofighter bears a strong resemblance to the EAP. Design work continued over the next five years using data from the EAP. Initial requirements were: UK: 250 aircraft, Germany: 250, Italy: 165 and Spain: 100. The share of the production work was divided among the countries in proportion to their projected procurement - British Aerospace (33%), DASA (33%), Aeritalia (21%), and Construcciones Aeronáuticas SA (CASA) (13%).

The Munich based Eurofighter Jagdflugzeug GmbH was established in 1986 to manage development of the project and EuroJet Turbo GmbH, the alliance of Rolls-Royce, MTU Aero Engines, FiatAvio (now Avio) and ITP for development of the EJ200. The aircraft was known as Eurofighter EFA from the late 1980s until it was renamed EF 2000 in 1992.

By 1990, the selection of the aircraft's radar had become a major stumbling block. The UK, Italy and Spain supported the Ferranti Defence Systems-led ECR-90, while Germany preferred the APG-65 based MSD2000 (a collaboration between Hughes (of the USA), AEG and GEC-Marconi). An agreement was reached after UK Defence Secretary

Tom King assured his West German counterpart Gerhard Stoltenberg that the British government would approve the project and allow GEC to acquire Ferranti Defence Systems from its troubled parent. GEC thus withdrew its support for the MSD2000.

Testing

The maiden flight of the Eurofighter prototype took place on 27 March 1994. Dasa chief test pilot Peter Weger took the prototype on a test flight around Bavaria. The 1990s saw significant arguments over work share, the specification of the aircraft and even participation in the project.

On 9 December 2004, Eurofighter Typhoon IPA4 began three months of Cold Environmental Trials (CET) at the Vidsel Air Base in Sweden, the purpose of which was to verify the operational behaviour of the aircraft and its systems in temperatures between -25 and -31 °C.

In May 2007, Eurofighter Development Aircraft 5 made the first flight with the CAESAR demonstrator system, a development of the Euroradar CAPTOR incorporating Active Electronically Scanned Array (AESA) technology.

The maiden flight of Instrumented Production Aircraft 7 (IPA7), the first fully equipped Tranche 2 aircraft, took place from EADS' Manching airfield on 16 January 2008.

The production version of the CAPTOR-E radar was being proposed as part of Tranche 3 of the Typhoon from 2012. Tranche 2 aircraft use the non AESA, mechanically scanned Captor-M which incorporates weight and space provisions for possible upgrade to CAESAR (AESA) standard in the future. The Italian Air Force doubted that the AESA radar would be ready in time for Tranche 3 production. In July 2010, Eurofighter announced that the AESA radar would enter service in 2015.

A German Luftwaffe Eurofighter Instrumented Production Aircraft.

Orders

The first production contract was signed on 30 January 1998 between Eurofighter GmbH, Eurojet and NETMA. The procurement totals were as follows: UK 232, Germany 180, Italy 121, and Spain 87. Production was again allotted according to procurement: British Aerospace (37%), DASA (29%), Aeritalia (19.5%), and CASA (14%).

On 2 September 1998, a naming ceremony was held at Farnborough, England. This saw the Typhoon name formally adopted, initially for export aircraft only. This was reportedly resisted by Germany; perhaps because the Hawker Typhoon was a fighter-bomber aircraft which served with the RAF during the Second World War against German targets. The name "Spitfire II" (for the famous British WWII fighter, the Supermarine Spitfire) had also been considered and rejected for the same reason early in the development program. In September 1998 contracts were signed for production of 148 Tranche 1 aircraft and procurement of long lead-time items for Tranche 2 aircraft. In March 2008 the final aircraft out of Tranche 1 was delivered to the German Luftwaffe, with all successive deliveries being at the Tranche 2 standard. On 21 October 2008, the first two of 91 Tranche 2 aircraft, ordered four years before, were delivered to RAF Coningsby.

In October 2008, the Eurofighter nations were considering splitting the 236-fighter Tranche 3 into two parts. In June 2009, RAF Air Chief Marshal Sir Glenn Torpy suggested that the RAF fleet might only be 123 jets, instead of the 232 previously planned. In spite of this reduction in the number of required aircraft, on May 14, 2009, British Prime Minister Gordon Brown confirmed that the UK would move ahead with the third batch purchase. A contract for the first part, Tranche 3A, was signed at the end of

July 2009 for 112 aircraft split across the four partner nations, including 40 aircraft for the UK, 31 for Germany, 21 for Italy and 20 for Spain. These 40 aircraft were said to have fully covered the UK's obligations in the project by Air Commodore Chris Bushell, due to cost overruns in the project.

Costs

In 1988, the Parliamentary Under-Secretary of State for the Armed Forces told the UK House of Commons that the European Fighter Aircraft would "be a major project, costing the United Kingdom about £7 billion". It was soon apparent that a more realistic estimate was £13 billion, made up of £3.3 billion development costs plus £30 million per aircraft. By 1997 the estimated cost was £17 billion; by 2003, £20 billion, and the in-service date (2003; defined as the date of delivery of the first aircraft to the RAF) was 54 months late. After 2003 the Ministry of Defence have refused to release updated cost estimates on the grounds of 'commercial sensitivity', however in 2011 the National Audit Office estimated the UK's "total programme cost [would] eventually hit £37 billion".

By 2007, Germany estimated the system cost (aircraft, training plus spare parts) to 120 M€ and said it was in perpetual increase. On 17 June 2009, Germany ordered 31 aircraft of Tranche 3A for 2,800 M€, leading to a system cost of 90 M€ per aircraft.

Delays

Political

The financial burdens placed on Germany by reunification caused Helmut Kohl to make an election promise to cancel the Eurofighter. In early to mid-1991 German Defence Minister Volker Rühe sought to withdraw Germany from the project in favour of using Eurofighter technology in a cheaper, lighter plane. Due to the amount of money already spent on development, the number of jobs dependent on the project, and the binding commitments on each partner government, Germany was unable to withdraw; "Rühe's predecessors had locked themselves into the project by a punitive penalty system of their own devising."

In 1995 concerns over workshare appeared. Since the formation of Eurofighter the workshare split had been agreed at the 33/33/21/13 (United Kingdom/Germany/Italy/Spain) based on the number of units being ordered by each contributing nation. All the nations then reduced their orders. The UK cut its orders from 250 to 232, Germany from 250 to 140, Italy from 165 to 121 and Spain from 100 to 87. According to these order levels the workshare split should have been 39/24/22/15 UK/Germany/Italy/Spain, Germany was unwilling to give up such a large amount of work. In January 1996, after much negotiation between UK and German partners, a compromise was reached whereby Germany would purchase another 40 aircraft. The workshare split is now 43% for EADS MAS in Germany and Spain; 37.5% BAE Systems in the UK; and 19.5% for Alenia in Italy.

The next major milestone came at the Farnborough Airshow in September 1996. The UK announced the funding for the construction phase of the project. In November 1996 Spain confirmed its order but Germany again delayed its decision. After much diplomatic activity between the UK and Germany, an interim funding arrangement of DM 100 million (€ 51 million) was contributed by the German government in July 1997 to continue flight trials. Further negotiation finally resulted in German approval to purchase the Eurofighter in October 1997.

Technical

On 21 November 2002, DA-6, the Spanish twin-seat prototype crashed due to a "double engine flame-out", said to be specifically related to the experimental trial standard of engine being used by that aircraft. The aircraft went down but the two crew members escaped unhurt.

The distribution of the parts supply and repairs over several countries has lead to parts shortages, long timescales for repairs and cannibalisation of some aircraft to keep others flying.

Production

Eurofighter Typhoon F2, RAF single-seat fighter variant

A Luftwaffe twin-seat trainer version of the Eurofighter

The Eurofighter Typhoon is unique in modern combat aircraft in that there are four separate assembly lines. Each partner company assembles its own national aircraft, but builds the same parts for all 683 aircraft (including exports). A fifth assembly line will be established for the final 48 Saudi aircraft.

- **Alenia Aeronautica** – Left wing, outboard flaperons, rear fuselage sections
- **BAE Systems** – Front fuselage (including foreplanes), canopy, dorsal spine, tail fin, inboard flaperons, rear fuselage section
- **EADS Deutschland** – Main centre fuselage
- **EADS CASA** – Right wing, leading edge slats

Production is divided into three tranches. Tranches are a production/funding distinction, and do not necessarily imply an incremental increase in capability with each tranche. Tranche 3 will most likely be based on late Tranche 2 aircraft with improvements added. Tranche 3 has been split into A and B parts.

Tranches are further divided up into production standard/capability 'blocks' and funding/procurement 'batches', though these do not coincide, and are not the same thing e.g. the Eurofighter designated 'FGR4' by the RAF is a Tranche 1, Block 5. Batch 1 covered Block 1, but Batch 2 covered Blocks 2, 2B and 5.

Expected production summary

Country	Tranche 1	Tranche 2	Tranche 3A	Total
Austria	15	0	0	15
Germany	33	79	31	143
Italy	28	47	21	96
Saudi Arabia	1	24	48	72
Spain	19	34	20	73
United Kingdom	53	67	40	160
TOTAL	**148**	**299**	**112**	**559**

Note: The change in Austria's order from 6 Tranche 1 and 12 Tranche 2 aircraft to 15 Tranche 1 jets led to a reduction in Tranche 1 quantities for the four partner nations, with a commensurate increase in Tranche 2 numbers. 24 Saudi aircraft were taken from UK Tranche 2 production, and were to have been replaced at the end of Tranche 2, but will now 'count' against the UK's Tranche 3A total. This marks an effective reduction of 24 aircraft in the UK order total.

Exports

Countries operating or ordering the Eurofighter Typhoon

Austria

On 2 July 2002, the Austrian government announced the decision to buy the Typhoon as its new air defence aircraft. The purchase of 18 Typhoons was agreed on 1 July 2003, and included training, logistics, maintenance, and a simulator. On 26 June 2007, Austrian Minister for Defense Norbert Darabos announced a reduction to 15 aircraft. The first aircraft was delivered on 12 July 2007 and formally entered service in the Austrian Air Force.

Saudi Arabia

After unsuccessful campaigns in South Korea and Singapore (losing in both cases to versions of the Boeing F-15E), on 18 August 2006 it was announced that Saudi Arabia had agreed to purchase 72 Typhoons. In November and December it was reported that Saudi Arabia had threatened to buy French Rafales because of a UK Serious Fraud Office investigation into the Al Yamamah ("the dove") defence deals which commenced in the 1980s.

On 14 December 2006 Britain's attorney general, Lord Goldsmith, ordered that the Serious Fraud Office discontinue its investigation in the BAE Systems' alleged bribery to senior Saudi officials in the al-Yamamah contracts, citing "the need to safeguard national and international security". *The Times* has raised the possibility that RAF production aircraft will be diverted as early Saudi Arabian aircraft, with the service forced to wait for its full complement of aircraft. This arrangement would mirror the diversion of RAF Tornados to the RSAF. *The Times* has also reported that such an arrangement will make the UK purchase of its tranche 3 commitments more likely. On 17 September 2007, Saudi Arabia confirmed it had signed a GB£4.43 billion contract for 72 aircraft. 24 aircraft will be at the Tranche 2 build standard, previously destined for the UK RAF, the first being delivered in 2008. The remaining 48 aircraft will be assembled in Saudi Arabia and delivered from 2011. Saudi Arabia is considering an order of 24 additional jets in the future, more recent reports suggest that number may be as high as 60 or 72, but this may have been superseded by Saudi Arabia's request in August 2010 to purchase 84 new F-15s.

On 22 October 2008 an aircraft in the full two-tone grey livery of the Royal Saudi Air Force flew for the first time at BAE Systems' Warton Aerodrome, marking the start of an initial test flight programme for RSAF aircraft.

Also in October 2008, the United States Department of State gave its approval for the sale that was needed because the Eurofighter contains a significant amount of American technology (ITAR).

Following the official handover event of the first Eurofighter Typhoon to the Royal Saudi Air Force on 11 June 2009, the delivery ferry flight took place, as planned, on 23 June 2009.

BAE has been training Saudi Arabian personnel at their factory in Warton, in preparation for setting up an assembly plant in Saudi Arabia.

Potential customers

India

Eurofighter Typhoon is one of the bidders in the Indian MRCA Competition, worth $10.5 billion, to supply the Indian Air Force with 126 'Multi-Role Combat Aircraft'. The other competitors are the Boeing F/A-18IN, Dassault Rafale, JAS 39 GripenNG/IN, Mikoyan MiG-35, and F-16IN Fighting Falcon. Bernhard Gerwert, CEO of military air systems, said that India is invited to join the Eurofighter Typhoon programme as a partner. The production of the Eurofighter Typhoon will create thousands of new jobs in India and Europe. He also said that in order to win the contract, EADS would move avionics jobs from Germany to India. The campaign is fully supported by the four European nations (Germany, United Kingdom, Spain and Italy), their four Air Forces and Europe's leading aerospace companies Alenia/Finmeccanica, BAE Systems and EADS.

In January 2010, India's ambassador to Italy, Arif Shahid Khan, said that the Eurofighter was "leading the race" to win the MRCA competition.

Japan

In March 2007, Jane's Information Group reported that the Typhoon was the favourite to win the contest for Japan's next-generation fighter requirement. The other competitors then were the F/A-18E/F Super Hornet and F-15E Strike Eagle. On 17 October 2007, Japanese Defence Minister Shigeru Ishiba confirmed that Japan may buy the Typhoon. Although the F-22 Raptor was in his words "exceptional", it was not "absolutely necessary for Japan", and the Typhoon was the best alternative. The F-22 is currently unavailable for export per US law. During a visit to Japan in June 2009, Andy Latham of BAE pointed out that while F-22 exports were restricted to keep advanced military technology from falling into the wrong hands, selling the Typhoon would take a "no black box approach", that is that even licensed production and integration with Japanese equipment would not carry the risk of leakage of restricted military technology. In July 2010 it was reported that the Japan Air Self-Defense Force favoured acquiring the F-35 ahead of the Typhoon and the F/A-18E/F to fulfil its F-X requirement due to its stealth characteristics, but the Defense Ministry was delaying its budget request to evaluate when the F-35 would be produced and delivered. David Howell of the UK foreign office has asked Japan to help develop and adapt the Eurofighter.

Greece

In 1999, the Greek government agreed to acquire 60 Typhoons in order to replace its existing second-generation combat aircraft. The purchase was put on hold due to budget constraints, largely driven by other development programs and the need to cover the cost of the 2004 Summer Olympics. In June 2006 the government announced a 22 billion euro multi-year acquisition plan intended to provide the necessary budgetary framework to enable the purchase of a next-generation fighter over the next 10 years. The Typhoon is currently under consideration to fill this requirement.

Others

During the 2008 Farnborough Airshow it was announced that Oman was in an "advanced stage" of discussions towards purchasing EF Typhoons as a replacement for its Jaguar aircraft. Oman remained interested in ordering Typhoons in April 2010 though the Saab

JAS 39 Gripen was also being considered. Oman asked the USA for an order of 18 F-16s, which makes a Eurofighter order less likely.

Other potential customers of the Typhoon are Denmark and Romania. BAE Systems itself reports that Typhoon is "actively being promoted in a number of other markets including Greece, Switzerland, Turkey and Japan". Turkey has indicated that it would rather just buy more F-35 Lightning II fighters and that the "Eurofighter is off Turkey's agenda".

On 2 December 2009, BAE Systems stated it will propose the Typhoon as replacement for the Royal Malaysian Air Force (RMAF) Mikoyan MiG-29N which is to be phased out in late 2010. According to the Regional Director-Business Development Dave Potter, the Typhoon's multi-role capabilities allow it to replace the MiG-29N. Other contenders include Boeing F/A-18E/F Super Hornet, F-15 Eagle, Dassault Rafale, JAS 39 Gripen NG, Sukhoi Su-35, and Lockheed F-16C/D Block 52 Fighting Falcon.

Serbia's government has shown interest in Eurofighter.

The Qatari Air Force is, as of January 2011, evaluating the Typhoon together with the Lockheed Martin F-35 Joint Strike Fighter, the Boeing F/A-18E/F Super Hornet, the Boeing F-15 and the Dassault Rafale to replace its current fighter inventory of Dassault Mirage 2000-5s. The total order will be between 24-36 aircraft with a procurement decision to be made by the end of 2012.

Upgrades

In 2002, the MBDA Meteor was selected as the long range air-to-air missile armament of Eurofighter Typhoon. Pending Meteor availability, Typhoon will be equipped with the Raytheon AMRAAM. The current in-service date for Meteor is predicted to be August 2012.

In 2009, Eurofighter operators and manufacturers are considering upgrading the current fleet with the possibility of adding the MBDA Meteor missile and an Active Electronically Scanned Array radar.

Eurojet is attempting to find funding to test a thrust vectoring nozzle (TVN) on a flight demonstrator.

The RAF is working on fitting conformal fuel tanks (CFT) to free up limited underwing space for weapons.

Design

Airframe and avionics

The Typhoon features lightweight construction (82% composites consisting of 70% carbon fibre composites and 12% glass reinforced composites) with an estimated lifespan of 6000 flying hours.

The fighter achieves high agility at both supersonic and low speeds by having a relaxed stability design. It has a quadruplex digital fly-by-wire control system providing artificial stability, as manual operation alone could not compensate for the inherent instability. The fly-by-wire system is described as "carefree" by preventing the pilot from exceeding the permitted manoeuvre envelope.

Spanish Air Force Typhoon taking off in the RIAT 2007.

Roll control is primarily achieved by use of the wing flaperons. Pitch control is by operation of the foreplanes and flaperons, the yaw control is by rudder. Control surfaces are moved through two independent hydraulic systems that are incorporated in the aircraft, which also supply various other items, such as the canopy, brakes and undercarriage. Each hydraulic system is powered by a 4000 psi engine-driven gearbox.

Navigation is via both GPS and an inertial navigation system. The Typhoon can use Instrument Landing System (ILS) for landing in poor weather.

The aircraft employs a sophisticated and highly integrated Defensive Aids Sub-System named Praetorian (formerly called EuroDASS). Threat detection is provided by a Radar Warning Receiver (RWR) and a Laser Warning Receiver (LWR, only for UK Typhoons). Protection is provided by Chaff, Jaff and Flares, Electronic Counter Measures (ECM) and a Towed Radar Decoy (TRD).

Praetorian monitors and responds automatically to the outside world. It provides the pilot with an all-round prioritised assessment of Air-to-Air and Air-to-Surface threats. It can respond to single or multiple threats.

The aircraft also features an advanced ground proximity warning system based on the TERPROM Terrain Referenced Navigation (TRN) system used by the Panavia Tornado but further enhanced and fully integrated into the cockpit displays and controls.

The Multifunctional Information Distribution System (MIDS) provides the Link 16 data link.

Cockpit

General features

MHDDs and Pedestal Panel with centre stick in the Typhoon cockpit

The Eurofighter Typhoon features a "glass cockpit" without any conventional instruments. It includes: three full colour Multi-function Head Down Displays (MHDDs) (the formats on which are manipulated by means of softkeys, XY cursor and voice (DVI) command), a wide angle Head Up Display (HUD) with Forward Looking Infra Red (FLIR), Voice & Hands On Throttle And Stick (Voice+HOTAS), Helmet Mounted Symbology System (HMSS) (known to test pilots as 'The Electric Hat'), Multifunction Information Distribution System (MIDS), a Manual Data Entry Facility (MDEF) located on the left glareshield and a fully integrated aircraft warning system with a Dedicated Warnings Panel (DWP). Reversionary flying instruments, lit by LEDs, are located under a hinged right glareshield.

The pilot flies the aircraft by means of a centre stick and left hand throttles. Emergency escape is provided by a Martin-Baker Mk.16A ejection seat, with the canopy being jettisoned by two rocket motors.

Voice control

The Typhoon DVI system utilises a Speech Recognition Module (SRM), developed by Smiths Aerospace (now GE Aviation Systems) and the then Computing Devices (now General Dynamics UK). It was the first production DVI system utilised in a military cockpit. DVI provides the pilot with an additional natural mode of command and control over approximately 26 non-critical cockpit functions, to reduce pilot workload, improve aircraft safety, and expand mission capabilities. An important technological breakthrough during the development of the DVI occurred in 1987 when Texas Instruments produced their TMS-320-C30 Digital Signal Processor (DSP). This greatly advanced the packaging of DVI from large complex systems to a single card module. This early advance allowed a viable high performance system. The project was given the go ahead in July 1997, with development and pilot assessment carried out on the Eurofighter Active Cockpit Simulator at BAE Systems Warton.

The DVI system is speaker-dependent, i.e. requires each pilot to create a template. It is not used for any safety-critical or weapon-critical tasks, such as weapon release or lowering of the undercarriage, but is used for a wide range of other cockpit functions. Voice commands are confirmed by visual or aural feedback. The system is seen as a major design feature in the reduction of pilot workload and even allows the pilot to assign targets to himself with two simple voice commands, or to any of his wingmen with only five commands.

***g* protection**

In the standard aircraft, *g* protection is provided by the *full-cover anti-*g *trousers* (FCAGTs). This specially developed *g* suit provides sustained protection up to 9 *g*. The Typhoon pilots of the German Air Force and Austrian Air Force wear a hydrostatic *g*-suit called *Libelle* (*dragonfly*) Multi G Plus instead, which also provides protection to the arms, theoretically allowing for more complete *g* tolerance.

Design process

The design of the cockpit had involved the inputs from both test and operational pilots from each of the four partner nations from the feasibility and concept stage and throughout the design process. This has necessitated the use of specially commissioned lighting and display modelling simulation facilities and the extensive employment of rapid prototyping techniques.

PIRATE IRST

The Passive Infra-Red Airborne Track Equipment (PIRATE) system is an Infrared Search and Track System (IRST) mounted on the port side of the fuselage, forward of the windscreen. SELEX Galileo is the lead contractor which, along with Thales Optronics (system technical authority) and Tecnobit of Spain, make up the EUROFIRST consortium responsible for the system's design and development.

PIRATE operates in two IR bands, 3-5 and 8-11 micrometres. When used with the radar in an air-to-air role, it functions as an Infrared Search and Track system (IRST), providing passive target detection and tracking. In an air-to-surface role, it performs target identification and acquisition. It also provides a navigation and landing aid. PIRATE is linked to the pilot’s helmet mounted display.

Eurofighters starting with Tranche 1 Block 5 have the PIRATE. The first Eurofighter Typhoon with PIRATE-IRST was delivered to the Italian Aeronautica Militare in August 2007. More advanced targeting capabilities can be provided with the addition of a targeting pod such as the LITENING pod.

Performance

Flight demonstration at WTD61 Manching/Germany.

A Royal Air Force Eurofighter Typhoon T1

In 2004, United States Air Force Chief of Staff General John P. Jumper said after flying the Eurofighter, "I have flown all the air force jets. None was as good as the Eurofighter."

The Typhoon's combat performance, compared to the F-22 Raptor and the upcoming F-35 Lightning II fighters and the French Dassault Rafale, has been the subject of much discussion. In March 2005, Jumper, then the only person to have flown both the Eurofighter Typhoon and the Raptor, talked to Air Force Print News about these two aircraft. He said,

> “ The Eurofighter is both agile and sophisticated, but is still difficult to compare to the F/A-22 Raptor. They are different kinds of airplanes to start with; it's like asking us to compare a NASCAR car with a Formula One car. They are both exciting in different ways, but they are designed for different levels of performance. ...The Eurofighter is certainly, as far as smoothness of controls and the ability to pull (and sustain high g forces), very impressive. That is what it was designed to do, especially the version I flew, with the avionics, the color moving map displays, etc. — all absolutely top notch. The maneuverability of the airplane in close-in combat was also very impressive." ”

In July 2007, the Indian Air Force fielded the Su-30MKI during the *Indra-Dhanush* exercise with Royal Air Force's Typhoon. This was the first time that the two jets had taken part in such an exercise. The IAF did not allow their pilots to use the MKI's radar during the exercise to protect the highly-classified N011M Bars. During the exercise, the RAF pilots candidly admitted that the Su-30MKI displayed maneuvering superior to that of the Typhoon but they had studied, prepared and anticipated this. The IAF pilots on their part were also visibly impressed by the Typhoon's agility in the air.

The Typhoon is capable of supersonic cruise without using afterburners (referred to as *supercruise*). According to the official German Luftwaffe and Austrian Eurofighter website, the maximum speed possible without reheat is between Mach 1.2 and Mach 1.5. *Air Forces Monthly* gives a maximum supercruise speed of Mach 1.1 for the RAF FGR4 multirole version. It has been suggested, in contradiction to other sources that the Eurofighter Typhoon could only supercruise in a clean configuration without external missiles and fuel tanks. While this is untrue, attention is drawn by these suggestions to the fact that not all weapons loadouts are necessarily certified for supersonic flight at all, even with afterburner.

The Eurofighter consortium claims their fighter has a larger sustained subsonic turn rate, sustained supersonic turn rate, and faster acceleration at Mach 0.9 at 20,000 feet (6,100 m) than the F-14 Tomcat, F-15 Eagle, F-16 Fighting Falcon, F/A-18 Hornet, Dassault Mirage 2000, Dassault Rafale, the Sukhoi Su-27, and the Mikoyan MiG-29.

In 2005, a trainer Eurofighter T1 was reported to have had a chance encounter the previous year with two U.S. Air Force F-15Es over the Lake District in the north of England. The encounter became a mock dogfight with the Eurofighter allegedly emerging "victorious".

In the 2005 Singapore evaluation, the Typhoon won all three combat tests, including one in which a single Typhoon defeated three RSAF F-16s, and reliably completed all planned flight tests. In July 2009, Former Chief of Air Staff for the Royal Air Force, Air Chief Marshal Sir Glenn Torpy, said that "The Eurofighter Typhoon is an excellent aircraft. It will be the backbone of the Royal Air Force along with the JSF".

In 2010, during a DACT exercises over the Canary Islands involving USAF and Spanish Air Force units, two Spanish Typhoons engaged 8 F-15Cs from Lakenheath, UK. 7 F-15s were "downed" while one managed to escape, with no losses for the Typhoons.

Air-to-ground capabilities

A Royal Air Force Eurofighter Typhoon FGR4 at Nellis AFB in Nevada, USA

The Typhoon is a multi-role fighter with maturing air-to-ground capabilities. Earlier than scheduled, the RAF integrated the air to ground capability, based on the Rafael/Ultra Electronics Litening III laser designator and the Enhanced Paveway II/III laser guided bomb under the "Austere" programme. A more comprehensive air-to-ground attack capability including Paveway IV, EGBU-16 bombs and a higher degree of automation will be achieved for all partner nations with the Phase 1 Enhancements currently in development.

The absence of such a capability is believed to have been a factor in the type's rejection from Singapore's fighter competition in 2005. At the time it was claimed that Singapore was concerned about the delivery timescale and the ability of the Eurofighter partner nations to fund the current capability packages. With the planned Phase 2 Enhancements Eurofighter GmbH hopes to increase the appeal of Typhoon to possible export customers and to make the aircraft more useful to partner air forces.

Radar signature reduction features

Although not designated a stealth fighter, measures were taken to reduce the Typhoon's radar cross section (RCS), especially from the frontal aspect. An example of these measures is that the Typhoon has jet inlets that conceal the front of the jet engine (a strong radar target) from radar. Many important potential radar targets, such as the wing, canard and fin leading edges, are highly swept, so will reflect radar energy well away from the front sector. Some external weapons are mounted semi-recessed into the aircraft, partially shielding these missiles from incoming radar waves. In addition radar absorbent materials (RAM) developed primarily by EADS/DASA coat many of the most significant reflectors, e.g. the wing leading edges, the intake edges and interior, the rudder surrounds, strakes, etc. The Typhoon does not use internal storage of weapons. External mounting points are used instead, which increases its radar cross section but allows for more and larger stores.

The Eurofighter operates automatic Emission Controls (EMCON) to reduce the Electro-Magnetic emissions of the current mechanically scanned Radar. The Captor-M was the first NATO-Radar with three rather than two working channels, one intended for classification of jammer and for jamming suppression. The German BW-Plan 2009 indicates that Germany will equip/retrofit the Luftwaffe's Eurofighters with the AESA Captor-E from 2012. The conversion to AESA will give the Eurofighter a Low Probability of Intercept Radar with much better jam resistance. These include an innovative design with a gimbal to meet RAF requirements for a wider scan field than a fixed AESA. The coverage of an fixed AESA is limited to 120 degree in azimuth and elevation.

According to the RAF, the Eurofighter's RCS is better than RAF requirements. Comments from BAE Systems suggest the radar return is around one quarter of that of the Tornado it replaces. The Eurofighter is thought to have an RCS of less than one square metre in a clean configuration by author Doug Richardson, although no official value is available. This compares with the estimated RCS of the Rafale of 2 square metres, the 20 square metres of the Sukhoi Su-30MKI, the 1 square metre of the Su-35BM, the American F-22A of 0.0001 square metres, and the American F-117 of 0.025 square metres. The manufacturers have carried out tests on the early Eurofighter prototypes to optimize the low observability characteristics of the aircraft from the early 1990s. Testing at BAE's Warton facility on the DA4 prototype measured the RCS of the aircraft and investigated the effects of a variety of RAM coatings. Another measure to reduce the likelihood of discovery is the use of passive sensors, which minimises the radiation of treacherous electronic emissions. While canards generally have poor stealth characteristics, the flight control system is designed to minimise the RCS in flight, maintaining the elevon trim and canards at an angle to minimise RCS.

Operational history

A Royal Air Force Eurofighter Typhoon

On 4 August 2003, Germany accepted the first series production Eurofighter (GT003). Also that year, Spain took delivery of its first series production aircraft.

On 16 December 2005, the Typhoon reached initial operational capability (IOC) with the Italian Air Force. Its Typhoons were put into service as air defence fighters at Grosseto Air Base, and immediately assigned to Quick Reaction Alert (QRA) at the same base.

On 9 August 2007, the UK's Ministry of Defence reported that No. XI Squadron of the RAF, which stood up as a Typhoon squadron on 29 March 2007, had taken delivery of its first two multi-role Typhoons. Two of XI Squadron's Typhoons were sent to intercept a Russian Tupolev Tu-95 approaching British airspace on 17 August 2007.

The RAF Typhoons were declared combat ready in the air-to-ground role by 1 July 2008. The RAF Typhoons were projected to be ready to deploy for operations by mid-2008. On or around 25 April 2008 a Typhoon from 17 Squadron at RAF Coningsby, operating at the US Naval Air Weapons Station China Lake test centre in California, USA, suffered extensive damage during landing when its landing gear did not deploy. Although no immediate cause was determined it was speculated that pilot error may have been to blame. A Board of Enquiry was convened.

On 11 September 2008, the combined flying time of the five customer Air Forces and the industrial Flight Test programme saw aircraft surpass the 50,000 flight hours milestone.

On 31 March 2009 a Eurofighter Typhoon fired an AMRAAM for the first time whilst having its radar in passive mode, the necessary target data for the missile was acquired by the radar of a second Eurofighter Typhoon and transmitted using the Multi Functional Information Distribution System (MIDS).

On 17 July 2009, Italian Air Force Eurofighters were deployed to protect Albania's airspace.

In September 2009, four RAF Typhoons deployed to RAF Mount Pleasant replacing the Tornado F3s defending the Falkland Islands. The government of Argentina "is understood to have made a formal protest".

On 24 August 2010, the project suffered its first fatality when a two seat Typhoon crashed, for unknown reasons, killing a Saudi Air Force Lieutenant Colonel, the front seat occupant, shortly after taking off from Moron Air Base in Spain. Experts suspect that a bird strike had destroyed "important sensors". The Spanish instructor ejected and sustained only minor injuries. Following this incident the German Luftwaffe grounded its 55 planes on 16 September 2010, amidst concerns that after ejecting successfully the pilot had fallen to his death. In response to the investigation of the crash, on 17 September 2010, the RAF temporarily grounded all Typhoon training flights. Quick Reaction Alert duties were unaffected. On 21 September, the RAF announced that the harness system had been sufficiently modified to enable routine flying from RAF Coningsby. The Austrian Air Force also said that all its aircraft had been cleared for flight. On 24 August 2010, the ejection seat manufacturer Martin Baker commented: ".. under certain conditions, the quick release fitting could be unlocked using the palm of the hands, rather than the thumb and fingers and that this posed a risk of inadvertent release," and added that a modification had been rapidly developed and approved "to eliminate this risk" and was being fitted to all Typhoon seats.

In January 2011 the aircraft passed the milestone of 100,000 flying hours across the entire fleet.

Variants

Prototype on display at the 1998 Dubai Airshow. The multiple roundels for the air forces are: (left to right) Spanish Ejército del Aire, Italian Aeronautica Militare, British Royal Air Force, and German Luftwaffe.

The Eurofighter is produced in single-seat and twin-seat variants. The twin-seat variant is not used operationally, but only for training. The aircraft has been manufactured in three major standards; seven Development Aircraft (DA), seven production standard Instrumented Production Aircraft (IPA) for further system development and a continuing number of Series Production Aircraft. The production aircraft are now operational with the partner nation's air forces.

The Tranche 1 aircraft were produced from 2000 onwards. Aircraft capabilities are being increased incrementally, with each software upgrade resulting in a different standard, known as blocks. With the introduction of the Block 5 standard, the R2 retrofit programme began to bring all aircraft to that standard.

Tranche 1

- Block 1 : Initial Operational Capability and basic Air Defence Capability.
- Block 2 : Initial air-to-air capabilities.
- Block 2B : Full air-to-air capabilities.
- Block 5 : Full Operational Capability (FOC) by combining existing air-to-air role with air-to-ground capabilities.

Tranche 2

- Block 8 : New mission computers required for the integration of future weapons such as Meteor, Storm Shadow and Taurus. (Differences in the build to Tranche 1 related to changes in production technology or obsolescence).
- Block 10 : Software: EOC 1 (advanced multi role step 1) AIM-120C-5 AMRAAM, IRIS-T digital. A2G: GBU-24, GPS-controlled weapons, ALARM, Paveway III & IV, Rafael Litening III
- Block 15 : Software: EOC 2 (advanced multi role step 2) A2A Meteor A2G: TAURUS, Storm Shadow, Brimstone

Tranche 3

These aircraft will have interfaces for possible future improvements, but will be delivered at a Tranche 2 level of capability.

The Indian Navy has made a request for information for a carrier based variant of the Eurofighter. In this contest it will once again be up against the Rafale, which split from the Eurofighter project over the need for a carrier based variant.

In February 2011, BAE debuted a navalized Typhoon in response to the Indian tender. The model offered is STOBAR (Short Take Off But Arrested Recovery) capable corresponding to the Indian Navy's future Vikrant class aircraft carrier. The changes needed to enable the Typhoon to launch by ski-jump and recover by arrestor hook; added about 500kg to the airframe. If however the Indian Navy pursues a catapult launch carrier, the Typhoon is uncompetitive against tender rivals (e.g. Rafale and Super Hornet) since meeting "... catapult requirements would add too much weight to the aircraft, blunt performance and add substantially to modification costs".

Operators

Typhoon F2 of the RAF

Spanish Eurofighter Typhoon

Austria

- Austrian Air Force - 15
    - Überwachungsgeschwader

Germany

- German Air Force - 55, 125 on order
    - Jagdgeschwader 73 Steinhoff
    - Jagdgeschwader 74
    - Jagdbombergeschwader 31 Boelcke

Italy

- Italian Air Force - 42, 96 on order
    - 9º Gruppo Caccia
    - 20º Gruppo Caccia
    - 12º Gruppo Caccia

Saudi Arabia

- Royal Saudi Air Force - 6, 66 on order, total 72.

Spain

- Spanish Air Force - 28, 59 on order.
    - 111 and 112 Operational Squadrons
    - 113 Squadron, OCU Tactical pilot training and evaluation

United Kingdom

- Royal Air Force - 62 of a confirmed order of 160 aircraft, an additional 72 as of yet uncommited, total 232.
    - No. 3 Squadron RAF
    - No. 6 Squadron RAF
    - No. 11 Squadron RAF
    - No. 17 Squadron RAF
    - No. 29 Squadron RAF
    - No. 1435 Flight RAF (Falkland Islands)

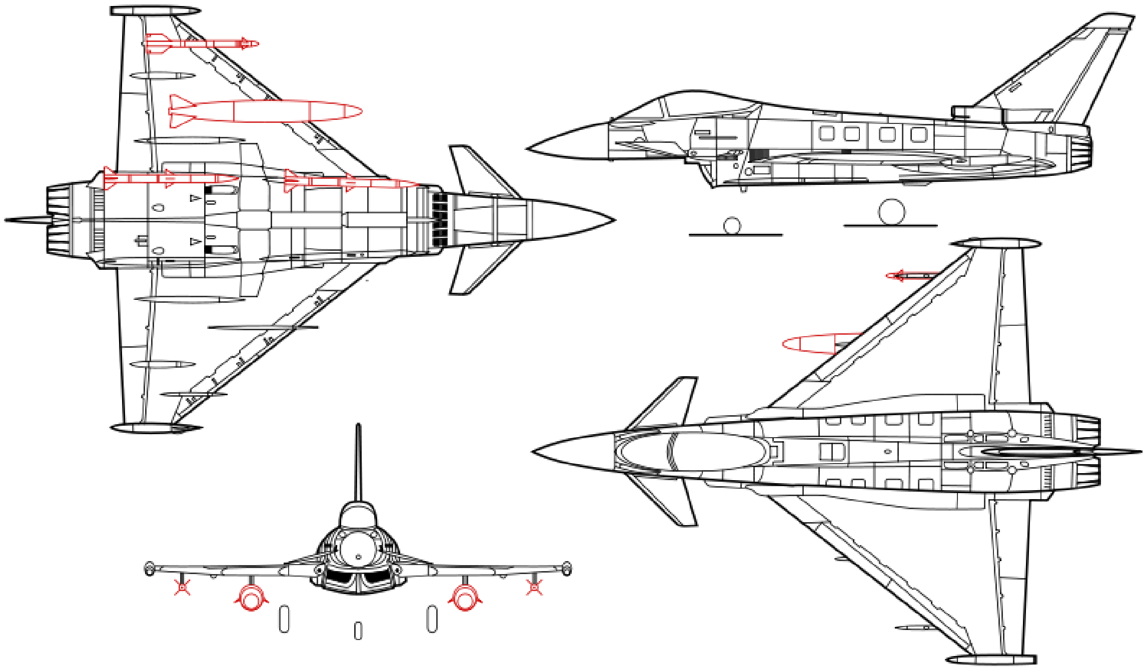
Accidents

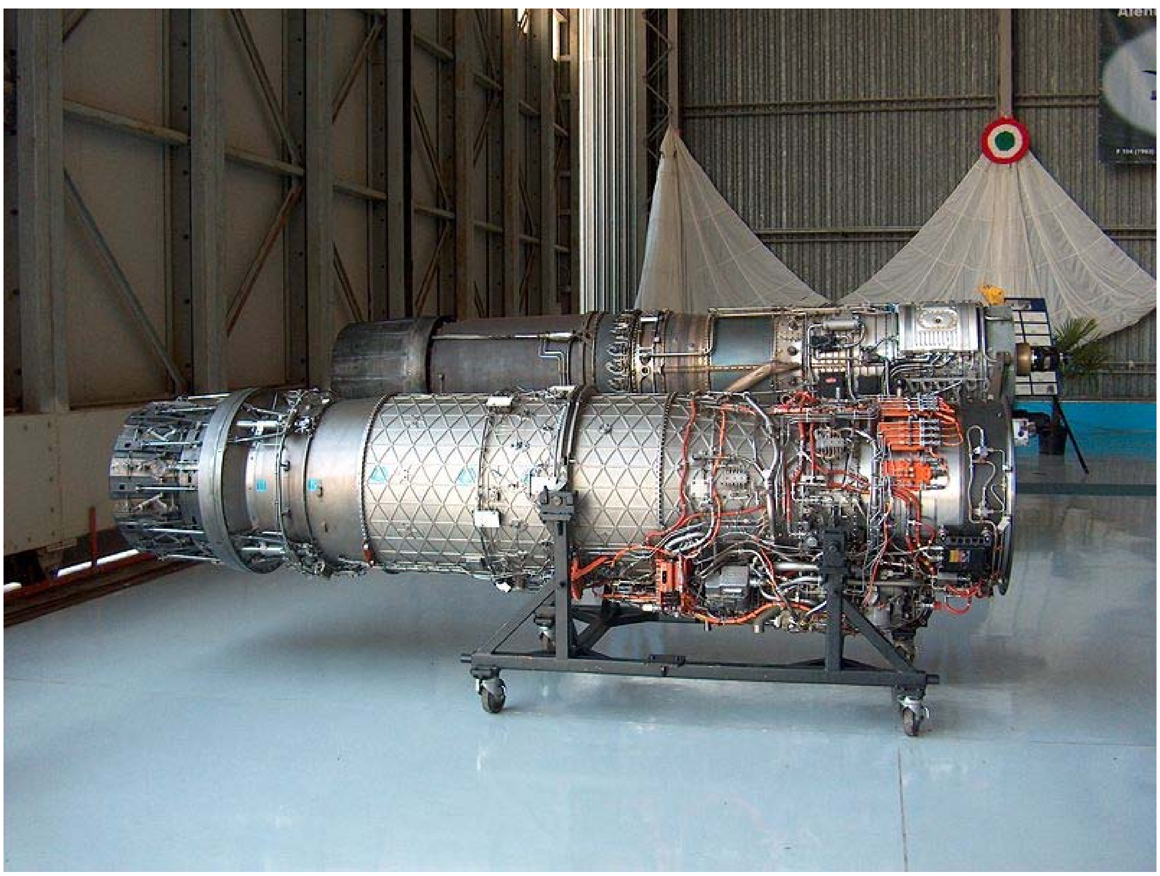
- On 21 November 2002, the Spanish twin-seat Eurofighter prototype DA-6 crashed due to a double engine flame-out caused by surges of the two engines. The two crew members escaped unhurt.
- On 24 August 2010, a Eurofighter aircraft crashed at Spain's Morón air base moments after take-off for a routine training flight. It was being piloted by a lieutenant colonel from the Saudi Arabian air force, who was killed, and a Spanish air force commander, who ejected safely.

Aircraft on display

- Eurofighter DA-2 Typhoon (serial number ZH588) is on display at the Royal Air Force Museum London. This aircraft is one of seven EF 2000 development aircraft built by the Eurofighter Partner Companies, and was used for flight testing. The aircraft was delivered by road on 22 January 2008. Engineers from RAF Coningsby and RAF St. Athan assembled the aircraft for display. It is hanging in the Museum's Milestones of Flight Exhibition Hall.
- The first development aircraft Eurofighter DA-1 can be seen at the Deutsches Museum Flugwerft Schleissheim at Oberschleißheim Airport in the north of Munich. Its first flight took place in 1994 and it was handed over to the museum in 2008.
- In summer 2009 Eurofighter DA-4, serial number ZH590, went on display at Imperial War Museum Duxford, having been given to the museum by the Ministry of Defence in 2008. It is exhibited as part of the museum's 'AirSpace' gallery, as an example of the development of aircraft technology.

Specifications





EJ200 engine (foreground)

The aircraft's turbofan engine (front)

General characteristics

- **Crew:** 1 (operational aircraft) or 2 (training aircraft)
- **Length:** 15.96 m (52 ft 5 in)
- **Wingspan:** 10.95 m (35 ft 11 in)
- **Height:** 5.28 m (17 ft 4 in)
- **Wing area:** 51.2 m^2 (551 ft^2)
- **Empty weight:** 11,150 kg (24,560 lb)
- **Loaded weight:** 16,000 kg (35,300 lb)
- **Max takeoff weight:** 23,500 kg (51,800 lb)
- **Powerplant:** 2× Eurojet EJ200 afterburning turbofan
  - **Dry thrust:** 60 kN (13,500 lb_f) each
  - **Thrust with afterburner:** 89 kN ref RR (20,000 lb_f) each
- **Fuel capacity:** 4,500 kg (9,920 lb) internal

Performance

- **Maximum speed:**
  - **At altitude:** Mach 2 (2,495 km/h, 1,550 mph)
  - **At sea level:** Mach 1.2 (1,470 km/h / 913.2 mph)

- **Supercruise:** Mach 1.1–1.5
- **Range:** 2,900 km (1,802 mi)
- **Combat radius:**
    - Ground attack, lo-lo-lo: 601 km (325 nmi)
    - Ground attack, hi-lo-hi: 1,389 km (750 nmi)
    - Air defence with 3-hr CAP: 185 km (100 nmi)
    - Air defence with 10-min loiter: 1,389 km (750 nmi)
- **Ferry range:** 3,790 km (2,300 mi)
- **Service ceiling:** 19,810 m (65,000 ft)
- **Rate of climb:** >315 m/s (62,000 ft/min)
- **Wing loading:** 312 kg/m^2 (64.0 lb/ft^2)
- **Thrust/weight:** 1.15
- ***g*-Limits:** +9/-3 *g*

German Luftwaffe soldiers mount an IRIS-T to an Eurofighter

Armament

- **Guns:** 1 × 27 mm Mauser BK-27 Revolver cannon with 150 rounds
- **Hardpoints:** Total of 13: 8 × under-wing plus 5 × under-fuselage pylon stations holding up to 7,500 kg (16,500 lb) of payload
- **Missiles:**
    - **Air-to-air missiles:**

        - AIM-9 Sidewinder, AIM-132 ASRAAM, AIM-120 AMRAAM, IRIS-T, and, in the future, MBDA Meteor
    - **Air-to-surface missiles:**
        - AGM-65 Maverick, AGM-88 HARM, Storm Shadow (AKA *Scalp EG*), Brimstone, Taurus KEPD 350, Penguin and in the future AGM Armiger
- **Bombs:** Paveway II/III/Enhanced Paveway series of Laser-guided bombs (LGBs), Joint Direct Attack Munition (JDAM), HOPE/HOSBO
- **Others:**
    - Flares/infrared decoys dispenser pod and chaff pod *and*
    - Electronic countermeasures (ECM) pods
    - LITENING III laser targeting pod
    - Up to 3 drop tanks for ferry flight *or* extended range/loitering time.

Avionics

- Euroradar CAPTOR Radar
- Passive Infra-Red Airborne Tracking Equipment (PIRATE)

Chapter 8

Saab JAS 39 Gripen

JAS 39 Gripen

Role	Multirole fighter
Manufacturer	Saab AB
First flight	9 December 1988
Introduction	9 June 1996
Status	Active service
Primary users	Swedish Air Force Czech Air Force Hungarian Air Force South African Air Force
Number built	219 as of 2010
Unit cost	US$40–61 million (export price VAT excluded)

The **Saab JAS 39 Gripen** (English: *Griffin*) is a lightweight single engine multirole fighter aircraft manufactured by the Swedish aerospace company Saab. Gripen International acts as a prime contracting organisation and is responsible for marketing, selling and supporting the Gripen fighter around the world.

The aircraft is in service with the Swedish Air Force, the Czech Air Force, the Hungarian Air Force, the South African Air Force, and the Royal Thai Air Force. A total of 236 Gripens have been ordered as of 2008.

Development

Origins

By the late 1970s a replacement for Sweden's aging Saab 35 Draken and Saab 37 Viggen was needed. A new fighter was being considered by 1979, with design studies beginning the following year. The development of the Gripen began in 1982 with approval from Swedish Parliament.

The Gripen was designed for performance, flexibility, effectiveness and survivability in air combat. The designation JAS stands for *Jakt* (Air-to-Air), *Attack* (Air-to-Surface), and *Spaning* (Reconnaissance), indicating that the Gripen is a multirole or swingrole fighter aircraft that can fulfill each mission type. The JAS 39 received the name Gripen through a public competition in 1982. The griffin is the heraldry on Saab's logo and suited the multirole characteristics of the aircraft.

Empire Test Pilots' School JAS 39B Gripen taxis after landing at RIAT 2008.

Sweden chose to develop the Gripen rather than purchase a variant of the General Dynamics F-16 Fighting Falcon, McDonnell Douglas F/A-18A/B, or the "F-5S" version of the Northrop F-20 Tigershark. The first Gripen was rolled out on 26 April 1987, marking Saab's 50th anniversary. The first prototype first flew on 9 December 1988.

The final aircraft of the 64-jet Batch 3 contract was delivered to FMV on 26 November 2008. This was accomplished at a 10% less than the agreed-upon price for the whole batch, putting the JAS 39C flyaway cost at under US$30 million. About 33% of the aircraft's content is sourced from the United States, with the other 67% split between Swedish and European suppliers.

Teaming agreements

In 1995, Saab Military Aircraft and British Aerospace or BAe (now BAE Systems) formed the joint venture company *Saab-BAe Gripen AB*, with the goal of adapting, manufacturing, marketing and supporting Gripen internationally. The deal was to take advantage of BAe's global marketing experience. BAe also saw the Gripen as a complementary product to its existing aircraft, fitting between its Hawk light attack/trainer and the larger Panavia Tornado and Eurofighter Typhoon fighters. This cooperation was extended in 2001 with the formation of Gripen International for the same purpose. In December 2004, Saab and BAE Systems agreed that from January 2005 Saab would take full responsibility for marketing of the Gripen in light of Saab's increased export marketing capabilities.

On 26 April 2007, Norway signed an agreement on a joint development programme of the aircraft regarding co-operation in advanced development work on future versions of the aircraft. The value of the deal, which will allow Norwegian companies to take part, is about NOK 150 million over two years.

In June 2007, Thales Norway A/S and Saab signed a contract concerning the development of communications systems for the Gripen fighter. This order for the Norwegian company is the first to be awarded under the provisions of the Letter of Agreement signed by the Norwegian Ministry of Defence and Gripen International in April 2007.

As part of Gripen International's marketing efforts in Denmark, a deal was signed in December 2007 with Danish technology supplier Terma A/S which allows them to participate in an industrial co-operation programme over the next 10–15 years. The total value of the programme is estimated at over 10 billion Danish krone, and is partly dependent on Denmark choosing the Gripen.

Gripen NG and recent developments

Saab Gripen NG demonstrator at RIAT 2010

A two-seat "New Technology Demonstrator" has been built, and was presented on 23 April 2008. It has increased fuel capacity, a more powerful powerplant, increased payload capacity, upgraded avionics and other improvements. The new Gripen NG (Next Generation) is also referred to as the "Gripen Demo", the "Gripen E/F", or MS 21.

The new Gripen NG has many new parts and is powered by the General Electric F414G, a development of the F/A-18E/F Super Hornet's engine. The engine produces 20% more thrust at 98 kN (22,000 lbf), enabling a supercruise speed of Mach 1.1 with air-to-air missiles.

Compared to the Gripen D, the Gripen NG's max takeoff weight has increased from 14,000 to 16,000 kg (30,900–35,300 lb) with an increase in empty weight of 200 kg (440 lb). Due to relocated main landing gear, the internal fuel capacity has increased by 40%, with a significant increase in range. Combat radius will be 1300 km with six AAMs + drop tanks, and 30 min on station. Ferry range will be 4,070 km (2,200 nmi) with drop tanks. The new undercarriage configuration also allows for the addition of two heavy stores pylons to the fuselage. Its PS-05/A radar adds a new AESA antenna for flight testing beginning in mid-2009.

Gripen Demo's maiden flight was conducted on 27 May 2008. The test flight lasted about 30 minutes and reached a maximum altitude of about 6,400 meters (21,000 ft). On 21 January 2009, the Gripen Demo flew at Mach 1.2 without reheat to test its supercruise capability.

Saab performed study work on an aircraft carrier based version in the 1990s. In 2009, Saab launched the Sea Gripen project in response to India's request for information on a carrier-borne aircraft. Brazil also has a potential carrier aircraft need. Sweden awarded Saab a four-year contract in 2010 to improve the Gripen's radar and other equipment, and lower its operating costs. In June 2010, Saab stated that Sweden plans to order the Gripen NG under the JAS 39E/F designation. The new variant is to enter Swedish service in 2017 or possibly earlier if export orders are received. The Swedish MS21 (Gripen E/F) project depends on both the results of the Indian MRCA competition and the Brazilian F-X2 competition, as well as the progress on the Swedish MS20 Gripen update programme. The Swedish MS20 project is to modernize all the Gripens in the Swedish Air Force mainly with the long-range MBDA Meteor missile and the short-range IRIS-T missile. This is to be made no later than 2014.

Design

Overview

Farnborough Airshow 2006

In designing the aircraft, several layouts were studied. Saab ultimately selected a canard design with relaxed stability. The canard configuration gives a high onset of pitch rate and low drag, enabling the aircraft to be faster, have longer range and carry a larger payload.

The combination of delta wing and canards gives the Gripen significantly better takeoff and landing performance and flying characteristics. The totally integrated avionics make it a "programmable" aircraft. It also has a built-in electronic warfare unit, making it possible to load more ordnance onto the aircraft without losing self defence capabilities. The 300-link is used to share data between fighters.

The Gripen affords more flexibility than earlier generations of combat aircraft used by Sweden, and its operating costs are about two thirds of those for JA 37 Viggen.

In the Swedish Air Force's list of requirements was the ability to operate from 800 m runways. Early on in the programme, all flights from Saab's facility in Linköping were flown from within a 9 m × 800 m outline painted on the runway. Stopping distance was reduced by extending the relatively large air brakes; using the control surfaces to push the aircraft down, enabling the wheel brakes to apply more force and tilting the canards downwards, making them into large air brakes and further pushing the aircraft down. In reality Gripen needs little more than half the specified take off and stopping distance.

Radar

The Gripen uses the modern PS-05/A pulse-doppler X-band radar, developed by Ericsson and GEC-Marconi, and based on the latter's advanced Blue Vixen radar for the Sea Harrier (which inspired the Eurofighter's CAPTOR radar as well).

The radar is capable of detecting, locating, identifying and automatically tracking multiple targets in the upper and lower spheres, on the ground and sea or in the air, in all weather conditions. It can guide four air to air missiles (e.g. AIM-120 AMRAAM, MBDA MICA) simultaneously at four different targets.

On 27 March 2009, Saab and Selex Galileo signed an agreement for joint development of the *Raven* AESA radar based on Selex Galileo's AESA Vixen and PS-05/A. This radar will be able to scan 200 degrees, from slightly behind to the left to slightly behind to the right.

On 9 September 2009, Gripen International offered the source code of their AESA radar as part of their bid for India's fighter competition.

Cockpit

The cockpit has three full colour head down displays and digital emergency instrument presentation unique to the aircraft. The cockpit layout provides a human-machine interface that eases pilot workload substantially and increases situational awareness, but still provides substantial future growth potential. The pilot flies the aircraft by means of a centre stick and left hand throttles.

The cockpit provides a display area some 30 percent larger than that available in most other fighters, with the multi-function displays taking up around 75 percent of available space.

It is dominated by three large (15.7 x 21 cm) active-matrix, liquid crystal, multi-function displays and a wide angle (20 x 28 degree) head-up display (HUD). The displays are equipped with light sensors for computer assisted brightness and contrast control.

Expeditionary capabilities

One interesting feature is the Gripen's ability to take off and land on public roads, which was part of Sweden's war defence strategy. The aircraft is designed to be able to operate even if the air force does not have air superiority.

During the Cold War, the Swedish Armed Forces were preparing to defend against a possible invasion from the Soviet Union. Even though the defensive strategy in principle called for an absolute defence of Swedish territory, military planners calculated that Swedish defence forces could eventually be overrun. For that reason, Sweden had military stores dispersed all over the country, in order to maintain the capacity of inflicting damage on the enemy even if military installations were lost.

Accordingly, among the requirements from the Swedish Air Force was that the Gripen fighter should be able to land on public roads near military stores for quick maintenance, and take off again. As a result, the Gripen fighter can be refueled and re-armed in ten minutes by a five man mobile ground crew operating out of a truck, and then resume flying sorties.

In the post-Cold War era, these dispersed operation capabilities have proved to be of great value for a different purpose. The Gripen fighter system is expeditionary in nature, and therefore well suited for peace-keeping missions worldwide, which has become the new main task of the Swedish Armed Forces.

Operational history

Current operators

Gripen taking off

Gripen in flight

Saab JAS 39 Gripen of the Czech Air Force

Hungarian Air Force Saab JAS39D Gripen at RIAT 2009

The Gripen is in operational service with the Swedish Air Force, which has ordered 204 aircraft (including 28 two-seaters).

The Czech Air Force and the Hungarian Air Force also operate the Gripen, and currently lease 14 Swedish Air Force aircraft each, with the option of eventually acquiring them. In both cases two of the aircraft are two-seaters. The Czech and the Hungarian Air Force are the first Gripen operators within NATO. One of the design modifications required in order to make it NATO compatible was the ability to undertake aerial refuelling. The Gripen refuelling trials was the first time a NATO tanker had refuelled a Swedish fighter.

Deliveries to the South African Air Force (26 aircraft, including nine two-seaters) commenced in April 2008, and are ongoing. As of June 2010, 15 aircraft, nine two-seater aircraft and six single-seaters have been delivered.

The Royal Thai Air Force has ordered 12 JAS 39 Gripens (8 single-seat JAS 39C and 4 four JAS 39D two-seaters). The first 6 aircraft were delivered on 22 February 2011. The order for the last 6 JAS 39C Gripens was finalized in November 2010.

The Empire Test Pilots' School (ETPS) in the United Kingdom uses the Gripen as its advanced fast jet platform for training test pilots from around the world.

Potential and future operators

Brazil

In October 2008, it was reported that the Brazilian Air Force had selected three finalists in their F-X2 program. They are Dassault Rafale, Boeing F/A-18E/F Super Hornet and Gripen NG. The number of aircraft involved is 36 and possibly up to 120 later. The decision was expected on 2 October 2009. On 2 February 2009, Saab submitted a tender for 36 Gripen NGs to the Brazilian Air Force Command. On 5 January 2010, it was reported in the media that the final evaluation report by the Brazilian Air Force placed the Gripen ahead of the other two contenders. The decisive factor was apparently the overall cost of the new fighters, both in terms of unit cost, and operating and maintenance costs. It appears that Brazil is likely to buy the Rafale offering, subject to the outcome of a legal challenge.

Croatia

The Croatian Air Force had announced plans to replace their MiG-21 bis aircraft, possibly with either the JAS 39 Gripen or the F-16 Falcon. The final projection calls for 12-18 aircraft. On 27 March 2008, the Swedish Defence Material Administration and Saab responded to Croatia's request for information regarding the procurement of 12 aircraft. Due to economic and political reasons, the Croatian Air Force postponed the decision and is now looking at a possible joint purchase with Slovenia of 12 aircraft.

Denmark

Denmark has signed a Memorandum of Understanding between the Defence Ministers of Sweden and Denmark to evaluate the Gripen, pending Denmark's future replacement of their fleet of 48 F-16s. Denmark has also requested new variants of Gripens to be developed that will include new avionics, a larger and more powerful engine, larger payload and, most importantly, longer range. This request was the basis for the Gripen NG, which satisfies all Denmark's requirements, such as the more powerful F414G engine.

On 24 March 2010, the Danish Ministry of Defence decided to postpone the decision on which fighter to buy until 2010–2014.

India

The Gripen is a contender in the Indian MRCA competition for 126 multi-role combat aircraft. Gripen International handed over its proposal on 28 April 2008. The company is offering the Gripen IN, a version of the Gripen NG for India's tender, and has opened an office in New Delhi in order to support its efforts in the Indian market. On 4 February 2009, it was announced that Saab had partnered with the Indian Tata Group to develop a new Gripen variant to fit India's needs. The Indian Air Force was rumored to have narrowed the choices to the Eurofighter and the Rafale, implying the exit of the MiG-35, F-16IN, F/A-18E/F and Gripen. Since then the IAF has reconfirmed that all six aircraft remain in the competition. Senior IAF officers, while happy with Gripen NG's features, also highlight the Gripen NG’s downside: a high level of US electronics, weaponry, and the GE F414 engine, which combine for one-third of the entire aircraft.

Netherlands

On 7 July 2008 *Dagens Industri* reported that the Netherlands announced they will evaluate Gripen NG together with four other competitors and announce the result in the end of 2008. Saab responded on 25 August 2008 to a 'Replacement Questionnaire' issued by the Dutch Ministry of Defence, offering 85 aircraft to the Royal Netherlands Air Force. The Netherlands evaluated the Gripen NG against the F-35. On 18 December 2008 media reported that the Netherlands evaluated the F-35 ahead of the Gripen NG, citing better performance and lower price. On 13 January 2009, *NRC Handelsblad* claimed that, according to Swedish sources, Saab has made an offer to the Dutch to deliver 85 Gripens for 4.8 billion euro, about 1 billion euro cheaper than budgeted for the F-35. This price includes training of pilots and maintenance for the next 30 years.

Switzerland

On 17 January 2008 the Swiss Defence Material Administration invited Gripen International to submit initial bids for supplying the Gripen as a replacement for their old F-5s. Saab responded with a proposal on 2 July 2008. The exact number of aircraft has not been disclosed.

Others

Bulgaria announced that they are to replace their aging Mikoyan MiG-21s with possible 16 JAS 39C/D Gripens, or 16 used F-16s.

Serbian officials are currently{{when} debating on which fighter aircraft will replace the aging MiG-21 fighters in 2010. 24 aircraft are sought and the JAS 39 Gripen is one option.

Other nations that are showing interest in the Gripen include Slovakia and Oman.

Missed contracts

Finland

In 1989 the Finnish Air Force began to look for a new fighter to replace its fleet of MiG-21s and Saab 35 Drakens. During 1991 and 1992, the Dassault Mirage 2000, Gripen, F-16, MiG-29 and F/A-18 Hornet were evaluated. On 6 May 1992, the Hornet was announced as the winner of the fighter competition and a total of 64 aircraft were ordered.

Norway

On 18 January 2008. the Norwegian Ministry of Defence issued a Request for Binding Information (RBI) to the Swedish Defence Material Administration, who responded on 28 April 2008 with a proposal offering 48 aircraft. The rival Lockheed Martin proposal amassed US diplomatic and political support. On 20 November 2008, the Norwegian government released a statement that they have selected the F-35 Lightning II for the Royal Norwegian Air Force. Norway stated the F-35 is the only fighter candidate to meet all of its operational requirements. Saab has criticized the selection, stating that there were flaws in Norway's cost calculations for the Gripen NG.

On 10 February 2009, Swedish defence minister Sten Tolgfors stated that Norway had miscalculated the deal. The offer was for 48 aircraft over 20 years, but Norway had extrapolated it to operating 57 aircraft over 30 years, thus doubling the cost. The Swedish Ministry of Defence has several other objections to Norway's calculations. Among other things, Norway projected the operational costs for their F-16s on both candidates, and did not consider the operational costs of Sweden's Gripens. Norway also calculated with more aircraft losses in accidents than what Sweden considers reasonable based on their operational experience of the type. According to Tolgfors, Norway's decision will make it more difficult to sell the Gripen to other countries. Tolgfors said that the Gripen does not meet the requirements set by the Norwegian government, though some media reports claim those requirements are tilted in favour of the F-35.

Romania

The Romanian Air Force announced they would replace their MiG-21 LanceR aircraft beginning in 2008, possibly with JAS 39 Gripen, F-16 Fighting Falcon or Eurofighter Typhoon. On 23 March 2010, the Romanian Ministry of Defence decided to purchase 24 second hand F-16s.

Variants

JAS 39 Gripen taxiing in after display, Farnborough 2006

JAS 39A

Fighter version that first entered service with the Swedish Air Force in 1996. A modification program has started and 31 of these will be upgraded to C/D standard.

JAS 39B

Two-seat version of the A variant. This variant is 0.9 meter (2 ft 2 in) longer than the single seat version.

JAS 39C

NATO-compatible version of Gripen with extended capabilities in terms of armament, electronics, etc. This variant can also be refueled in flight.

JAS 39D

Two-seat version of the C variant.

Gripen Demo

A two-seat technology demonstrator for improvements slated for the Gripen NG.

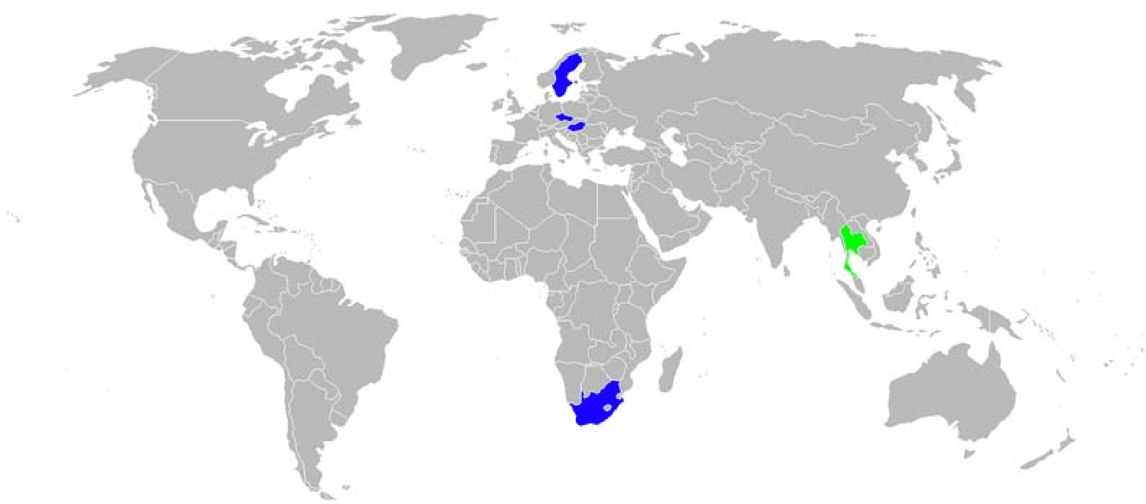
Gripen NG/IN

(Next Generation) Proposed version with new engine (F414G), increased fuel capacity, higher payload, upgraded avionics and other improvements. The Gripen IN version is a contender for the Indian MRCA competition.

Sea Gripen

Proposed carrier-based version based on the NG/IN version.

Operators



Gripen users 2010 in blue, orders in green

JAS 39 Gripen of the Hungarian Air Force, Kecskemét open day 2007

There were 155 Gripens in service in January 2010.

- Czech Republic
  - Czech Air Force has 14 Gripens on lease, including 2 two-seaters, with all in operation as of January 2010.
- Hungary
  - Hungarian Air Force has 14 Gripens on a lease-and-buy arrangement, including 2 two-seaters (C/D versions). The final 3 aircraft were delivered in December 2007.
- South Africa
  - South African Air Force ordered 26 aircraft (down from 28), 9 two-seater D-models and 17 single seat C-models. The first delivery, a two-seater, took place on 30 April 2008. The South African Air Force has 9 two-seaters and 6 single-seaters in inventory as of June 2010.
- Sweden
  - Swedish Air Force: 204 aircraft originally ordered, including 28 two-seaters (121 in service). Sweden leases 28 of the aircraft, including 4 two-seaters, to the Czech and Hungarian Air Forces. In 2007 the Swedish government decided that the future Swedish Air Force will deploy no more than 100 JAS 39C/D Gripen fighters. A program to upgrade 31 of the air force's JAS 39A/B fighters to JAS 39C/Ds was started. The SAF has 121 JAS 39s, including 53 JAS 39As, 10 JAS 39Bs, 45 JAS 39Cs and 13 JAS 39D in service in January 2010.
- Thailand

The Royal Thai Air Force ordered 6 Gripens (2 single-seat C-models and 4 two-seat D-models) in February 2008, with deliveries to begin in 2011. 6 more Gripen Cs were ordered in November 2010. The Gripens take the place of retiring F-5B/Es and be based at Surat Thani Airbase.

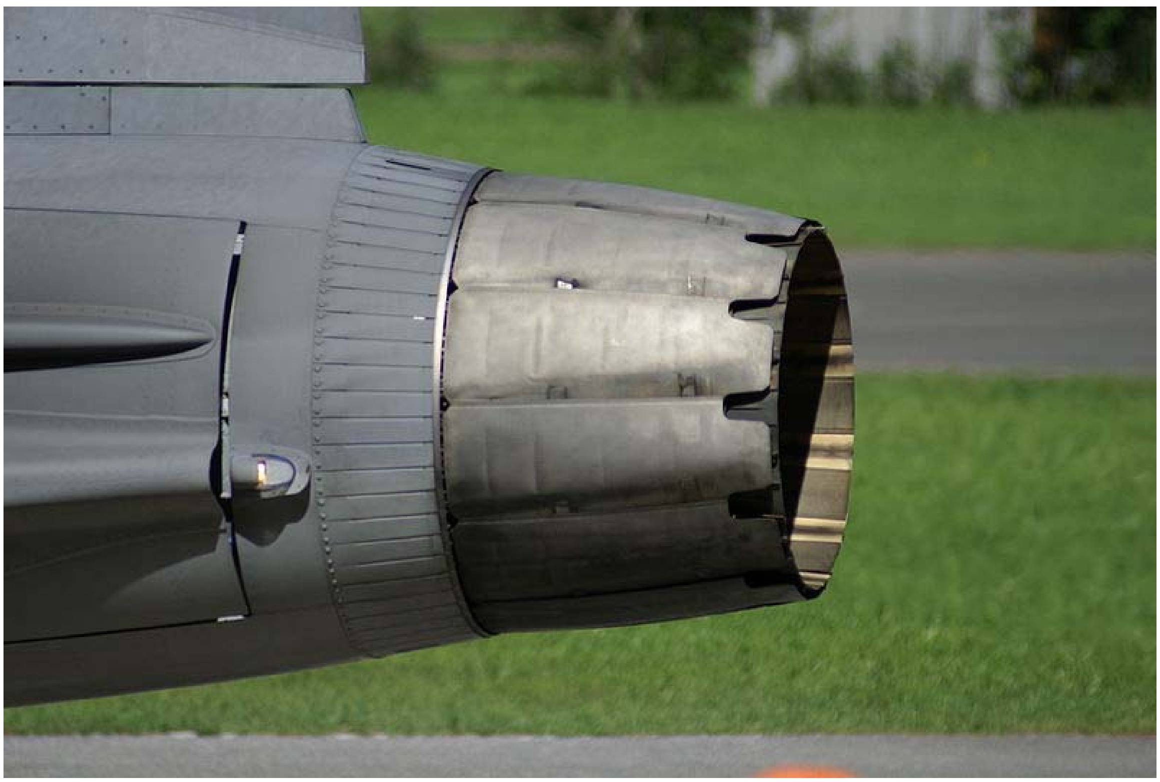
United Kingdom

Empire Test Pilots' School: Under the agreement, ETPS instructor pilots and students undergo simulator training with the Swedish Air Force, and go on to fly the two-seater Gripen at Saab in Linköping, in two training campaigns per year (spring and autumn). The agreement was renewed in 2008.

Incidents

Six Gripens have crashed causing only minor injuries; one prototype, one production aircraft and four in service with the Swedish Air Force.

Specifications (JAS 39 Gripen C/D)



Gripen engine nozzle

General characteristics

- **Crew:** 1 (2 for JAS 39D)
- **Payload:** 5,300 kg ()
- **Length:** 14.1 m (46 ft 3 in)
- **Wingspan:** 8.4 m (27 ft 7 in)

- **Height:** 4.5 m (14 ft 9 in)
- **Wing area:** 30.0 m² (323 ft²)
- **Empty weight:** 6,800 kg (12,600 lb)
- **Loaded weight:** 8,500 kg (18,700 lb)
- **Max takeoff weight:** 14,000 kg (31,000 lb)
- **Powerplant:** 1× Volvo Aero RM12 afterburning turbofan
    - **Dry thrust:** 54 kN (12,100 lbf)
    - **Thrust with afterburner:** 80.5 kN (18,100 lbf)
- **Wheel track:** 2.4 m (7 ft 10 in)
- **Length (two-seater):** 14.8 m (48 ft 5 in)

Performance

- **Maximum speed:** Mach 2 (2,204 km/h, 1,372 mph)
- **Combat radius:** 800 km (500 mi, 432 nmi)
- **Ferry range:** 3,200 km (2,000 mi) with drop tanks
- **Service ceiling:** 15,240 m (50,000 ft)
- **Wing loading:** 283 kg/m² (58 lb/ft²)
- **Thrust/weight:** 0.97

Armament

- **Hardpoints:** 8 (three on each wing and two under fuselage) and provisions to carry combinations of:
    - **Rockets:** 4× rocket pods 13.5 cm rockets
    - **Missiles:**
        - 6× Rb.74 (AIM-9) or Rb 98 (IRIS-T)
        - 4× Rb.99 (AIM-120) or MICA
        - 4× Rb.71 (Skyflash) or Meteor
        - 4× Rb.75
        - 2× KEPD.350
        - 2× Rbs.15F anti-ship missile
    - **Bombs:**
        - 4× GBU-12 Paveway II laser-guided bomb
        - 2× Bk.90 cluster bomb
        - 8× Mark 82 bombs

Chapter 9

Piaggio P.180 Avanti

P180 Avanti

Aeronautica Militare Piaggio P180 Avanti

Role	Executive transport
Manufacturer	Piaggio Aero
First flight	26 September 1986
Primary users	Italian Armed Force Avantair
Number built	203 delivered to September 2010
Unit cost	US$ 7 million

The **Piaggio P180 Avanti** is an Italian twin-engine turboprop aircraft produced by Piaggio Aero. It seats up to nine passengers in a pressurized cabin, and may be flown by one or two pilots.

The innovative design places the main wing behind and above the canard-like horizontal stabiliser, features a laminar flow fuselage and has engines in pusher configuration.

Development

Cockpit and instrument panel aboard a P180 Avanti.

The P180 design was tested in wind tunnels in Italy and the U.S. in 1980 and 1981. A collaboration with Learjet to develop the aircraft began in 1983 but ended on 13 January 1986, with Piaggio continuing development on its own. The first prototype flew on 23 September 1986. U.S. and Italian certification was obtained on 7 March 1990. Learjet's influence can be seen in the two "delta fins" mounted on the bottom of the tail, as found on most Learjets; these devices provide aerodynamic recovery force in the event of an aerodynamic stall. The first 12 fuselages were manufactured in Wichita, with H & H Parts and Plessey Midwest, then flown to Italy for final assembly. Avanti Aviation Wichita ran out of money in 1994; the project languished until a group of investors led by Piero Ferrari became involved in 1998. The 100th aircraft was delivered in October 2005 and the 150th in May 2008. Piaggio has reported that as of October 2010, the Avanti and Avanti II fleets have now logged over 500,000 flight hours.

An improved **Avanti II** obtained European and U.S. certification in November 2005. Six months later, 70 planes were already ordered, including 36 by Avantair. The Avanti II features uprated Pratt & Whitney Canada PT6 turboprop engines and flies about 18 km/h (11 mph) faster, with better fuel economy; an all-new "glass panel" avionics suite reduces cockpit clutter. In addition to heading, attitude and navigation information, flat panel color LCD displays add collision avoidance (TCAS), ground proximity (TAWS) and real-time graphic weather depiction.

Design

The Avanti's turboprop engines are placed on a mid-fuselage, high aspect ratio wing, located behind the cabin. The design utilizes both a T-tail and a pair of small, fixed anhedral forward wings that lack control surfaces. The arrangement of the wing surfaces allows all three to provide lift, as opposed to a conventional configuration, where the horizontal stabilizer creates a downward force to counteract the nose-down moment generated by the center of gravity being forward of the center of lift. This is patented as "Three-Lifting-Surface Configuration" (3LSC). The Avanti II's forward wing has flaps that move in concert with main wing flaps. The forward wing pitch angle is set so it stalls before the main wing, producing an automatic nose-down effect; its five degree negative dihedral keeps the stream wash interference clear of the engine inlets, the main wing and the horizontal stabilizer

Distinctive design features include a non-constant cross section cabin, the revolutionary shape of which approximates a NACA airfoil section. Piaggio claims the fuselage contributes up to 20% of the Avanti's total lift, with horizontal stabilizer, front and rear wing providing the remaining 80%. Because of the unusual fuselage shape, the mid cabin is considerably wider than the cockpit, and the entire cabin is ahead of the main wing spar. The front and rear airfoils are custom sections designed by Dr. Jerry Gregorek of The Ohio State University's AARL to achieve a drag-reducing 50% laminar flow at cruise.

The company claims the overall design of the P180 Avanti II enables the wing to be 34% smaller than on conventional aircraft and a specific range of 0.84 nmi/lb of fuel. This is significantly better than the 0.31-0.48 nmi/pound of similar small jets.

The P180 makes a distinctive square wave noise when passing overhead, similar to the Beech Starship, due to the wing wake and engine exhaust effects on the pusher propellers.

Variants

Aeronautica Militare P180 Avanti

P.180 Avanti
: First production variant.

P180 M
: Military version with a combination passenger/freighter configuration for use as a VIP and light utility transport.

P.180 RM
: Variant for use in radio calibration.

P.180 AMB
: Air ambulance variant.

P.180 APH
: Aerial cartography.

P.180 Avanti II
: Variant with improved avionics.

Operators

Avanti belonging to Vigili del Fuoco, Rome-Ciampino

Avanti parked on tarmac

Avanti at Colorado Springs Municipal Airport

Civil

Bangladesh

- Youngone - 1

Canada

- Avmax International Aircraft - 3
- Bell Aliant - 1
- Cascades Inc. - 2
- Skyservice Business Aviation - 2
- Royal Canadian Mounted Police - 1
- Starlink Aviation - 1

Czech Republic

- Icarus Aiviation Group - 1

France

- Brittany Ferries - 1
- Pan Européenne Air Service - 1
- Transport'Air - 4

Indonesia

- Susi Air - 2

India

- TajAir - 1

Italy

- Blue Panorama Airlines - 2
- Eurofly Service - 1
- Protezione Civile
- State Forestry Corps - 1
- State Police - 1
- Vigili del Fuoco - 2
- Windjet - 2

Jordan

- Saraya Skies - 3 (3 others in option)

Mexico

- Republicair

Poland

- Lotnicze Pogotowie Ratunkowe (Polish Medical Air Rescue) - 2

Netherlands

- JetNetherlands - 1
- Solid Air - 1

United States

- Avantair - 56 aircraft ordered
- Mountain Aviation - 1

Military

Italy

- Italian Air Force
- Italian Army
- Italian Navy

United Arab Emirates

- United Arab Emirates Air Force ordered two aircraft at the 2009 Paris Air Show.

Specifications (P180 Avanti)

Data from Brassey's World Aircraft & Systems Directory 1999-2000

General characteristics

- **Crew:** one or two pilots
- **Capacity:** up to nine passengers
- **Cabin dimensions:** 1.75 m (5 ft 9 in) high, 1.85 m (6 ft 1 in) wide, 4.45 m (14 ft 7 in) long
- **Payload:** 907 kg (2,000 lb)
- **Length:** 14.41 m (47 ft 3½ in)
- **Wingspan:** 14.03 m (46 ft 0½ in)
- **Height:** 3.97 m (13 ft 0¾ in)
- **Wing area:** 16 m^2 (172.2 ft^2)
- **Empty weight:** 3,400 kg (7,500 lb)
- **Useful load:** 1,860 kg (4,100 lb)

- **Max takeoff weight:** 5,239 kg (11,550 lb)
- **Powerplant:** 2× Pratt & Whitney Canada PT6A-66 turboprops, 634 kW (850 shp) each

Performance

- **Maximum speed:** 732 km/h (395 kn, 455 mph)
- **Cruise speed:** 593 km/h (320 kn, 368 mph) (econ cruise)
- **Range:** 2,592 km (1,400 nmi, 1,612 mi) at 11,900 m (39,000 ft) with reserves
- **Service ceiling:** 12,500 m (41,000 ft)
- **Rate of climb:** 14.98 m/s (2,950 ft/min)
- **Wing loading:** 327 kg/m² (67.1 lb/ft²)
- **Power/mass:** 0.24 kW/kg (6.79 lb/hp)

Chapter 10

Saab 37 Viggen

AJ/JA 37 Viggen

Swedish Air Force JA 37

Role	Attack, Fighter, Reconnaissance
Manufacturer	Saab
First flight	8 February 1967
Introduction	21 June 1971
Retired	25 November 2005
Status	Retired
Primary user	Swedish Air Force
Number built	329

The **Saab 37 Viggen** (English: *Thunderbolt*) was a Swedish single-seat, single-engine, short-medium range fighter and attack aircraft, manufactured between 1970 and 1990. Several variants were produced to perform the roles of all-weather fighter-interceptor, ground attack and photo-reconnaissance, as well as a two-seat trainer.

Development

The Viggen was initially developed as a replacement for the Saab 32 Lansen in the attack role and later the Saab 35 Draken as a fighter. The first studies were carried out between 1952 and 1957 involving the Finnish aircraft designer Aarne Lakomaa. Several different concepts were studied involving both single- and twin engines and also with separate lift engines, both simple and double delta wings and also with canard wings. Even VTOL designs were considered.

The aim was to produce a robust aircraft with good short-runway performance that could be operated from numerous specially prepared roads and highways to reduce the vulnerability to attack in the event of war. Other requirements included supersonic ability at low level, Mach 2 performance at altitude, and the ability to make short landings at low angles of attack (to avoid damaging improvised runways). The aircraft was also designed from the beginning to be easy to repair and service, even for personnel without much training.

To meet these design goals, Saab selected a radical configuration: a conventional delta wing with small, high-set canard wings. Canards have since become common in fighter aircraft, notably with the Eurofighter Typhoon, Dassault Rafale, Saab JAS 39 Gripen and the IAI Kfir, but mainly for agility reasons rather than STOL capabilities. The final proposal was presented and accepted on 28 September 1962. Construction started in 1964, with a first prototype maiden flight on 8 February 1967.

In 1960, the U.S. National Security Council, led by President Eisenhower, formulated a military security guarantee for Sweden. The U.S. promised to help the Swedish militarily in the event of a Soviet attack against Sweden; both countries signed a military-technology agreement. In what was known as the "37-annex", Sweden was allowed access to advanced U.S. aeronautical technology which made it possible to design and produce the Saab 37 Viggen much faster and cheaper than would otherwise have been possible.

According to the doctoral research of Nils Bruzelius at the Swedish National Defence College, the reason for this officially unexplained U.S. support was the need to protect U.S. Polaris submarines deployed just outside the Swedish west coast against the threat of Soviet anti-submarine aircraft.

However, Bruzelius' theory have been thoroughly debunked by Simon Moores and Jerker Widén.

Design

Propulsion

The Viggen was powered by a single Volvo RM8 turbofan. This was essentially a licence-built variant of the Pratt & Whitney JT8D engine that powered commercial airliners of the 1960s, with an afterburner added for the Viggen. The airframe also incorporated a thrust-reverser to use during landings and land manoeuvres, which, combined with the aircraft having flight capabilities approaching a limited STOL-like performance, enabled operations from 500 m airstrips with minimal support. The thrust reverser could be pre-selected in the air to engage when the nose-wheel strut was compressed after touchdown. The Viggen was the first aircraft to feature both afterburners and thrust-reversers. Only the Viggen, Concorde and the Panavia Tornado featured both afterburners and thrust-reversers.

The cockpit and air intake of JA 37 Viggen

The requirements from the Swedish Air Force dictated Mach 2 capability at high altitude and Mach 1 at low altitude. At the same time, short-field takeoff and landing performance was also required. Since the Viggen was developed initially as an attack aircraft instead of an interceptor (the Saab 35 Draken fulfilled this role), some emphasis was given to low fuel consumption at high subsonic speeds at low level for good range. With turbofan engines just emerging and indicating better fuel economy for cruise than turbojet engines, the former was favoured, since the latter were mainly limited by metallurgy development resulting from limitations in turbine temperature. Mechanical simplicity was also favoured, so the air intakes were simple D-section types with boundary layer splitter plates, while the fixed inlet had no adjustable geometry for improved pressure recovery. The disadvantage was that the required engine would be very large. In fact, at the time of introduction, it was the second largest fighter engine, with a length of 6.1 m and 1.35 m diameter; only the Tumansky R-15 was bigger.

Saab had originally wanted the Pratt & Whitney TF30 as the Viggen's powerplant. Since the engine design had not been completed in 1962 when the airframe vs. engine design size needed to be frozen, the JT8D was chosen as the basis for modification instead. The RM8 became the second operational afterburning turbofan in the world, and also the first equipped with a thrust reverser. It had a bypass ratio of around 1.07:1 in the RM8A, which reduced to 0.97:1 in the RM8B.

The two-seat trainer version of 37 Viggen

The AJ, SF, SH and SK 37 models of the Viggen had the first version of the RM8A engine with uprated internal components from the JT8D that it was based on. Thrust was 65.6 kN dry and 115.6 kN with afterburner. For the JA 37, the RM8A was modified to an 8B by replacing one LP compressor stage with a fan stage and improved combustor, turbine and afterburner. Thrust is 72.1 kN dry and 125.0 kN with afterburner.

The engine was started via a small gas turbine, itself started by an electric motor. Standby power and cooling air for onboard avionics were supplied via an external cart. An internal battery permitted start of the starter turbine and main engine in absence of the standby power cart.

Wing and airframe

With the performance requirements to a large extent dictating the choice of the engine, the airframe turned out to be quite bulky compared to contemporary slimmer designs with turbojet engines. The first prototypes had a straight midsection fuselage that was later improved with a "hump" on the dorsal spine for reduced drag according to the area rule.

The wing had the shape of a double delta with a dogtooth added to improve longitudinal stability when carrying external stores. Each dogtooth was also used as a fairing for a radar warning receiver (RWR) antenna.

A consequence of a tailless delta design, such as in the Viggen, is that the elevons, which replace more conventional control surfaces, operate with a small effective moment arm; their use adds substantial weight to the aircraft at takeoff and landing. Hinged leading edge surfaces can help counteract this, but an even more effective tool is the canard. The canards were positioned behind the inlets and placed slightly higher than the main wing, but were not movable as control surfaces (however, they were equipped with flaps). The purpose of the canard wings were to act as vortex generators for the main wing and therefore provide more lift. An added benefit was that they also improved roll stability in the transonic region around Mach 0.9. The canard flaps were deployed in conjunction with the landing gear to provide even more lift for takeoff and landing.

To withstand the stresses of no-flare landings, Saab made extensive use of titanium in the construction of the Viggen, especially in the fuselage, and incorporated an unusual arrangement for the main landing gear, in which the two wheels on each leg were placed in tandem. While such a layout is common in airliners and cargo aircraft, it is rare in fighters, but allows stowage in a thinner wing.

Vertical stabilizer

The tall single vertical stabilizer (45 degrees sweepback on the leading edge) was foldable to make it easier to store in hangars. After prototype testing of the SK variant, reduced longitudinal stability was discovered. To correct this, the vertical stabilizer was extended 10 cm (4 in) and the pitot tube was moved from the top of the fin leading edge to about midpoint where a sawtooth was also incorporated. The JA model later used the same improvements.

The six tanks in the fuselage and wings held approximately 5,000 litres of fuel with an additional 1,500 litres in an external drop tank. The specific fuel consumption was only 0.63 for cruise speeds (fuel consumption was rated 18 mg/Ns dry and 71 with afterburner). The Viggen's consumption was around 15 kg/sec at maximum afterburner, which meant that the internal fuel was exhausted in just seven minutes due to the relative inefficiency of the turbofan over a turbojet at full afterburner. Performance comparisons with other aircraft from the same age are however slightly difficult, since no other fighter or attack aircraft aside from the Harrier and Yak-38 were designed for STOL or VTOL capability.

Avionics

The CK 37 computer

In the early 1960s, it was decided that the Viggen should be a single seat aircraft. A digital central computer and a head-up display replaced the human navigator. This computer, called CK 37 (centralkalkylator 37), was the world's first airborne computer to use integrated circuits. It utilized the STRIL 60 system to be linked with the Swedish defence systems. The main sensor was an Ericsson PS 37 X-band monopulse radar with several functions: air-to-ground and air-to-air telemetry and cartography. A Honeywell radar altimeter with transmitter and receiver in the canard wings was used to assist low altitude flight. A Decca Type 72 doppler navigation radar and a series of other electronic sub-systems were also provided. A novel landing-aid device, the TILS (Tactical Instrument Landing System), made by Cutler-Hammer AIL, was used to improve landing accuracy down to 30 m from the threshold on the short highway airbase system. ECM consisted of a Satt Elektronik radar warning receiver system in the wings and the tail, an optional Ericsson Erijammer pod and BOZ-100 chaff/flare pod. In total, the electronics weighed 600 kg which was a substantial amount for a single-engine, late 1960s fighter.

The SK 37 trainer omitted the radar and CK 37 navigational computer, navigating only using the Decca system and later DME. The radar warning receiver electronics were also removed.

Initially, only a single reconnaissance (S) variant was considered, but fitting cameras as well as a radar proved to be impossible. The SH 37 maritime strike and reconnaissance variant was very similar to the AJ 37 and differed mainly in a maritime optimized PS 371/A radar with longer range and cockpit camera and tape recorder for mission analysis. "Red Baron" and LOROP camera pods were usually carried on the fuselage pylons. The centerline fuel tank was converted for a short period of time to a camera pod with two Recon/Optical CA-200 1676 mm cameras. In addition to the reconnaissance equipment, the SH 37 could also use all weapons for the AJ 37.

For the photographic SF version, the radar in the nose was omitted in favour of one SKa 24 57 mm, three SKa 24C 120 mm and two SKa 31 600 mm photographic cameras as well as one VKa 702 Infrared linescan camera. The "Red Baron" and LOROP camera pods could also be carried on the fuselage pylons.

The avionics suite of the JA was a major improvement over the other variants designed a decade earlier. The onboard computer was a Singer-Kearfott SKC-2037 built under license by Saab as CD 107, a Garrett AiResearch LD-5 air data computer (also used in the F-14 Tomcat), a Saab-Honeywell SA07 automatic flight control systems (which was the first digital variant to enter production) and a KTL-70L inertial navigation system. In the cockpit, several dial-indicator instruments were replaced by two CRT displays; one target indicator MI (sw: *MålIndikator*) in the center and one tactical moving- and rotating map indicator TI (sw: *Taktisk Indikator*) to the right while the head-up display SI (sw: *SiktlinjesIndikator* - line-of-sight indicator) was retained.

The radar on the JA 37 was upgraded to a multi-mode, pulse-Doppler Ericsson PS 46/A unit more optimized for the fighter/interceptor role. It sported lookdown/shootdown capability, range up to 48 km (30 mi), continuous-wave illumination for the Skyflash missiles as well as the ability to track two targets while scanning. The MTBF was reported as 100 hours, a very high reliability level for that generation of avionics systems.

In 1992, an upgrade program of some of the AJ/SF/SH (with least hours on the airframe) to AJS/AJSF/AJSH was initiated because of delays of the new JAS 39 Gripen. The modifications were not too extensive and consisted to the major part of a new Ericsson computer processor system, MIL-STD-1553B databus and MIL-STD-1760 stores interface system to carry the Rb 15F anti-ship missile and DWS 39 Mjölner submunitions dispenser. An upgraded radar warning receiver system with recording capability as well as a Mission planning system via a portable cartridge were also implemented. The original PS 37/A radar from the AJ 37 was upgraded to the PS 371/A (from the SH 37) allowing the new AJS 37 to perform radar reconnaissance missions. No airframe- and very minor cockpit modifications were made.

The JA 37 was continuously upgraded throughout its lifetime. In 1985, the "fighter link" went into service, permitting encrypted data communication between four fighters and ground radar based fighter command. This enabled one fighter to "paint" an airborne enemy with guidance radar for the Skyflash missiles of the three other fighters in a group while they had their search and guidance radar switched off. This system was operational ten years before any other country's. The autopilot was also slaved to the radar control to obtain better precision firing the cannon.

In 1990, the PS 46/A was upgraded with higher resistance to jamming and the ability to track several targets at the same time. In 1993, the ability to generate virtual targets in the radar reduced the cost of flying aggressors for training.

Between 1992 and 1997, a major avionics upgrade program to the JA was implemented, given the new designation JA 37D. It consisted of an Ericsson CD207 mission computer, an ANP-37 stores management computer, linked via dual MIL-STD-1553B databuses permitting use of the Rb 99 AMRAAM. In the cockpit, a TI 327 color tactical moving-map display (originally intended for the Gripen) and a Synthetic Attitude Heading Reference System were installed. The ECM and ECCM suite were enhanced with improved electronics, upgraded radar warning receivers, a new Ericsson U95 jammer pod as well as the ability to carry BOY-401 chaff/flare dispensers on a separate location from the weapon pylons.

Between 1998 and 2000, the conversion of ten Sk 37 trainers to Sk 37E electronic aggressors was completed. The fairly substantial upgrade package consisted of the nose-radome mounted G24 jammer inherited from the decommissioned J 32E Lansen, U22/A jammer- and KB chaff/flare pods and radar warning receivers from the AJS 37 and a new U95 jammer pod all linked together with the MIL-STD-1553B databus. The rear cockpit for the Electronic Warfare Officer was improved with new displays and controls while retaining the ability to convert back to the original flight training role.

Cockpit

The displays in the original cockpit were all of the traditional analogue/mechanical type with the exception of an electronic HUD which could be used as a precision landing aid.

Original layout drawings show the forward display area dominated by a central large Horizontal Situation Indicator (HSI) with its integral altitude warning light. To the left were the attitude indicator, altimeter and airspeed indicator / MACH displays and to the right, twelve smaller displays including a clock, g-meter, destination indicator, standby instruments, R.P.M. indicator, distance indicator, EPR indicator and fuel indicator.

The ejection seat was the Raketstol 37 (literally; Rocket chair 37) and was the last Saab designed seat in service. A derivative of the Saab 105 trainer seat, the seat was optimized for low altitude, high speed ejections. Low speed capability was limited to speeds above 75 km/h (47 mph) on the runway. The seat was angled back by 19 degrees to help counter g-forces in flight.

The pilot flew with a centre stick and left side throttle. The hands-on-throttle–and-stick HOTAS controls included trim, autopilot disengage, event marker and trigger (on the stick) and ECM switch and missile seeker un-cage (on the throttle). Adjacent to the throttle was a separate radar joystick.

There were dedicated warning caption panels each side of the pilot's legs. On the right console panel were numerous dedicated controls and indicators, including weapons and missile controls, nav panel, oxygen on/off, windshield de-fogging, IFF control, lighting controls. Situated on the left console panel were radar controls, canopy handle, landing gear handle, radio controls and the cabin pressure indicator.

A detailed schematic diagram of the original cockpit layout may be found in "Control in the Sky" by L.F.E. Coombs. Photographs of the original cockpit may be found at:

Armament

A weapons load of up to 7,000 kg could be accommodated on seven hardpoints; one centerline pylon, two fuselage pylons, two inner and two outer wing pylons. The centerline pylon was the only *wet* pylon and was usually occupied by an external fuel tank. The outboard wing pylons were never used in peacetime since aerodynamic flutter loads would structurally fatigue the wing.

AJ 37

The AJ 37 was designed to carry two RB 04E anti-ship missiles on the inboard wing pylons with an optional third missile on the centerline pylon. An optional load consisted of two RB 05A air-to-surface missiles on the fuselage pylons. The RB 05A was later replaced by Rb 75 TV-guided missiles. In a ground-attack role, a combination of unguided 135 mm rockets in sextuple pods and 120 kg fragmentation bombs on quadruple-mounts could be used. Self-defense was provided with either ECM or 30 mm ADEN cannon pods with 150 rounds of ammunition on the inboard wing pylons.

Rockets had warheads of several types: the 50 mm M56GP 4 kg armour-piercing, the M56B with 6.9 kg of HE, and the M70 with a 4.7 kg HEAT warhead. T

For the secondary air-to-air role and self defence, the Rb 28 IR-missile was initially selected, but was never used due to poor performance. This left the outboard wing pylons unutilised as the Rb 28 was the only missile integrated there up until the AJS modernisation. Instead, Rb 24/Rb 24J were used on the fuselage pylons and inboard wing pylons or in combination with optional 30 mm underwing ADEN cannon pods.

AJ 37 was under consideration as a carrier of both nuclear and chemical weapons, although no nuclear or chemical weapons were adopted by Sweden.

SH 37

The SH 37 was capable of carrying the same configuration of weapons as the AJ 37. However, since it was only used in the maritime role, only the RB 04E in combination with Rb 24/Rb 24J for self defense were employed. The chaff and jammer-pods was the most commonly used load.

SF/SK 37

Both the SF and SK variants lacked the radar and could not carry the guided air-to-surface missiles as the AJ and SH. The SF could carry Rb 24/Rb 24J for self defense though. The unguided cannon and rocket pods were also an option.

JA 37

With the introduction of the JA 37 in 1979 came the Ericsson PS 46/A radar capable of guiding the two semi-active radar homing Rb 71 missiles on the fuselage pylons simultaneously in combination with Rb 24J/Rb 24J air-to-air missiles. Unlike the strike variant a KCA 30mm Oerlikon internal cannon was carried as well as 126 rounds, in a conformal pod under the fuselage. The firing rate was selectable at 22 or 11 rounds. The KCA cannon fired 50% heavier shells at higher velocity than the older ADENs, giving a much higher kinetic energy. This, in conjunction with the fire control system, allowed air-to-air engagements at longer range than other fighters. The unguided cannon and rocket pods were available in the secondary ground-attack role.

The centerline pylon was almost exclusively carried a semi-permanent fuel tank, which was jettisonable in the event of a dogfight.

In 1987, the more advanced all-aspect Rb 74 air-to-air missile was introduced for the JA 37. With the major upgrade of the JA to JA 37D in 1997 came the ability to carry four Rb 99 on the fuselage- and inner wing pylons. In addition, a U95 ECM pod could now be carried under the right wing in place of an AMRAAM as well as chaff and flare dispensers on a pair of hitherto unused pylons just behind the main landing gear on each wing.

AJS/AJSF/AJSH 37

With the extensive electronics upgrade of the old AJ/SF/SH in 1992 came the ability to carry the new Rb 74 on all weapons pylons. The AJS and AJSH also received the Rb 15F anti-ship missile and BK 90 stand-off cluster bomb originally intended for the delayed JAS 39 Gripen.

Operational history

A Viggen at the Swedish air force museum.

Special red version Viggen that can also be seen at the Swedish air force museum in Linköping.

One hundred and ten of the original, ground-attack optimized variant, **AJ 37** were built, with the first operational squadron established in 1972 at F 7 Såtenäs.

A two-seat trainer was not initially planned since it was considered that new pilots could get enough experience with delta-winged aircraft on the SK 35 Draken trainer. Eventually, however, 18 **SK 37** two-seat trainers were ordered and delivered in 1973. To make room for the second cockpit, one fuel tank and some avionics were removed. The radar was also omitted limiting the weapons load to gun pods and unguided rockets.

A total of 26 of the **SH 37** maritime reconnaissance and strike variant were built in 1974, replacing the S 32C Lansen. Although fitted with radar and weaponry, the SH 37 Viggen could also undertake photographic missions with its single long-range camera, while external pods could carry a photographic day-set, a "Red Baron" IR set, an ELINT set, and AQ series ECM (made by SATT).

A further 26 of the **SF 37** reconnaissance variant were also delivered to replace the S 35 Draken in 1975. These were recognizable by having an elongated nose, equipped with six cameras and a VKa 702 infrared linescanner for night reconnaissance. Also, the "Red Baron" pod, with three IR cameras was widely used, as well as an ELINT set.

Although the Viggen was offered for sale worldwide, and regarded as a very competent aircraft, no export sales occurred. Reasons to explain Saab's failure to sell a competitively priced, highly advanced and well-respected aircraft include the Swedish government's relatively strict controls on arms exports to undemocratic countries, potential customers' doubts about continuity of support and supply of spare parts in the event of a conflict disapproved of by Sweden, and strong diplomatic pressure of larger nations. The United States blocked an export of Viggens to India in 1978 by not issuing an export license for the RM8/JT8D engine, forcing India to choose the SEPECAT Jaguar instead.

The Viggen saw initial service in natural metal, later receiving an extremely elaborate disruptive camouflage scheme for the AJ/SF/SH/SK variants and the first 27 JA aircraft. The 28th JA was painted in a gray tone that turned out too close to white. All latter JA aircraft were painted in a darker light/dark gray, appropriate for a high altitude fighter.

The final Viggen production variant was the **JA 37** interceptor entering service in 1980. The last of 149 JA 37s was delivered in 1990. Differences from the previous models included an improved and more powerful RM8B engine, a new PS 46/A interception radar, new computers, HUD, ECM and some other subsystems.

Swedish JA 37 fighter pilots have managed to lock their missiles on the SR-71 Blackbird, using the predictable flight patterns of SR-71 routine flights over the Baltic Sea.

Unusually for a 1970s fighter, three multi-purpose CRT display screens were fitted within the cockpit, in a system called AP-12, that also included a new model of HUD. The new radar was compatible with the Skyflash medium-range missiles, for the first time in a Swedish fighter. Two Skyflash missiles could be carried under the wings on hardpoints, as well as four Sidewinder J or L models. Another improvement was the addition of an Oerlikon KCA 30 mm cannon mounted internally, with 126 rounds of 360 g ammunition.

The structural strength was also improved, especially for the multi-sparred wings (initially Viggens had a high loss rate, with 21 aircraft lost in the early years). Various upgrades have been performed over the years, mainly to cockpit equipment, weapons and sensor fit. Between 1998 and 2000, ten SK 37 trainers were converted to SK 37E electronic warfare trainers to replace the aging J 32E Lansen.

Retirement

The Viggen has been phased out in favour of the advanced later generation JAS 39 Gripen with the last front line Viggen retired from the Swedish Air Force in November 2005. A few aircraft were kept flying for electronic warfare training against JAS 39 at F 17M in Linköping. The last Viggen flight took place in June 2007.

Variants

in chronological order

AJ 37

Primarily a single-seat ground-attack fighter aircraft, with a secondary fighter role. First delivery in 1971, serial numbers 37001-37108. RM 8A powerplant. PS 37A radar. Partially decommissioned in 1998, some upgraded to AJS 37.

SK 37

Two-seat trainer aircraft, first delivery in 1973, serial numbers 37801-37817. No radar. Decommissioned in 2003, some airframes converted to SK 37E.

SF 37

Single-seat photographic reconnaissance aircraft, first delivery in 1975, radar replaced with four cameras, serial numbers 37950-37977. Partially decommissioned in 1998, some upgraded to AJSF 37.

SH 37

Single-seat maritime reconnaissance and strike aircraft, first delivery in 1975, PS-371A radar, serial numbers 37901-37927. Partially decommissioned in 1998, some upgraded to AJSH 37.

Saab 37E Eurofighter

Proposed NATO replacement of F-104 Starfighter in 1975, none built.

Saab 37X

Proposed export version, none built.

JA 37

Primarily a single-seat all-weather interceptor fighter, with a secondary attack role. First delivery in 1979, serial numbers 37301-37449. A 10 cm (4 in) stretch in the shape of a wedge wider at the bottom than on the top of AJ 37 fuselage between canard and main wing. PS 46A LD/SD radar. Partially decommissioned in 1998, some upgraded to JA 37D.

AJS/AJSF/AJSH 37

Upgrade of some AJ/SF/SH 37 between 1993 and 1998. Avionics and software upgrade. Decommissioned in 2005.

JA 37C

Upgrade of older JA 37, avionics and software upgrade.

JA 37D

Upgrade of older JA 37 between 1993 and 1998, avionics and software upgrade.

JA 37Di

Upgrade of older JA 37, avionics and software upgrade.

SK 37E

Electronic warfare trainer, conversion of ten obsolete SK 37 trainers from 1998 to 2000, serial numbers 37807-37811 & 37813-37817, decommissioned in 2007.

Operators

Sweden

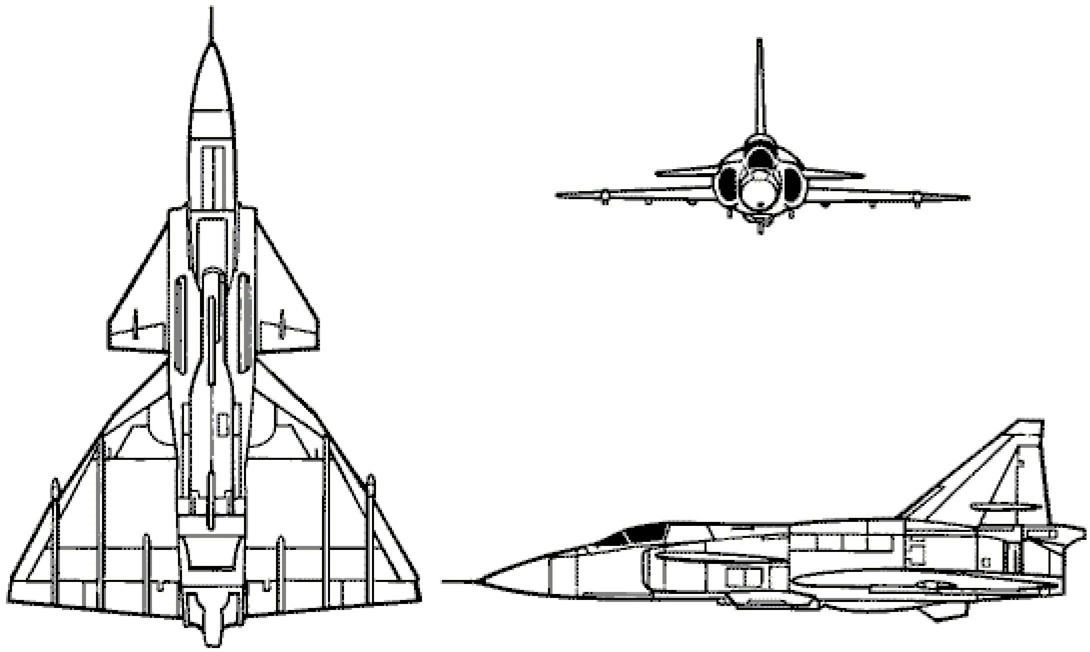
- Swedish Air Force

Operational units

- F 4 Frösön
    - 2 squadrons JA 37 1983-2003

    - 1 squadron SK 37 1999-2003
    - 1 squadron SK 37E 1999-2003
- F 6 Karlsborg
    - 2 squadrons AJ 37 1978-1993
- F 7 Såtenäs
    - 3 squadrons AJ 37 1972-1998
    - 1 squadron SK 37 1972-1974
- F 10 Ängelholm
    - 1 squadron AJ/SF/SH 37 (combined) 1993-2001
- F 13 Norrköping
    - 1 squadron SF/SH 37 (combined) 1977-1993
    - 1 squadron JA 37 1980-1993
- F 15 Söderhamn
    - 2 squadrons AJ 37 1974-1998
    - 1 squadron SK 37 1974-1998
- F 16 Uppsala
    - 2 squadrons JA 37 1986-2003
- F 17 Kallinge
    - 1 squadron JA 37 1981-2002
    - 1 squadron SF/SH 37 (combined) 1979-1993
    - 1 squadron JA 37 1993-2002
- F 21 Luleå
    - 2 squadrons JA 37 1983-2004
    - 1 squadron SF/SH 37 1979-2002
    - 1 squadron SK 37E (combined) 2003-2007

Specifications (JA 37 Viggen)



General characteristics

- **Crew:** One
- **Length:** 16.4 m (53 ft 9 in)
- **Wingspan:** 10.6 m (34 ft 9 in)
- **Height:** 5.9 m (19 ft 4 in)
- **Wing area:** 46 m² (500 ft²)
- **Empty weight:** 9,500 kg (21,000 lb)
- **Loaded weight:** AJ 16,000 kg; JA 17,000kg (AJ 35,273 lb; JA 37,478 lb)
- **Max takeoff weight:** 20,000 kg (44,000 lb)
- **Powerplant:** 1× Volvo RM8B afterburning turbofan, 72.1 kN / 125.0 kN afterburning (16,200 lbf dry, 28,110 lbf afterburning)

Performance

- **Maximum speed:** Mach 2.1, 2,231 km/h (1,386 mph) at 11,000 m (1,386 mph at 36,100 ft (11,003 m))
- **Range:** 2,000 km internal fuel only (1242 mi)
- **Service ceiling:** 18,000 m (59,100 ft)
- **Rate of climb:** 203 m/s (12,200 m/min) (40,026 ft/min)

Armament

- 1x 30 mm Oerlikon KCA cannon with 150 rounds
- Six missile stations for two RB71 Skyflash (only JA37), four AIM-120 AMRAAM (JA 37D), or six AIM-9 Sidewinder or four 135 mm (5.4 in) rocket pods. Anti ship rockets RBO4E or RBS15 or AGM-65A. 500kg bomb or 120kg Virgo fragmentary bomb
- U95 ECM pod (JA 37D)

Chapter 11

Sukhoi Su-30

Su-30

Su-30 of the Russian Air Force in flight over Russia

Role	Multi-role fighter
Manufacturer	Sukhoi
First flight	31 December 1989
Introduction	1996
Status	Operational
Primary users	PLA Air Force (China) Indian Air Force Venezuelan Air Force
Unit cost	US$33–45 million
Developed from	Sukhoi Su-27
Variants	Sukhoi Su-30MKI Sukhoi Su-30MKK

The **Sukhoi Su-30** (Cyrillic: Сухой Су-30) (NATO reporting name **Flanker-C**) is a twin-engine, two-seat military aircraft developed by Russia's Sukhoi Aviation Corporation. It is a multi-role fighter for all-weather, air-to-air and air-to-surface deep interdiction missions.

The Su-30 started out as an internal development project in the Sukhoi Su-27 family by Sukhoi. The design plan was revamped and the name was made official by the Russian Defense Ministry in 1996. Of the Flanker family, only the Su-27, Su-30 and Su-35 have been ordered into serial production by the Defense Ministry. All the others, such as Su-37, were prototypes.

The Su-30 has two distinct branches, manufactured by competing organizations: KnAAPO and the IRKUT Corporation, both of which come under the Sukhoi group's umbrella. KnAAPO manufactures the Su-30MKK and the Su-30MK2, which were designed for and sold to China, and later Indonesia and Vietnam. Due to KnAAPO's involvement from the early stages of developing Su-35, these are basically a two-seat version of the mid-1990s Su-35. The Chinese chose an older but lighter radar so the canards could be omitted in return for increased payload. It is a dedicated strike fighter designed for long-range air-to-surface attack missions, similar to the American F-15E.

Irkut traditionally served the Soviet Air Defense and, in the early years of Flanker development, was given the responsibility of manufacturing the Su-27UB, the two-seat trainer version of the Su-27. When India showed interests in the Su-30, Irkut offered the multi-role Su-30MKI, which originated as the Su-27UB modified with avionics appropriate for fighters. Along with its ground-attack capabilities, the series adds features for the air-superiority role, such as thrust-vectoring, forward canards and a long-range phase-array radar. Its derivatives include the MKM, MKA and MKV for Malaysia, Algeria and Venezuela, respectively.

Development

Su-27PU long-range interceptor

While the original Su-27 had good range, it still did not have enough for certain air-defense tasks required by the PVO Strany ("PVO" or *Protivo-Vozdushnaya Oborona* — "Air Defense") whose requirements spanned the need to cover the vast expanse of the Soviet Union. Hence, development began in 1986 on the Su-27PU, an improved-capability variant of the Su-27 capable of serving as a long-range interceptor or airborne command post. The two-seat Su-27UB combat trainer was selected as the basis for the Su-27PU, because it had the performance of a single-seat Su-27 and long-range missions require two crewmen. A "proof-of-concept" demonstrator flew 6 June 1987, and this success led to the kick-off of development work on two Su-27PU prototypes. The first Su-27PU flew at Irkutsk on 31 December 1989, and the first of three pre-series models flew in 14 April 1992.

To adapt the Su-27UB to its new role, the aircraft was fitted with a retractable in-flight refueling probe to increase range; the probe is offset to the left side of the nose and, to accommodate it, the IRST was offset to the right. The aircraft's avionics were changed, fitting special communications and guidance equipment to command formation flights of single-seat Su-27 interceptors. The rear cockpit received a large CRT display which provides the formation leader with tactical information regarding targets and interceptors.

The navigation and fly-by-wire systems were also upgraded. It was fitted with an updated NIIP N001 radar, providing some ability for ground attack and to track and engage multiple aerial targets simultaneously.

Sukhoi offered the Su-27PU to be used as a "fighter controller", a sort of mini-AWACS, with the back-seater using the radar and data links to control other fighters. However, the PVO was not interested in buying the Su-27PU. All five Su-27PUs, with the new designation of "Su-30", ended up in PVO service in the training role. Deliveries to the 54th Interceptor Air Regiment at the advanced training base at Savostleyka began in 1996.

A Su-30M two-seat multi-role variant was proposed for Russian use and a few may have been built in the mid-1990s for evaluation.

Sukhoi proposed an export variant, Su-30MK, where "MK" stood for "Modernizirovannyi Kommercheskiy" (Modernized Commercial). Sukhoi displayed a Su-30MK demonstrator at the Paris Air Show in 1993. A much more optimized Su-30MK demonstrator, rebuilt from the first production Su-27PU, was displayed in 1994.

Design

The Su-30 is a multi-role fighter. It has a two seat cockpit with an airbrake behind the canopy.

The Su-30MK is capable of accomplishing a wide variety of combat missions at significant distances from the home base, in any weather conditions and during radar jamming, both by day and night. This multi-role aircraft is adequately fitted for the entire spectrum of tactical and operational combat employment scenarios, varying from counter-air tasks (i.e. gaining air superiority, air defense, air patrol and escort) to ground attack, suppression of enemy air defenses, air interdiction, close air support and maritime attack. Additionally, the Su-30MK can perform ECCM and early warning tasks, as well as exercise command-and-control over a group of aerial combat assets performing joint missions. It has a 9 g load maneuverability.

Angle of attack

The Su-30MK's aerodynamic configuration is an unstable-in-longitude triplane. To increase lifting effectiveness and enhance maneuverability of the aircraft, canards are installed. They are deflected automatically to ensure controlled flight at high angles-of-attack. Canards, however, are installed only in some Su-30 variants like the Su-30MKI.

The integrated aerodynamic configuration, combined with the thrust vectoring control ability, results in unprecedented maneuverability and unique takeoff and landing characteristics. Equipped with a digital fly-by-wire system, the Su-30MK is able to perform some very advanced maneuvers. They include the well-known Pugachev’s Cobra and the Bell. This allows the aircraft to rapidly strip airspeed, causing a pursuing fighter to overshoot. While performing a somersault maneuver the aircraft makes 360-degree turn in the pitch plane without any loss of altitude. In the Controlled Flat Spin maneuver the aircraft performs several full turns in the horizontal plane, with zero forward speed, virtually on the spot.

Powerplant

The aircraft's power plant incorporates two Saturn AL-31F afterburning low-bypass turbofan engines. Two AL-31F turbofans, each rated at 12,500 kgf (123 kN, 27,550 lb) of full afterburning thrust ensures Mach 2 horizontal flight speed, 1,350 km/h speed at low altitude, and a 230 m/s climbing rate.

With a normal fuel reserve of 5,270 kg, the Su-30MK is capable of performing a 4.5-hour combat mission with a range of 3,000 km. An in-flight refueling system increases the flight duration up to 10 hours with a range of 5,200 km (3,231 miles) at cruise altitudes of 11–13 km.

The long range significantly increases deployment options. The missions vary from prolonged patrols, and escorts to long-range intercepts and ground attacks.

Differential ±15-degree deflection of the engines' asymmetric nozzles (with turn axes positioned at 32-deg angle to each other) enables pitch/yaw thrust vectoring control. Depending on the maneuver to be performed, nozzles deflections can be synchronized with or differ from the deflections of horizontal tail planes.

Two-member crew

A two-member crew configuration contributes significantly to enhanced combat capabilities, due to rational distribution of workload between crew members. While the first pilot flies the aircraft, controls weapons and performs manoeuvring dogfight, the co-pilot employs BVR air-to-air and air-to-ground guided weapons in long-range engagements, monitors tactical environment to ensure situational awareness, and performs command-and-control tasks in group missions.

Avionics

- Radar: Either a N001VE or Phazotron N010 Zhuk-27 or an N011M BARS pulse Doppler passive electronically scanned array radar. Capable of detecting and tracking up to 15 air targets, while concurrently attacking four of them. The N011M BARS radar (featuring a 20-m (65.6 ft) resolution) ensures detection of large sea-surface targets at a distance of up to 400 km (248.5 mi), and small-size ones at a distance of up to 120 km (74.5 mi).
- Other avionics include an integrated optronic sighting-and-navigation system with a laser gyro navigation system; helmet-mounted displays, a head-up-display, multi-function color LCDs with image mixing ability; and a GPS system (GLONASS/NAVSTAR compatible).

- IR and laser sighting pods to detect and engage small-size ground targets are available for installation. The aircraft is provided with an ECCM facility intended to subvert hostile electronic and electro-optical countermeasures.
- The aircraft features autopilot ability at all flight stages including low-altitude flight in terrain-following mode, and individual and group combat employment against air and ground/sea-surface targets. Automatic control system interconnected with the navigation system ensures route flight, target approach, recovery to airfield and landing approach in automatic mode.

Unit Costs

- A standard Su-30K is estimated at US$34 million.
- A Su-30MKK variant is estimated at US$53 million.

Variants

Su-27PU
: Long range interceptor based on two-seater Su-27UB trainer. Later renamed Su-30.

Su-30
: Testbed fighter with canards added.

Su-30K
: Commercial version of the basic Su-30.

Su-30KI (Flanker-B Mod. 2)
: Sukhoi proposal for upgrading Russian AF single seat Su-27S. Also proposed export version for Indonesia, 24 were ordered but subsequently cancelled due to the 1997 Asian Financial Crisis. the only single seat in Su-30 family.

Su-30KN (Flanker-B Mod. 2)
: Upgrade project for operational two-seat fighters, the Su-27UB, Su-30 and Su-30K. This was canceled but later revived as Su-30M2.

Su-30M
: An upgraded Su-27PU, first real multi-role aircraft in Su-27 family.

Su-30MK of the Indonesian Air Force

Su-30MK
: Commercial version of Su-30M first revealed in 1993. Export versions include navigation and communication equipment from Hindustan Aeronautics Ltd.

Su-30M2
: A Su-30 version from manufacturer KnAAPO based on the Su-30MK with canards and optional thrust-vectoring. Four were ordered by Russian Air Force in 2009. Factory tests were completed in September 2010.

Su-30MKI
: MKI stands for "Modernizirovannyi Kommercheskiy Indiski" meaning "Modernized Commercial India". Jointly-developed with India's Hindustan Aeronautics Limited for the Indian Air Force. Includes Thrust Vectoring Control (TVC) and canards. Equipped with a multi-national avionics complex sourced from Israel, India, Russia and France.

Su-30MKK
: Export version for China. MKK stands for *Modernizirovannyi Kommercheskiy Kitaya* or Modernized Commercial China.

Su-30MKM
: A derivative of the India-Russian MKI, the MKM is a highly specialized version for Royal Malaysian Air Force (M is for 'Malaysia'). It includes Thrust Vectoring Control (TVC) and canards but with avionics from various countries. It will feature head-up displays (HUD), navigational forward-looking IR system (NAVFLIR) and Damocles Laser Designation pod (LDP) from Thales Group of France, MAW-300 missile approach warning sensor (MAWS), RWS-50 RWR and laser warning sensor (LWS) from SAAB AVITRONICS (South Africa) as well as the Russian NIIP N011M BARS PESA radar, electronic warfare (EW) system, optical-location system (OLS) and a glass cockpit.

Su-30MKV
: Export version for Venezuela is most likely to be similar to the Su-30MK2. This is based on the presence of two such demonstrator models (No. 0460 and No. 1259) from the KNAAPO facility that took part in July 2006 national day parade in Caracas.

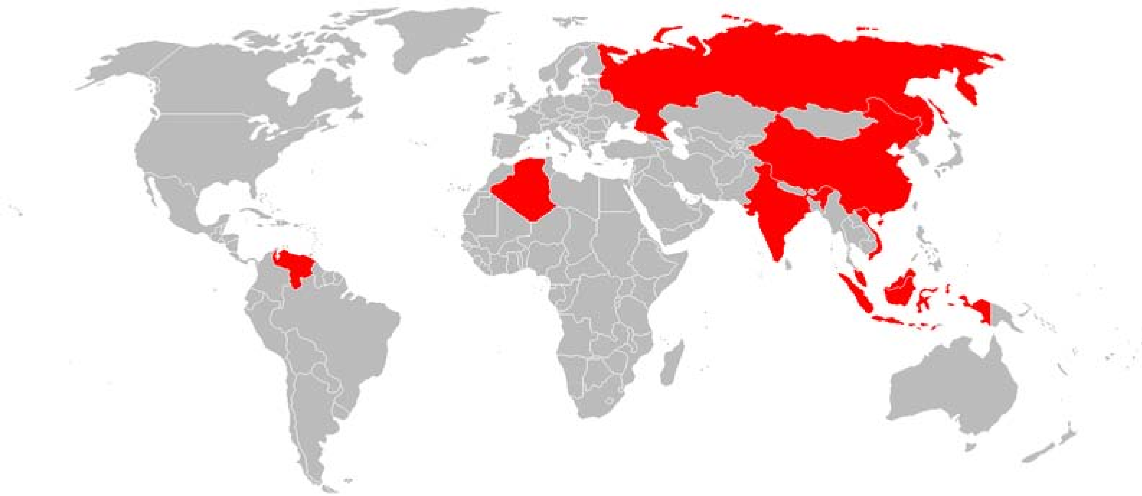
Su-30MK2
: Su-30MKK with upgraded electronics that enabled support for anti-ship missiles.

Su-30MK2V
: Su-30MK2 variant for Vietnam with minor modifications.

Su-30MK3
: Su-30MKK with Zhuk MSE radar and Support for Kh-59MK anti-ship missile.

Su-30MKA
: A specialised version for Algeria is similar to the MKI, but will principally be equipped with French and Russian avionics. It will feature head-up and multifunction displays from the Thales Group and Sagem of France.

Operators



Operators of the Su-30 as of 2010

Sukhoi-30MKI, Indian Air Force, Aeroindia 05.

Algeria

- Algerian Air Force has 28 Su-30MK fighters in service as of January 2010. 16 more are on order to be delivered instead of 36 MiG-29SMT/UBT aircraft.

People's Republic of China

- People's Liberation Army and People's Liberation Army Naval Air Force were operating a total of 127 Su-30MKK and Su-30MK2 fighters according to September 2008 data from Jane's Information Group.
- People's Liberation Army Naval Air Force had 23 Su-30MK2s in service as of January 2010. They were ordered in January 2003 and were received by August 2004.

India

- Indian Air Force decided to purchase 50 Su-30 aircraft in 1996 and acquired the licence from Sukhoi and Russia to manufacture an additional 140 Su-30MKI aircraft. The Indian Air Force has received 105 Su-30MKIs of the 230 on contract as of October 2009. India is near completing an order for another 42 Su-30s in June 2010.

Indonesia

- Indonesian Air Force ordered three Su-30MK2 and received two on 26 December 2008 and the third in 2009. The Indonesian Air Force has 2 Su-30MKs and 3 Su-30MK2s in service as of early 2009, and ordered 6 more Su-30MK2s in 2010.

Malaysia

- Royal Malaysian Air Force after a close visit to see India's Su-30MKI, signed a deal to purchase 18 of Su-30MKM in May 2003. The first 2 Su-30MKMs were formally handed over in Irkutsk on 23 May 2007, later arrived in Gong Kedak airbase on 21 June. As part of the contract, Russia sent the first Malaysian cosmonaut to the International Space Station in October 2007. Malaysia had 12 Su-30MKMs in service with 6 on order in November 2008. Malaysia has had problems with support for the aircraft so it will purchase spare parts from China.

Russia

- Russian Air Force operates 9 Su-30s

Uganda

- Ugandan Air Force has ordered 6 Su-30MK2

Venezuela

- Venezuelan Air Force and the government of Venezuela on 14 June 2006, announced the purchase of 24 units of the Su-30MK2 aircraft. The first two Su-30MK2s arrived in the first week of December 2006 while another 8 were commissioned during 2007, fourteen more units have arrived in 2008 with the last 4 being delivered in August. Has 24 Su-30MK2s in service as of early 2009. A second batch of 12 Su-30MKV is also being considered.

Vietnam

- Vietnam People's Air Force operates 4 Su-30MK2s as of January 2010. Vietnam reportedly signed a contract was for 12 more Su-30MK2s in 2009, but the contract was reduced to 8 fighters. On 20 July 2010, it was announced at Farnborough International Airshow that a contract for up to 20 Su-30MK2s had been signed with Vietnam.

Specifications (Su-27PU/Su-30)

General characteristics

- **Crew:** 2
- **Length:** 21.935 m (72.97 ft)
- **Wingspan:** 14.7 m (48.2 ft)
- **Height:** 6.36 m (20.85 ft)
- **Wing area:** 62.0 m^2 (667 ft^2)
- **Empty weight:** 17,700 kg (39,021 lb)
- **Loaded weight:** 24,900 kg (54,900 lb)
- **Max takeoff weight:** 34,500 kg (76,060 lb)
- **Powerplant:** 2× AL-31FL low-bypass turbofans
    - **Dry thrust:** 7,600 kgf (74.5 kN, 16,750 lbf) each
    - **Thrust with afterburner:** 12,500 kgf (122.58 kN, 27,560 lbf) each

Performance

- **Maximum speed:** Mach 2.0 (2,120 km/h, 1,320 mph)
- **Range:** 3,000 km (1,620 nmi) at altitude
- **Service ceiling:** 17,300 m (56,800 ft)
- **Rate of climb:** 230 m/s (45,275 ft/min)
- **Wing loading:** 401 kg/m^2 (82.3 lb/ft^2)
- **Thrust/weight:** 1.0

Armament

The Su-27PU had 8 hardpoints for its weapon load, whereas the Su-30MK's combat load is mounted on 12 hardpoints: 2 wingtip AAM launch rails, 3 pylons under each wing, 1 pylon under each engine nacelle, and 2 pylons in tandem in the "arch" between the engines. All versions can carry up to 8 tonnes of external stores.

- **Guns:** 1 × GSh-30-1 gun (30 mm caliber, 150 rounds)

- **AAMs:** 6 × R-27ER1 (AA-10C), 2 × R-27ET1 (AA-10D), 6 × R-73E (AA-11), 6 × R-77 RVV-AE(AA-12)
- **ASMs:** 6 × Kh-31P/Kh-31A anti-radar missiles, 6 × Kh-29T/L laser guided missiles, 2 × Kh-59ME
- **Aerial bombs:** 6 × KAB 500KR, 3 × KAB-1500KR, 8 × FAB-500T, 28 × OFAB-250-270

Incidents and accidents

- 12 June 1999: Paris Air Show, Le Bourget, France, a Russian Su-30MK crashed — both pilots ejected safely and no one was hurt on the ground.
- 30 April 2009: an Indian Air Force Su-30MKI crashed near Jaisalmer. A pilot died.
- 30 November 2009: an Indian Air Force Su-30MKI crashed near Jaisalmer. The pilots survived.
- The Chinese have lost 5 Flankers, of which 4 are Su-30s.

Chapter 12

Tupolev Tu-144

The Tu-144LL used by NASA to carry out research for the High Speed Civil Transport

The **Tupolev Tu-144** (NATO reporting name: "**Charger**'") was one of the world's two supersonic transport aircraft (SST) to enter commercial service, along with the Concorde, and was constructed under the direction of the Soviet Tupolev design bureau headed by Alexei Tupolev.

The Tu-144 was outwardly similar to the Aérospatiale / British Aircraft Corporation Concorde, under development at the same time, and there were frequent allegations that Soviet espionage played a key role, giving the Tu-144 the nickname "**Konkordski**" or "**Concordski**". The Tu-144 was Tupolev's only supersonic commercial airliner venture, as the company's other large supersonic aircraft were designed and built to military specifications. All these aircraft benefited from technical and scientific input from TsAGI, the Central Aerohydrodynamic Institute. McDonnell Douglas, Lockheed and Boeing were three other manufacturers who attempted to design SST airliners for the US market during the 1960s without success.

A prototype (OKB: *izdeliye 044* - article 044) first flew on 31 December 1968 near Moscow, two months before the Concorde. The Tu-144 first broke the speed of sound on 5 June 1969, and on 15 July 1969 it became the first commercial transport to exceed Mach two. The Tu-144 was introduced into passenger service on 1 November 1977, almost two years after the Concorde, and was withdrawn after 55 scheduled passenger flights due to potentially severe problems with aircraft safety and was not re-introduced to service.

Although the Tu-144 was technically broadly comparable to the Concorde, it lacked a passenger market within the Soviet Union and service was halted after only 102 scheduled flights (55 passenger flights, the rest cargo). The Concorde remained in service until 2003, being withdrawn three years after the crash of Air France Flight 4590 near Paris on 25 July 2000, the only loss of an SST in commercial service.

Design and development

Tu-144 Prototype in June 1971, Berlin-Schönefeld

The Soviets published the concept of the Tu-144 in an article in the January 1962 issue of the magazine *Technology of the Air Transport*. The air ministry started development of the Tu-144 on 26 July 1963, following approval by the Council of Ministers 10 days earlier. The project started two years later than the Concorde. The plan called for five flying prototypes to be built in four years. The first aircraft was to be ready in 1966.

Despite the close similarity in appearance of the Tu-144 to the Anglo-French supersonic aircraft, there were significant differences in the control, navigation and engine systems. In areas such as range, aerodynamic sophistication, braking and engine control, the Tu-

144 lagged behind the Concorde. While the Concorde utilized an electronic engine control package from Lucas, Tupolev was not permitted to purchase it for the Tu-144 as it could also be used on military aircraft. The Concorde's designers used the fuel of the airliner as the coolant for air conditioning the cabin and the hydraulic system. Tupolev installed additional equipment on the Tu-144 to accomplish this, increasing the weight of the airliner.

Alexey A. Tupolev continued to work to improve the Tu-144. Many substantial upgrades and changes were made on the Tu-144 prototype (serial number *68001*). While both the Concorde and the Tu-144 prototype had ogival delta wings, the Tu-144's wing lacked the Concorde's conical camber. Production Tu-144s replaced this wing with a double-delta wing including conical camber, and they added an extra simple but practical device: two small retractable canard surfaces one on either side of the forward section on the aircraft to increase lift at low speed.

Moving the elevons downward in a delta-wing aircraft increases the lift, but that also pitches its nose downward. The canard cancels out this nose-downwards moment, thus reducing the landing speed of the production Tu-144s to 315–333 km/h (170-180 kn, 196-207 mph) - still faster than that of the Concorde. The NASA study lists final approach speed during performed Tu-144LL test flights as 170 to 181 knots (315 to 335 km/h), however these were approach speeds exercised during *test* flights specifically intended to study landing effects at maximum possible range of speeds, regardless of how hard and stable the landing can be. As to regular landings, FAA circular lists Tu-144S approach speed as 178 knots (330 km/h), as opposed to BAC/Aerospatiale Concord(e) approach speed of 162 knots (300 km/h), based on the characteristics declared by the manufacturers to Western regulatory bodies. It is open to argument how stable was Tu-144S at the listed airspeed. In any event, when NASA subcontracted Tupolev bureau in the 1990s to convert one of the remaining Tu-144D to a Tu-144LL standard, the procedure set by Tupolev for landing defined the Tu-144LL "final approach speed... on the order of 360 km/hr depending on fuel weight." Brian Calvert, the Concorde's technical flight manager and its first commercial pilot executing several inaugural flights, cites final approach speed of a typical Concorde landing to be 155 to 160 knots, i.e. 287 to 296 km/h. Lower Concorde landing speed compared to Tu-144 is due to the Concorde's more refined design of the wing profile that provides higher lift at low speeds without degrading supersonic cruise performance — a feature often mentioned in Western publications on the Concorde and acknowledged by Tupolev designers as well.

Paris Air Show crash

At the Paris Air Show on 3 June 1973, the development program of the Tu-144 suffered severely when the first *Tu-144S* production airliner (reg 77102) crashed.

While in the air, the Tu-144 underwent a violent downwards maneuver. Trying to pull out of the subsequent dive, the Tu-144 broke up and crashed, destroying 15 houses and killing all six people on board the Tu-144 and eight more on the ground.

The causes of this incident remain controversial. A popular theory was that the Tu-144 tried to avoid a French Mirage chase plane that was attempting to photograph its canards, which were very advanced for the time, and that the French and Soviet governments colluded with each other to cover up such details. The flight of the Mirage was denied in the original French report of the incident, perhaps because it was engaged in industrial espionage. More recent reports have admitted the existence of the Mirage (and the fact that the Russian crew were not told about the Mirage's flight) though not its role in the crash. The official press release did state: "though the inquiry established that there was no real risk of collision between the two aircraft, the Soviet pilot was likely to have been surprised." Howard Moon stresses that last-minute changes to the flight schedule would have disoriented the pilots in a cockpit with notable poor vision. He cites an eyewitness who claims the co-pilot had agreed to take a camera with him, which he may have been operating at the time of the evasive maneuver.

Another theory claims that the black box was recovered by the Soviets and decoded. The cause of this accident is now thought to be due to changes made by the ground engineering team to the auto-stabilisation input controls prior to the second day of display flights. These changes were intended to allow the Tu-144 to outperform the Concorde in the display circuit. The changes also inadvertently connected some factory-test wiring which resulted in an excessive rate of climb, leading to the stall and subsequent crash.

A third theory relates to deliberate misinformation on the part of the Anglo-French team. The main thrust of this theory was that the Anglo-French team knew that the Soviet team were planning to steal the design plans of the Concorde, and the Soviets were allegedly passed false blueprints with a flawed design. The case, it is claimed, contributed to the imprisonment by the Soviets of Greville Wynne in 1963 for spying. Wynne was imprisoned on 11 May 1963 and the development of the Tu-144 was not sanctioned until 16 July 1963.

Operational service

Tu-144 with distinctive Droop-nose at the MAKS-2007 exhibition

The Tu-144S went into service on 26 December 1975, flying mail and freight between Moscow and Alma-Ata in preparation for passenger services, which commenced in November 1977 and ran a semi-scheduled service until the first Tu-144D experienced an in-flight failure during a pre-delivery test flight, and crash-landed with crew fatalities on 23 May 1978. The Aeroflot flight on 1 June 1978 was the Tu-144's 55th and last scheduled passenger service.

A scheduled Aeroflot freight-only service recommenced using the new production variant *Tu-144D* ("D" for *Dal'nyaya* - "long range") aircraft on 23 June 1979, including longer routes from Moscow to Khabarovsk made possible by the more efficient Kolesov RD-36-51 turbojet engines used in the Tu-144D version, which increased the maximum cruising speed to Mach 2.15. Including the 55 passenger flights, there were 102 scheduled Aeroflot flights before the cessation of commercial service.

It is known that Aeroflot still continued to fly the Tu-144D after the official end of service, with some additional non-scheduled flights through the 1980s. One report claimed that it was used on a flight from Crimea to Kiev in 1987.

Production

A total of 16 airworthy Tu-144s were built: the prototype Tu-144 reg *68001*, a pre-production Tu-144S reg *77101*, nine production Tu-144S reg *77102 – 77110*, and five Tu-144D reg *77111 – 77115*. A 17th Tu-144 (reg *77116*) was never completed. There was also at least one ground test airframe for static testing in parallel with the prototype *68001* development.

Along with early Tu-134s, the Tu-144 was one of the last commercial aircraft with a braking parachute.

Engines

Although studies showed that turbojet engines are highly desirable for supersonic airliners, none were available. Therefore, originally the Tu-144 prototype was fitted with the inefficient Kuznetsov NK-144 turbofan engines and additionally gave much greater nacelle drag. While this permitted early test flights, it did not permit cruise at Mach 2 without the afterburner on: a maximum cruising speed of 2,430 km/h (1,510 mph) (Mach 2.29) was obtained requiring the afterburner to be engaged. One important offshoot of this was that while the Concorde could supercruise (maintain supersonic flight without using its afterburners), the Tu-144 could not. Later work on the *Tu-144S* resolved this shortcoming. The turbofan engines suffered from heavy fuel consumption, and this limited range to about 2,500 km (1,600 miles), giving the Tu-144 far less range than the Rolls-Royce/Snecma Olympus 593 turbojet powered Concorde.

The Tu-144S model, of which nine were produced, featured the Kuznetsov NK-144F turbofan engines that offered better fuel efficiency over the original engines. The four engines had a maximum afterburning thrust of 200 kN (20,000 kgp / 44,122 lbf) each and each had separate inlet ducts in each nacelle and variable ramps in the inlets. It gave it a cruising speed of 2,000 km/h (1,200 mph) (Mach 1.88). This also gave it a longer range of 3,080 km (1,914 miles), still less than half the range of the Concorde.

The final Tu-144D model of which six were produced was powered by the Kolesov RD-36-51 turbojet. This gave the Tu-144D the ability to cruise at a comparable speed to the Concorde at 2,124 km/h (1,320 mph) (Mach 2.0). The new engines also gave the Tu144D a much larger range- more than double the original model at 6,500 km (4,039 miles). Plans for an aircraft with 7,000+ km (3,780 nmi, 4,350 mi) range were never implemented.

Post-production use

Tu-144D #77112 on display at Sinsheim Auto & Technik Museum, Germany

Although its last commercial passenger flight was in 1978, production of the Tu-144 did not cease until six years later, in 1984, when construction of the partially complete Tu-144D reg *77116* airframe was stopped. During the 1980s the last two production aircraft to fly were used for airborne laboratory testing, including research into ozone depletion at high altitudes.

Tu-144LL in flight

In the early 1990s, a wealthy businesswoman, Judith DePaul, and her company IBP Aerospace negotiated an agreement with Tupolev and NASA, (also Rockwell and later Boeing). They offered a Tu-144 as a testbed for its High Speed Commercial Research program, intended to design a second-generation supersonic jetliner called the High Speed Civil Transport. In 1995, Tu-144D [reg 77114] built in 1981 (with only 82 hours and 40 minutes total flight time) was taken out of storage and after extensive modification at a total cost of US$350 million was designated the *Tu-144LL* (where LL is a Russian abbreviation for Flying Laboratory, Russian: *Letayuschaya Laboratoriya*, Летающая Лаборатория). It made a total of 27 flights in 1996 and 1997. Though regarded as a technical success, the project was canceled for lack of funding in 1999.

The Tu-144LL was reportedly sold in June 2001 for $11 million via on-line auction, but the aircraft sale did not proceed — Tejavia Systems, the company handling the transaction, reported in September 2003 that the deal was not signed. The replacement Kuznetsov NK-321 engines (from the Tupolev Tu-160 bomber) are military hardware and the Russian government did not allow them to be exported.

At the 2005 Moscow Air & Space Show, Tejavia founder Randall Stephens found the Kuznetsov NK-321 engine on display, and the Tu-144LL rusting on Tupolev's test base at the Gromov Flight Test Center. In late 2003, with the retirement of the Concorde, there was renewed interest from several wealthy individuals who wanted to use the Tu-144LL for a transatlantic record attempt; but Stephens advised them of the high cost of a flight readiness overhaul even if military authorities would authorize the use of NK-321 engines outside Russian Federation airspace.

The last two production aircraft remain at the Tupolev production plant in Zhukovsky, reg *77114* and *77115*. In March 2006, it was announced that these airframes had been sold for scrap. Later that year, however, it was reported that both aircraft would instead be preserved. One of them could be erected to a pedestal near Zhukovsky City Council and TsAGI or above the LII entrance from the Tupolev avenue.

Civil operators

Soviet Union

- Ministry of Aviation Production
- Aeroflot Soviet Airlines

While several Tu-144s were donated to museums in Moscow Monino, Samara and Ulyanovsk, at least two Tu-144D remained in open storage in Moscow Zhukovsky.

As of June 2010, two aircraft are located outdoors at LII aircraft testing facility, Zhukovsky (at coordinates 55°34′11″N 38°09′20″E / 55.569786°N 38.155652°E and 55°34′18″N 38°09′08″E / 55.571776°N 38.152304°E). Previously, they were constantly on display at MAKS Airshows.

The only Tu-144 on display outside the former Soviet Union was acquired by the Auto & Technikmuseum Sinsheim in Germany, where it was shipped — not flown — in 2001 and where it now stands, in its original Aeroflot livery, on display next to an Air France Concorde.

Reasons for failure and cancellation

Due to political pressures resulting from the Concorde's launch into regular commercial service, the Tu-144S was prematurely launched into passenger service before proper testing and tuning of the aircraft were completed.

Early flights in scheduled service indicated the Tu-144S was extremely unreliable. During 102 flights and 181 hours of scheduled freight and passenger flight time, the Tu-144S suffered at least 226 failures, 80 of them in flight. (The list was included in the Tu-144 service record provided by the USSR to BAC-Aérospatiale in late 1978, when requesting Western technological aid with the Tu-144, and is probably incomplete). A total of 80 of these failures were serious enough to cancel or delay the flight.

After the inaugural flight, two subsequent flights, during the next two weeks, were cancelled and the third flight rescheduled for several days later. The official reason given by Aeroflot for cancellation was bad weather at Alma-Ata, however when the journalist called Aeroflot office in Alma-Ata about local weather, Alma-Ata office said that the weather there was perfect and one aircraft had already arrived in fine condition that morning. Subsequently, outright flight cancellations might have become less common, as several Tu-144s were docked at Moscow Domodedovo airport (travelers at Domodedovo during the years of Tu-144 passenger service noted up to four Tu-144s parked in the airport and presumably several Tu-144s were also available at all times in Alma-Ata as standby replacements).

Some of the failures included decompression of the cabin in flight on 27 December 1977, and overheating of an engine exhaust duct causing the flight to be aborted and returned to the takeoff airport on 14 March 1978.

Alexei Tupolev, Tu-144 chief designer, and two USSR vice-ministers (of aviation industry and of civil aviation) had to be personally present in Domodedovo airport before each scheduled Tu-144 departure to review the condition of the aircraft and make a joint decision on whether it could be released into flight.

Tu-144 pilot Aleksandr Larin remembers a particularly troublesome flight on or around 25 January 1978 that he piloted. The flight with passengers aboard suffered the failure of 22 to 24 on-board systems. Seven to eight systems failed before takeoff; given the large number of foreign TV and radio journalists aboard the flight, and also some other foreign notables aboard, it was decided to proceed with the flight in order to avoid the embarrassment of cancellation. After takeoff, failures continued to multiply. While the aircraft was supersonic en route to the destination airport, Tupolev bureau's crisis center predicted that front and left landing gear would not extend and that the aircraft would have to land on right gear alone – at the aircraft landing speed of over 300 km/h. Due to expected political fallout, Soviet leader Leonid Brezhnev was personally notified of what was going on in the air. With the accumulated failures, an alarm siren went off immediately after the takeoff with sound and loudness similar to that of a civil defense warning. The crew could figure no way to switch it off and the siren stayed on throughout the remaining 75 minutes of the flight. Eventually the captain ordered the navigator to borrow a pillow from the passengers and stuff it inside the siren's horn. Luckily, all landing gears extended and aircraft was able to land.

The last passenger flight of Tu-144 on around May 30, 1978 involved valve failure on one of the fuel tanks.

Suggesting low confidence of the Soviet decision-makers in Tu-144 is also the fact that only one route was ever used, with flights limited to once a week, despite having eight Tu-144S certified aircraft by the time passenger service commenced in 1977 and a number of routes suitable for supersonic flights. Booking was limited to 70–80 passengers a flight or less, well below the Tu-144's seating capacity, despite waiting lists. Over its 55 scheduled flights, Tu144s transported 3194 passengers, an average of 58 passengers per flight. With officials being acutely aware of the aircraft's poor reliability and fearful of possible crashes, Soviet decision-makers were purposefully limiting flight frequency to the absolute minimum possible that still allowed them to claim regular service, and also were constraining passenger load to minimize the impact and political fallout of a possible crash.

The most serious problem with the aircraft was discovered when two Tu-144S airframes suffered catastrophic destruction during lab testing soon before the Tu-144 was allowed to enter passenger service. This data is also included as a chapter in Firdlyander's memoirs. The destruction of two airframes during stress testing is also mentioned in Bliznyuk et al. The problem discovered in 1976 may not have been unknown even before then: reports of the large crack in the airframe of the Tu-144 prototype (aircraft 68001) discovered in Warsaw during the prototype return flight in June 1971 after the tour to Salon Aeronautique coming back to Moscow via East Berlin and Warsaw might have manifested the same problem.

In retrospect, the most fatal design decision for Tu-144 was the decision to assemble the Tu-144 from large machined blocks and panels, many over 19 m (62 ft) long and 0.64 to 1.27 m (2 ft 1 in to 4 ft 2 in) wide. While at the time this approach was heralded as an advanced feature of the Tu-144 design program, it turned out that large whole-moulded and machined parts were bound to contain non-uniformities in alloy structure that cracked at stress levels well below what the part was supposed to withstand. Once a crack started to develop, it spread quickly across the entire large part, for many meters, with nothing to stop it. The same kind of catastrophic cracks developed from fatigue too. In 1976 during repeat-load and static testing in TsAGI, a Tu-144S airframe cracked at 70% of expected flight stress with cracks running many meters in both directions from the spot of their origin.

Later the same year, a Tu-144 was subject to a test simulating heat and pressure conditions during actual flight. The Tu-144 was placed into a hyperbaric chamber heated to 130–150 degrees Celsius to make it contract and expand just as it would during flight. Contraction and expansion happens because of the cooling during ascent and descent, heating during supersonic acceleration and cruise, and because of the pressure change from high altitude (low outside pressure causing the airframe to expand) to ground-level pressure (causing it subsequently to contract). The airframe creaked heavily and eventually cracked in a similar way as during the TsAGI load testing.

While fatigue cracks are normal in aircraft, the normal occurrence is that a crack develops slowly and stops once it reaches the end of the panel of which larger parts are assembled. Thus an aircraft could fly with a minor crack for a sufficiently long time, before it could be fixed. The Tu-144 design was the opposite of standard practice, not only fostering a higher incidence of non-uniformities in alloy structure leading to crack formation, but also allowing the crack to develop fast and for many meters. Academician Fridlyander, leading Soviet metallurgist and long-term collaborator of Tupolev and his bureau for virtually all of the bureau's civil and military aircraft since mid-1940s and through the 1990s, including Fridlyander's participation in Tu-144 development and testing, concludes his account of the Tu-144 program: "Airplane (the Tu-144) was doomed as soon as the decision was made to compose it of large monolithic fragments machined of large metal panels. Instead of safely damageable design, this created its antipode — unsafely damageable design".

Fridlyander's account also stresses safety considerations during the design of the Concorde airframe, as opposed to the Tu-144 airframe design. Bliznyuk et al. mention an attempt to counter the problem by requesting the redesign of the alloy to slow down the development of the cracks and to tighten uniformity controls; however it is left unreported to what extent it was possible to deliver on these requests, and in any event these attempts were directed at limiting the scope of the problem rather than resolving it. Noteworthy, when requesting Western technological aid with the development of the Tu-144 in 1977-1978, one of the technological items requested by the Soviet Union in the late 1978 was the ways to reinforce airframe strength to withstand damage.

It is also noteworthy that the Soviet leadership made a political decision to enter the Tu-144 into passenger service in November 1977 despite receiving testing reports indicating that the Tu-144 airframe was unsafe and basically not airworthy for regular service. Curiously, Aeroflot appears to have thought so little of the aircraft that it didn't even mention it in its five-year plan for 1976–1980. However, it was not the airline executives' decision and Aeroflot reluctantly put the Tu-144 into passenger service on 1 November 1977.

Though the decision to cancel the Tu-144S passenger service came a few days after the Tu-144D crashed during the test flight on 23 May 1978, this crash was only the last drop to an already full cup of fears and concerns about the reliability of the Tu-144. Even the fact that the technical reason for the crash was specific to the Tu-144D fuel pump system and did not apply to the Tu-144S did not help. The decision to pull the Tu-144S out of passenger service after merely 55 flights is thus more likely to be attributable to high incidence of failures during and before the scheduled flights. Coupled with already existing concerns about the airframe reliability, and underscored by recent Tu-144D crash, it must have incited Soviet leadership to satisfy themselves with the symbolic status already achieved by token flights, rather than keep risking the embarrassment of a crash with passengers on board.

The problem most noticeable for passengers during flights was very high discomforting level of noise inside the cabin. The noise was partially coming from the engines, but the chief source of the noise was air conditioning and the aircraft skin cooling system. Unlike conventional subsonic aircraft, a cooling system is absolutely vital for supersonic cruise to cool off the aircraft skin and prevent it from overheating and losing structural integrity. Heat generated by intense air-to-surface friction in supersonic flight is passed to the coolant (cabin air, in case of both the Tu-144 and the Concorde) and subsequently discharged via heat exchangers to the fuel stream right before it is pumped to the engines. Unlike the Concorde, the Tu-144 cooling system was very noisy. Passengers seated next to each other could have a conversation only with difficulty, and those seated two seats apart could not hear each other even when screaming and had to pass hand-written notes instead. Noise in the back of the aircraft was unbearable. Alexei Tupolev, who was aboard the flight, acknowledged the problem to foreign passengers and promised to fix it.Available publications do not provide any clues that might suggest what was the exact technical reason for the aircraft being this noisy. It is also not known whether the problem was eventually fixed or not. The fact that publications based in Tupolev sources (Gordon, Bliznyuk) that go into some detail describing the cooling system design avoid mentioning this well-publicized problem that was major passengers' complaint at all, suggests that it had likely stayed unresolved. It was rumored that Aeroflot eventually resorted to issuing earplugs to Tu-144 passengers, but it is unclear whether these rumors are accurate.

As to the component of the cabin noise originating from the engines, it was stronger in the Tu-144 than in the Concorde in part because Tu-144's engines were located much closer to the cabin. (This also increased the potential for contagious engine failure, where the shock wave from one stalled engine disrupts the others.)

A redesign of the Tu-144 to resolve the issues mentioned would have required a substantial time before it would be possible to re-enter the Tu-144 in passenger service as an aircraft trying to compete, if only symbolically and politically, with the Concorde.

A degree of desperation of Tu-144 proponents among the Soviet policy makers over the USSR ability to deliver the Tu-144 as operationally capable aircraft with decent characteristics is apparent in the unprecedented Soviet request for Western technological aid with the development of the Tu-144 – a request that was made despite it obviously not helping to foster Soviet technological prestige, which was one of the key purposes of the whole Tu-144 programme. In 1977 the USSR approached Lucas Industries plc, a designer of the engine control system for the Concorde, requesting help with the design of the electronic management system of the Tu-144 engines, and also asked BAC-Aérospatiale for assistance in improving the Tu-144 air intakes. (The design of air intakes' variable geometry and their control system was one of the most intricate features of the Concorde, contributing to its fuel efficiency. Over half of the wind-tunnel time during the Concorde development was spent on the design of air intakes and their control system.) In late 1978 the USSR requested a wide range of Concorde technologies, obviously reflecting a broad spectrum of unresolved Tu-144 technical problems. The list included de-icing equipment for the leading edge of the air intakes, fuel-system pipes and devices to improve durability of these pipes, drain valves for fuel tanks, fireproof paints, navigation and piloting equipment, systems and techniques for acoustical loading of airframe and controls (to test against acoustic fatigue caused by high jet-noise environment), ways to reinforce airframe strength to withstand damage, firefighting equipment, including warning devices and lightning protection, emergency power supply, landing gear spray guards (aka water deflectors or "mud flaps" that increase engine efficiency when taking off wet airstrip). These requests were denied after the British government vetoed them on the ground that the same technologies, if transferred, could be also employed in Soviet bombers. Soviet approaches were also reported in British mainstream press of the time, such as *London Times*.

On 31 August 1980, Tu-144D (77113) suffered a compressor disc failure in supersonic flight leading to further destruction of airframe structural elements and onboard systems. The crew was able to perform an emergency landing at Engels-2 strategic bomber base.

On 12 November 1981, a Tu-144D's RD-36-51 engine was destroyed during bench tests, leading to a temporary suspension of all Tu-144D flights. One of the Tu-144Ds (77114, aka aircraft 101) suffered a crack across the bottom panel of its wing. In all likelihood, the list of problems was more extensive.

Finally, the 1970s hikes in oil prices were starting to catch up with the Soviet Union. Much later than in the West, but since the late 1970s, commercial efficiency was starting to become a factor in aviation development decision-making even in the USSR. The Tu-144 disappeared from Aeroflot published prospects, replaced by the wide-body jet IL-86 as the new coming flagship Soviet aircraft.

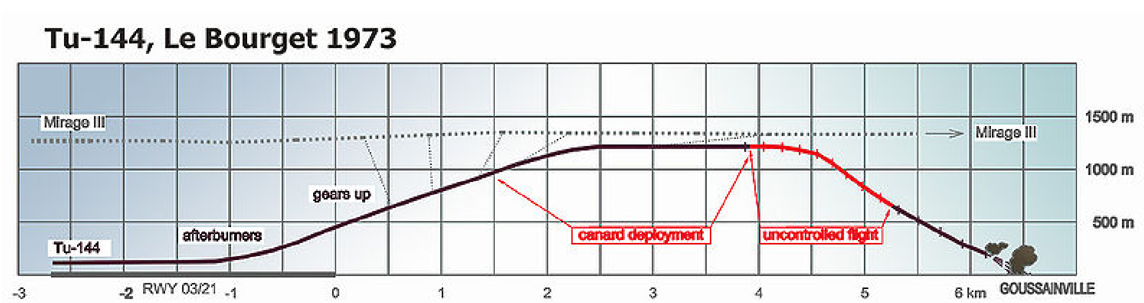
In the late 1970s Soviet insiders were intensely hopeful in conversations with their Western counterparts to reintroduce Tu-144 passenger service for the 1980 Moscow Olympic games, even perhaps for flights to Western Europe, giving the aircraft high visibility, but apparently the technical condition of the aircraft weighed against such re-introduction even for token flights.

As discussed by Moon, economic efficiency alone would not have doomed the Tu-144 altogether: continuation of token flights for reasons of political prestige would have been possible, if only the aircraft itself would have allowed for it, but it did not. The Tu-144 was to a large extent intended to be and trumped as a symbol of Soviet technological prestige and superiority. With a Soviet aircraft that could counterpose the Concorde nowhere near in sight for at least years to come, the Tu-144 programme was becoming more of a political embarrassment rather than pride to the Soviet Union, a symbol of technological race lost to the West, and was quietly rolled down.

The decision to cease Tu-144D production was issued on 7 January 1982, followed by a USSR government decree dated 1 July 1983 to cease the whole Tu-144 programme and hereafter to use produced Tu-144 aircraft only as flying laboratories. A formal decision to cease the Tu-144 programme was also in all likelihood related, to an extent, to the generational change in the Soviet leadership and departure of those officials who had strong individual commitment to the Tu-144 and stakes in the project, and corresponding change in the bureaucratic balance. The Tu-144 luck fared worse after the death of Minister Petr Dementiev on 14 May 1977, but the last bureaucratic straw must have been the death of Brezhnev on 10 November 1982.

In retrospect it is apparent that the Tu-144 suffered from a rush in the design process to the detriment of thoroughness and quality, and this rush to get airborne exacted a heavy penalty later. The rush is apparent even in outward timing: the 1963 government decree launching the Tu-144 programme defined that the Tu-144 should fly in 1968, so it did indeed fly on the last days of 1968 to fulfill government goals arbitrarily set five years earlier. (By the way of comparison, the Concorde's first flight was originally scheduled for February 1968, but was pushed back several times until March 1969 in order to iron out problems and test components better). Unlike the Concorde development, the Tu-144 project was also strongly driven by ideologically and politically motivated haste of Soviet self-imposed racing against the Concorde; Aleksei Poukhov, one of Tupolev's designers, reminiscences: "For the Soviet Union to allow the West to get ahead and leave it behind at that time was quite unthinkable. We not only had to prevent the West from getting ahead, but had to compete and leapfrog them, if necessary. This was the task Khruschev set us... We knew that when Concorde's maiden flight had been set for February or March, 1969, we would have to get our plane up and flying by the end of 1968."

The introduction of the Tu-144 into passenger service was timed to the 60th anniversary of the Communist revolution, as was duly noted in Soviet officials' speeches delivered at the airport before the inaugural flight – whether the aircraft was actually ready for introduction into passenger service was deemed of secondary importance. Even the outward details of the inaugural Tu-144 flight betrayed the haste of its introduction into service: several ceiling panels were ajar, service trays stuck, window shades dropped without being pulled, reading lights did not work, not all toilets worked and a broken ramp delayed departure half an hour. On arrival to Alma-Ata, the Tu-144 was towed back and forth for 25 minutes before it could be aligned with the exit ramp. Equally telling is the number of hours spent on flight testing. Whereas the Concorde had been subjected to 5,000 hours of testing by the time it was certified for passenger flight, making it the most tested aircraft ever, total flight testing time of the Tu-144 by the time of its introduction into passenger service was less than 800 hours — over six times less than for the Concorde. Flight testing time logged on the prototype (68001) was 180 hours flight testing time for the Tu-144S till the completion of state acceptance tests was 408 hours; service tests till the commencement of passenger service were 96 hours of flight time; altogether totalling 756 hours. It is unclear why the Minister of Aviation Industry and the Minister of Civil Aviation did not endorse the protocols of state acceptance tests for four months after the tests completion. One reason could be the change of the guard — Minister Dementiev, who was one of the chief backers of Tu-144, died a day before the tests completed (something Gordon fails to notice) — but it might also had something to do with aircraft reliability record uncovered during the tests that was in all likelihood not better than subsequent dismal service record in 1977–1978.



Flight profile of Tu-144 and Mirage IIIR

Perhaps one of the most tragic manifestations of ideologically driven haste during the Tu-144 programme was the 1973 crash of the Tu-144 during the Paris Air Show. A picture of the events and causes is well-emerged by now after the revelations in recent years. The details are briefly as follows. The day before the Tu-144 crash the Concorde performed an impressive lively display at Le Bourget; landing on the airstrip, engaging thrust reversers and stopping, then accelerating and taking off again from the middle of the airstrip. The Tu-144S could not match this performance; it did not have thrust reversers and was braked, like a bomber, by the braking parachute, so it could not take off immediately after landing without packing the chute first. The Tu-144S also had poorer general landing characteristics, such as higher landing speed, compared to the Concorde. After heated discussion in the hotel that evening, key members of the Soviet delegation and the Tu-144 crew decided to try beating the Concorde show by performing the next day some impromptu designed air manoeuvres with the Tu-144, including the steep "hump" manoeuvre that ended in the crash. Their impromptu decision was approved by the higher leadership, apparently by Soviet Aircraft Industry Minister Petr Dementiev. This decision was a flagrant violation of safety and general basic rules and multiple air regulations. The intended manoeuvres were not included in the flight plan, but more than that, they had never been tried on the Tu-144 before. Experimental parts of the aircraft control system were engaged, apparently in an attempt to improve the aircraft manoeuvrability for performing the intended air "tricks". The cockpit panel that controlled experimental parts of the flight control system had a cover specifically placed over it before the departure from Moscow, and the cover was sealed off in Moscow. In Paris, the seal and the cover were removed and switches were engaged to activate experimental parts of the aircraft control system. Pilots tried to perform the steep manoeuvre that had never been tried or thought through, driving the Tu-144 into a regime relying on the aircraft stability characteristics that the crew did not fully account for, and with pilots engaging new elements of the control system that had not been well tested yet, the effects of which the crew did not fully understand and that proved to work differently than the crew expected – all in a hasty attempt to rival the Concorde.

Fridlyander also points out that in addition to the Tu-144, Tupolev's bureau had to work in parallel on other projects, including the Tu-154 passenger aircraft and the Tu-22M bomber. Despite large and high-priority resource investment in the Tu-144 development programme and the fact that a large part of the whole Soviet R&D infrastructure was subordinated to the Tu-144 project, parallel project development overwhelmed the bureau and caused it to lose focus and make design errors. (Design errors affected not only the Tu-144, but the Tu-154 as well). The first batch of 120 Tu-154s suffered from wing destruction due to excessive structural load and had to be withdrawn.

The rush and introduction in service of poorly tested aircraft also happened previously with another Tupolev project that had high political visibility and prestige: the Tu-104 passenger jet liner that was the first successful passenger jet airliner in service (the de Havilland Comet 1 was not considered successful because four of the original nine aircraft crashed). In a decision-making similar to the Tu-144 story, the Soviet government introduced the Tu-104 into passenger service before satisfactory stability and controllability of the aircraft could have been achieved, despite the fact that during high-altitude and high-speed flights the aircraft was prone to longitudinal instability, and also that at high echelons, it had a narrow range of attack angle separating the aircraft from stalls. These problems created the preconditions for spin dives, that happened twice before the Tu-104 was eventually properly tested and the problem was resolved.

This politically motivated rush, coupled with the fact that the project was essentially ideologically motivated rather than driven by intrinsic needs of the Soviet society, coupled with general technological backwardness and backwardness of Soviet industrial base, contributed to the final undoing of the Tu-144 project. (Alexadner Poukhov, one of the Tu-144 design engineers who subsequently rose to be one of the bureau's senior designers, subsequently was estimating in 1998 that the Tu-144 project was 10–15 years beyond the current USSR's capabilities).

Moon suggests that subordination of available Soviet R&D resource allocation to the Tu-144 programme significantly slowed down the development of other Soviet aircraft projects, including more sound ones such as the IL-86 wide-body jet, and stagnated Soviet aviation development for almost a decade.

After project cancellation

The Tu-144 programme was ceased by Soviet government decree dated 1 July 1983 that also provided for future use of the remaining Tu-144 airplanes as airborne laboratories.

The Tu-144 was indeed used as a flying research laboratory. Starting in 1985, Tu-144D was used for training of pilots for the Soviet "Buran" space shuttle. In 1986–1988 the Tu-144D №77114 was used for medical and biological research of high-altitude atmosphere radiological conditions. Further research was planned but ceased due to lack of funding.

In 1996-1999 the Tu-144D №77114 was used as a testbed by NASA teaming with Russian and U.S. airspace industries to develop technologies for a proposed second-generation supersonic airliner.

Right after ceasing the Tu-144 programme, Tu-144D №77114 (aka aircraft 101 or 08-2) performed a number of flights on 13–20 July 1983 to establish 13 world records registered with FAI. The list of the records can be retrieved from the FAI online database. In a nutshell, these records establish a top altitude of 18,200 meters with range of loads up to 30 tons, and sustained speed over a closed circuit up to 2,000 km of 2,032 km/h under similar loads.

The clause about loads probably does not have much significance, as loads were almost certainly compensated by the reduction of fuel load to maintain the same total aircraft takeoff weight. Indeed, it would be hard to imagine the aircraft suddenly carrying the load thrice what it was designed to carry, with the maximum fuel load at the same time. Furthermore, submitted records cover a range of closed circuit lengths up to 2,000 km, but go no further: the fact that the USSR did not attempt to submit flight records for longer circuit lengths suggests that the aircraft was carrying only a partial fuel load.

Still, these record numbers are surprisingly low and it is doubtful whether they indeed represent the aircraft's maximum achievable performance. To put the numbers in prospect, Concorde's service ceiling during routine flight under typical trans-Atlantic load of about 10 tons is set to 60,000 ft (18,290 m), higher than the record set by the Tu-144D, but Concorde could surely climb further above the regular service ceiling if the goal were to set the record altitude. According to unverified sources, during a 26 March 1974 test flight a Concorde reached its maximum speed ever of 2,370 km/h (1,480 mph, Mach 2.23) at an altitude of 63,700 ft (19.4 km) and during subsequent test flights reached maximum altitude of 68,000 ft (20.7 km). It is unclear why Tu-144D's maximum achievable altitude would be lower than the Concorde's even regular flight altitude given that Tupolev's data claim better lift-to-drag ratio for the Tu-144 compared to the Concorde (over 8.0 for Tu-144D vs Concorde's 7.3-7.7 at M2.x) and the thrust of the Tu-144D's RD-36-51 engines is higher than the Concorde's Olympus 593 engines.

While the Concorde set over 170 world records since its first flight in 1969, it apparently did not log records in flying over a closed circuit category, but it is nevertheless unclear why the sustained airspeed of 2,032 km/h claimed in Tu-144D's records would be lower than even the Concorde's typical commercial cruising speed of M2.02 to 2.05.

While the Concorde was originally designed for cruising speeds up to M2.2, its regular service speed was limited to M2.02 to reduce fuel consumption and extend airframe longevity, and also apparently to provide a safety margin. One of Tupolev's web site pages concurs that "TU-144 and TU-160 aircraft operation has demonstrated expediency of limitation of cruise supersonic speed of M=2,0 to provide structure service life and to limit cruising altitude". The Concorde's maximum design cruise speed was M2.2 and maximum tested speed was M2.23.

Neither the Concorde nor the Tu-144 are limited in their maximum speed by the airframe drag, nor by the engines thrust, they are limited by the airframe heating and structural integrity of their aluminium alloys, with alloys used in both aircraft being very similar in their properties. The Tu-144 prototype (airplane №68001) might have had a slight edge since about 15-20% of its parts were built of titanium. Indeed, the Tu-144 №68001 shortly achieved maximum speed of 2,443 km/h (M 2.26) during one of the test flights on 25 May 1970. However the use of titanium for production Tu-144's was radically cut down and the Tu-144S/Tu-144D were built almost entirely of aluminium alloys; titanium and stainless steel were used only for the leading edges, elevons, rudder and under-surface of the rear fuselage (that was heated by the engines exhaust, since Tu-144 engines were located close to the fuselage). Given that the alloys used for both airplanes are almost identical, as well as the thermodynamics of their critical edges is very similar, one should expect that the speeds achievable by both aircraft while maintaining the same level of structural safety should also be about the same. The Tu-144S might have had an edge due to its much higher fuel expenditure per km, that also doubled as a heat discharge medium, and thus potentially might have been able of stronger heat discharge, but the Tu-144D moved closer to the Concorde in its fuel consumption.

Proposed military versions

Earliest project configurations of the Tu-144 were based on the unbuilt Tu-135 bomber, retaining the latter aircraft canard layout, wings and engine nacelles. Deriving from the

Tu-135 bomber, early Tupolev's design for supersonic passenger airplane was code-named Tu-135P before acquiring the Tu-144 project code.

Over the course of the Tu-144 project, the Tupolev bureau performed early designs of a number of military versions of Tu-144. Neither of these versions were ever built. In the early 1970s Tupolev was developing the Tu-144R intended to carry and air-launch up to three solid-fueled ICBMs. The launch was to be performed from within the Soviet air space, with the aircraft accelerating to its maximum speed before releasing the missiles. The original design was based on the Tu-144S, but later changed to be derived from the Tu-144D. Another version of the design was to carry air-launched long-range cruise missiles similar to the Kh-55. The study of this version envisioned the use of liquid hydrogen for the afterburners. The NK-144 engines with cryogenic afterburning passed bench test.

In the late 1970s Tupolev contemplated the development of a long-range heavy interceptor (DP-2) based on the Tu-144D that was also to be able to escort bombers on long-range missions. Later this project evolved into an aircraft for deployment of electronic countermeasures (ECM) to suppress enemy radars and facilitate bomber's penetration through enemy air defenses (Tu-144PP). In the early 1980s this functionality was supplanted with theatre and strategic reconnaissance (Tu-144PR). The dimmer civil prospects for Tu-144 were becoming, the more Tupolev was trying to "sell" the aircraft to the military. One of the last attempts to "sell" the Tu-144 to the military was a project for a long-range reconnaissance aircraft for the Soviet Navy (Tu-144MR) intended to provide targeting information to the Navy's ships and submarines on sea and oceanic theaters of operations; another proposed navy version was to have a strike capability (two Kh-45 air-to-surface cruise missiles) along with reconnaissance function.

The military were unreceptive to Tupolev's approaches. Vasily Reshetnikov, then commander of Soviet strategic aviation, and subsequently a vice-commander of the Soviet Air Force remembers how in 1972 he was dismayed by Tupolev's attempts to offer for military use the aircraft that "fell short of its performance target, was beset by reliability problems, fuel-thirsty and difficult to operate.

Reshetnikov goes on to remember:

The development and construction of the supersonic airliner, the future Tu-144, was included in the five-year plan and was under the auspices of the influential D.F. Ustinov (then Soviet minister of defence and confidant of Brezhnev, who represented interests of defence industries lobby in opposition to the military) who regarded this mission as a personal responsibility — not so much to his country and people as to "dear Leonid Il'ych" (Brezhnev) whom he literally worshipped, sometimes to the point of shamelessness... Yet the supersonic passenger jet was apparently not making headway and, to the dismay of its curator, it looked like Brezhnev might be disappointed. It was then that Dmitry Fedorovich (Ustinov) jumped at someone's bright idea to foist Aeroflot's "bride in search of a wedding" on the military. After it had been rejected in bomber guise, Ustinov used the Military Industrial Commission (one of the most influential Soviet government bodies) to promote the aircraft to the Strategic Aviation as a reconnaissance or ECM platform, or both. It was clear to me that these aircraft could not possibly work in concert with any bomber or missile carrier formation; likewise I could not imagine them operating solo as "Flying Dutchmen" in a war scenario, therefore I resolutely turned down the offer.

Naval Aviation Commander Aleksandr Alekseyevich Mironenko, followed suit.

But nothing worked! Ustinov could not be put off that easily. He managed to persuade the Navy C-in-C (admiral) S.G. Gorshkov who agreed to accept the Tu-144 for Naval Aviation service as a long-range reconnaisance aircraft without consulting anyone on the matter. Mironenko rebeled against this decision, but the commander-in-chief would not hear of heed — the issue is decided, period. On learning of this I was extremely alarmed: if Mironenko had been pressured into taking the Tu-144, this meant I was going to be next. I made a phone call to Aleksandr Alekseyevich, urging him to take radical measures; I needn't have called because even without my urging Mironenko was giving his C-in-C a hard time. Finally Ustinov got wind of the mutiny and summoned Mironenko to his office. They had a long and heated discussion but eventually Mironenko succeeded in proving that Ustinov's ideas were unfounded. That was the last time we heard of Tu-144.

Espionage against the Concorde and influence by the Concorde

The development of the Tu-144 is said to be closely related to industrial espionage against the French company Aérospatiale, which was developing the Concorde, although the TU-144 flew two months before. When Sergei Pavlov —officially acting as Aeroflot's representative in Paris—was arrested in 1965, he was in possession of detailed plans of the braking system, the landing gear and the airframe of the Concorde. Another agent named Sergei Fabiew, who was arrested in 1977, was believed to have obtained the entire plans of the prototype Concorde back in the mid-60s. However, these were early development plans, and would not have permitted the USSR engineers to come up with their own aircraft; they could only serve as a general indication of the work of the Concorde design team. An espionage theory purportedly involved the Anglo/French Concorde team that knew that the Soviets were planning to steal the plans. For this reason, a set of dummy blueprints were put into circulation by the Anglo/French team with deliberate design flaws.

Variants

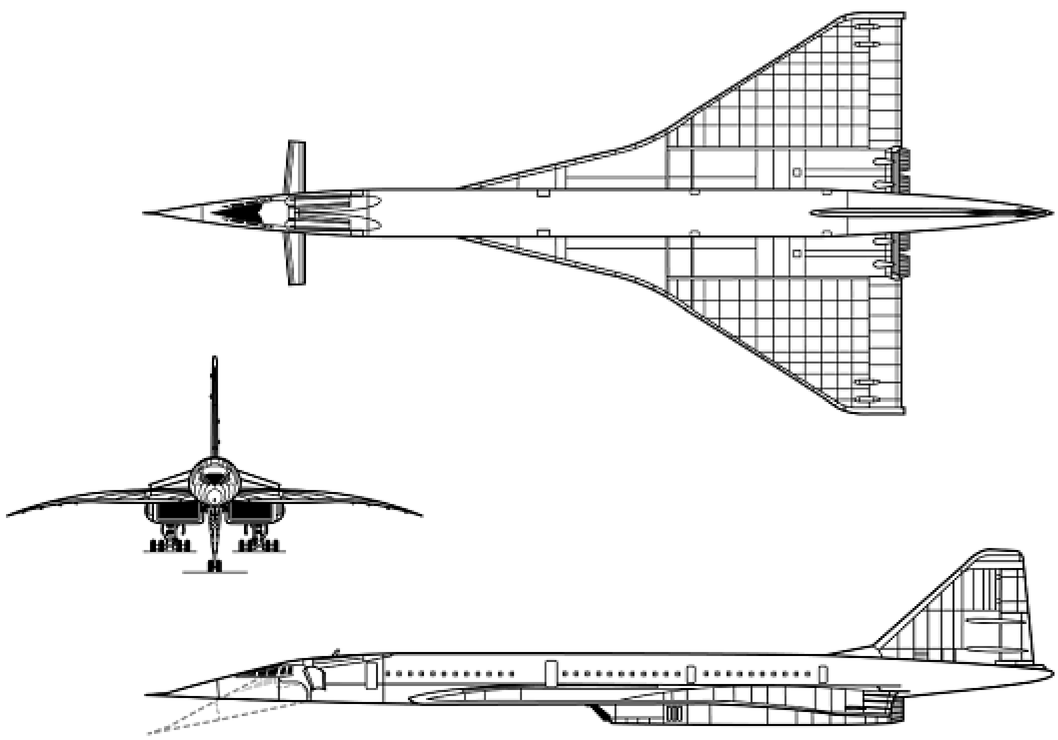
- **Tu-144** - (***izdeliye 044*** - article 044) The sole prototype Tu-144 aircraft
- **Tu-144** - (***izdeliye 004*** - article 004) Six re-designed production aircraft powered by Kuznetsov NK-144 engines in widely spaced nacelles, and re-designed undercarriage
- **Tu-144S** - (S - *Sereeynyy* - series) Alternative designation of production aircraft
- **Tu-144D** - (***izdeliye 004D*** - article 004D)(D-*Dahl'neye* - long-range) Production Tu-144 aircraft powered by Koliesov RD36-51 non after-burning engines. One

aircraft converted from Tu-144 CCCP-77105(c/n10031) and five production aircraft (CCCP-77111 [c/n10062] to CCCP-77115 [c/n 10091]) plus one (CCCP-77116) uncompleted

- **Tu-144DA** - Projected improved version of the Tu-144D with greater fuel capacity and therefore longer range
- **Tu-144LL** - One Tu-144D aircraft (CCCP-77114 [c/n10082]) converted to a flying laboratory with four Kuznetsov NK-321 afterburning turbofan engines and re-registered RA-77114. The first flight took place on 19 November 1996 with the 27th and last flight on 28 February 1998

Specifications

These are the specification for the later experimental version the Tu-144D which employs the more efficient turbojet engines.



Dryden Flight Research Center February 1998
Tu-144LL 3-view

General characteristics

- **Crew:** 3
- **Capacity:** 120-140 passengers, but normally 70~80 passengers

- **Length:** 65.50 m (215.54 ft)
- **Wingspan:** 28.80 m (94.48 ft)
- **Height:** 10.50 m (34.42 ft)
- **Wing area:** 438.0 m^2 (4,715 ft^2)
- **Empty weight:** 85,000 kg (187,400 lb)
- **Loaded weight:** 120,000 kg (264,555 lb)
- **Max takeoff weight:** 180,000 kg (397,000 lb))
- **Powerplant:** 4× Kolesov RD-36-51 afterburning turbojet, 200 kN (44,122 lbf) each
- **Fuel capacity:** 70,000 kg (154,000 lb)

Performance

- **Cruise speed:** Mach 2.0 (2,142 km/h, 1,320 mph)
- **Range:** (Tu-144LL Only) 6,500 km, 2,920 km with full afterburner (3,500 nm, 4,000 mi)
- **Service ceiling:** 18,000 m (59,100 ft)
- **Rate of climb:** 3,000 m/min (9,840 ft/min)
- **Wing loading:** 410.96 kg/m^2 (84.20 lb/ft^2)
- **Thrust/weight:** 0.44

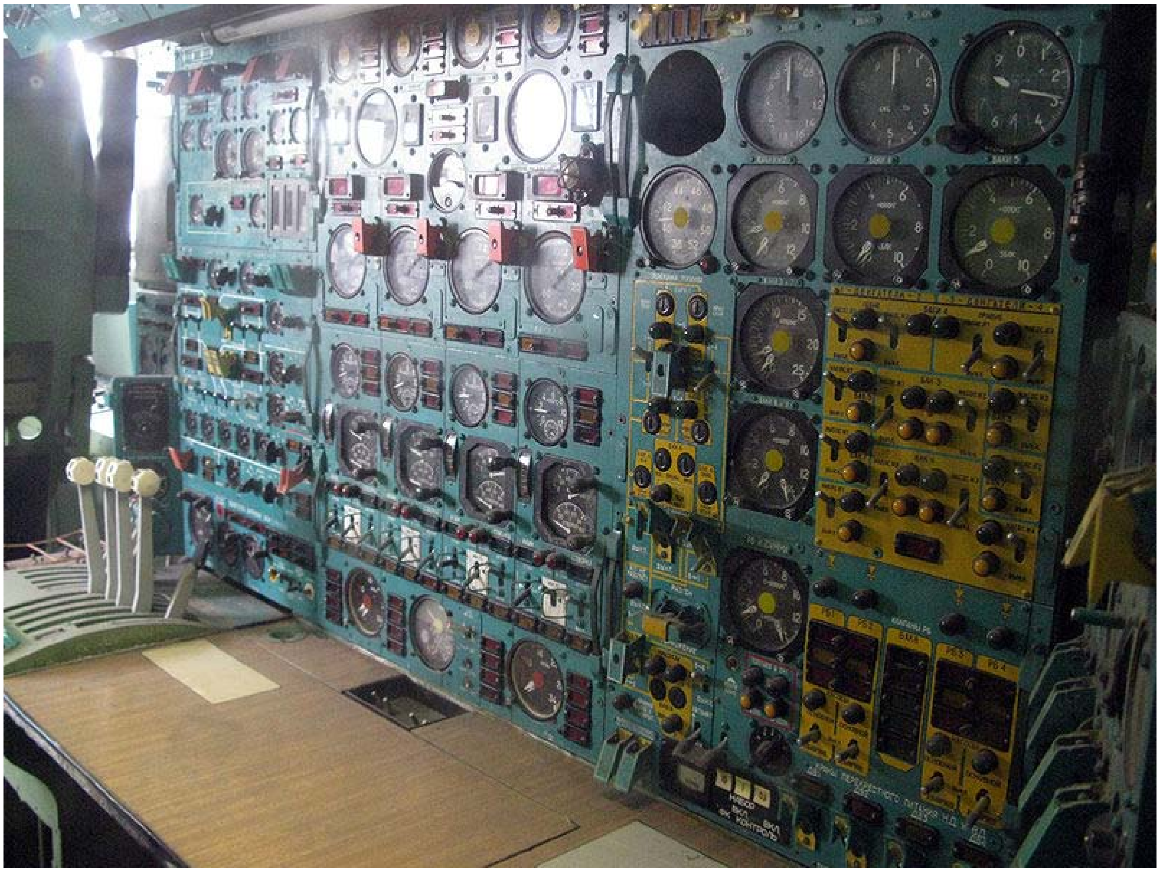
Image gallery

Engines RD-36-51A of a Tu-144D

Nose of the Tu-144

Fuselage of the Tu-144

Cockpit of the Tu-144



Cockpit of the Tu-144

Cabin of the Tu-144 in Sinsheim Auto & Technik Museum

empennage