NASA Facts

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The Tu-144LL: A Supersonic Flying Laboratory

Project Summary

The National Aeronautics and Space Administration (NASA) teamed with American and Russian aerospace industries over a five-year period in a joint international research program to develop technologies for a proposed future second-generation supersonic airliner to be developed in the 21st century. The centerpiece of the project was the Tu-144LL, a former first-generation Russian supersonic jetliner that was modified by its developer, Tupolev ANTK, into a flying laboratory for supersonic research.

Using the Tu-144LL to conduct flight experiments allowed researchers to compare full-scale supersonic aircraft flight data with results from models in wind tunnels, computer-aided techniques and other flight tests. The flight experiments provided unique aerodynamic, structures, acoustics and operating environment data on supersonic passenger aircraft.

Six flight and two ground experiments were conducted during the program's first flight phase, which began in June, 1996 and concluded in February, 1998 after 19 research flights. A shorter follow-on program involving about seven flights

began in September, 1998 and concluded in April, 1999. All flights were conducted in Russia from Tupolev's facility at the Zhukovsky Air Development Center near Moscow.

Tu-144 Development History

The Tu-144 was one of only two first-generation supersonic transports or SST's (the other being the Anglo-French Concorde) to go into actual production and commercial service. The sleek, double-delta-winged craft was the brainchild of famed Russian aircraft designer Andrei N. Tupolev, who oversaw the development of the Tu-144 as general designer. The prototype Tu-144 was first flown on Dec. 31, 1968, about two months before the competing Concorde prototype took to the air.

On Nov. 1, 1977, the Russian airline Aeroflot inaugurated passenger service with a production model Tu-144 when it flew from Moscow to Alma-Ata, Kazakhstan. Limited range and other technical problems led to service being discontinued in 1978 after only 102 passenger flights. By comparison, the Concorde began commercial trans-Atlantic service with British Airways and Air France in January, 1976, and that service continues today.

A total of 17 Tu-144's were manufactured, including a prototype, two production test versions and 14 production aircraft. The latter included five "D" models which were fitted with different engines.

Tu-144LL Modifications

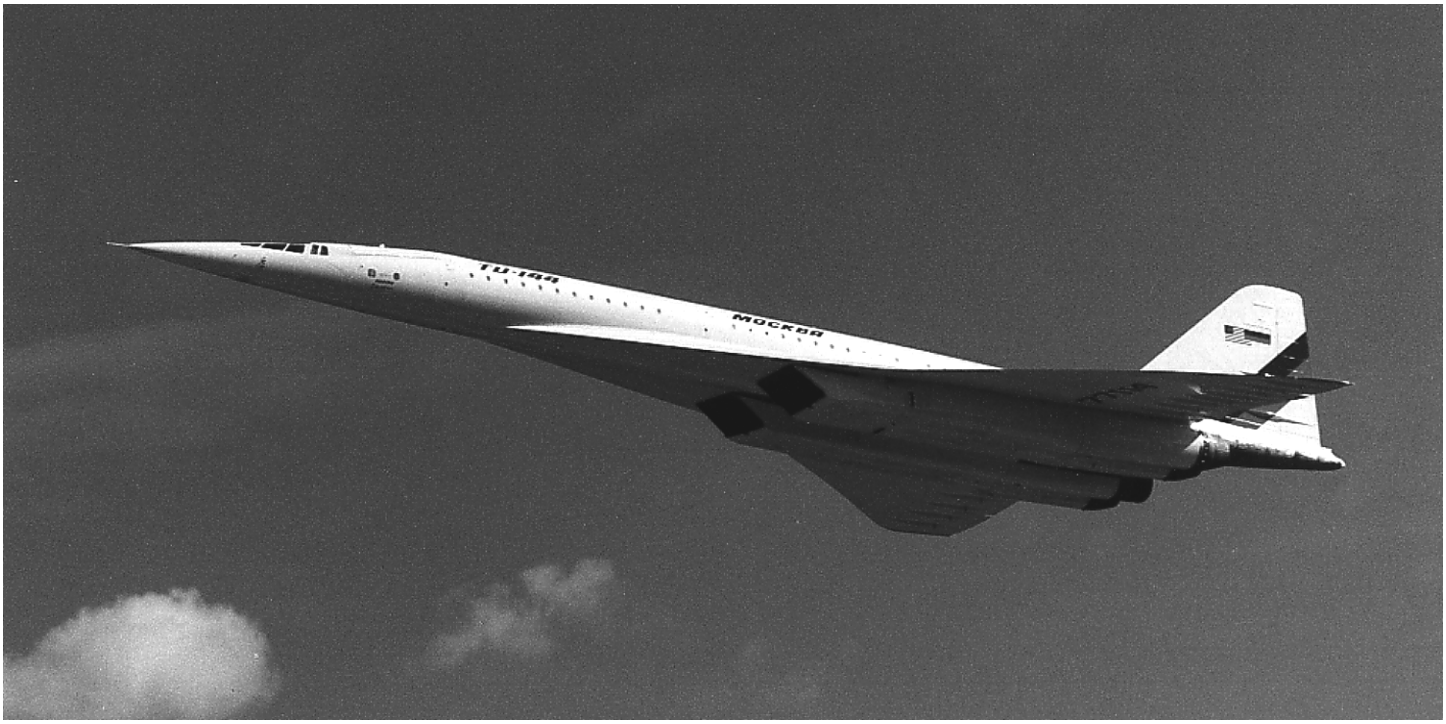
The aircraft flown in NASA's research program was a "D" model and was the last Tu-144 built. Bearing tail number 77114, it was constructed in 1981 and had logged a total flight time of only 82 hours and 40 minutes, most of that for research and test purposes, before being selected for the NASA-sponsored program. It was never used in commercial service.

The aircraft underwent many upgrades and modifications in its conversion to the "LL" Flying Laboratory, including the installation of more powerful NK-321 augmented-turbofan engines that were originally produced for the Tupolev Tu-160 Blackjack bomber.

A new Damien digital data collection system replaced an earlier analog system to collect airworthiness data and data from the experiments. Thermocouples, pressure sensors, microphones and skin friction gauges were placed on the Tu-144LL to measure the aerodynamic boundary layer—the layer where the air interacts with the surfaces of a moving aircraft. It also carried a significant number of other research instruments. An emergency crew escape system was also installed.

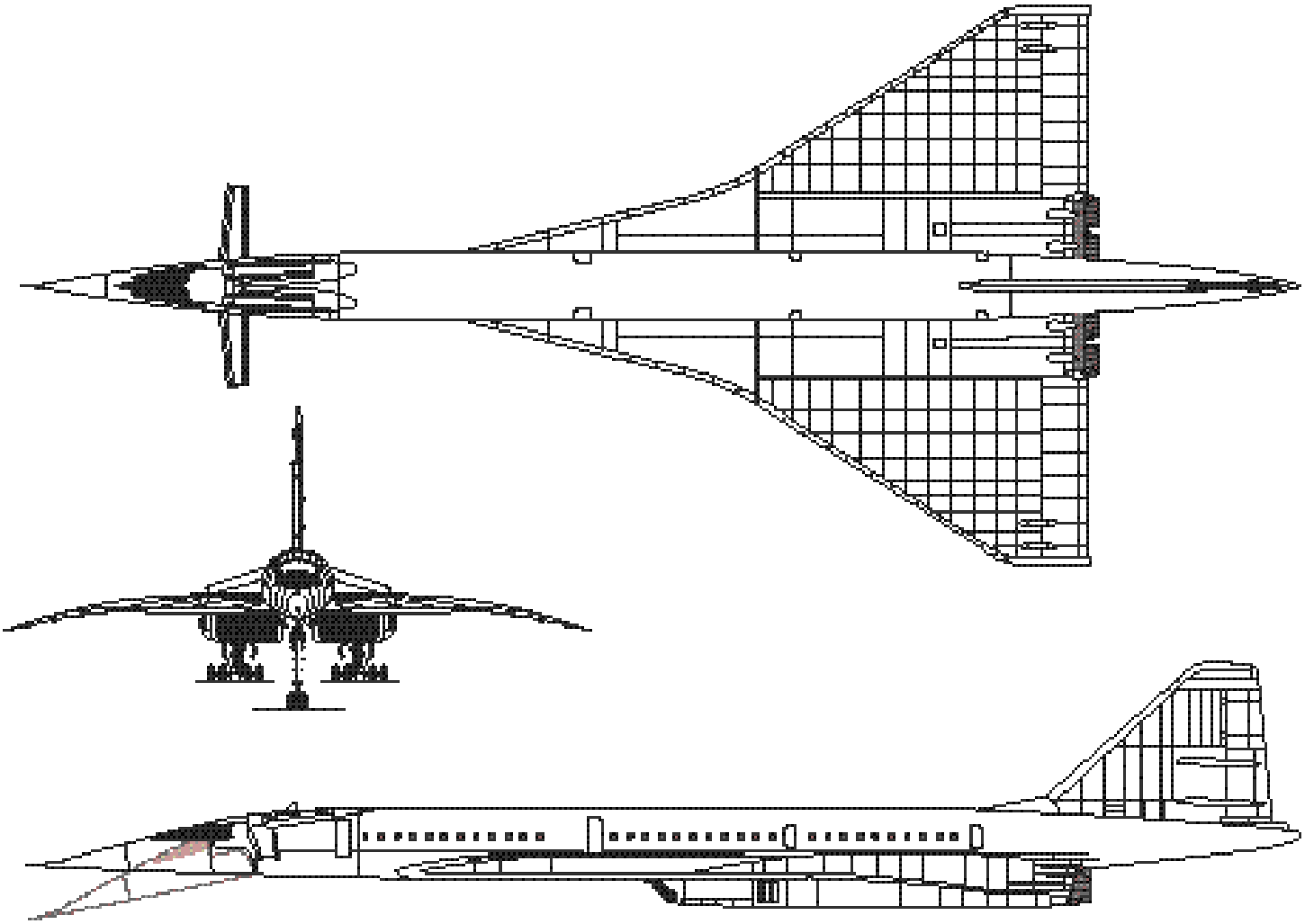
Flight and Ground Experiments

Out of 50 experiments originally proposed, project officials selected eight, including six flight and two ground engine



experiments, for the first phase of flight research. The flight experiments included studies on the aircraft's exterior surface, internal structure and engine temperatures, boundary layer airflow, the wing's ground effect characteristics, interior and exterior noise, handling qualities in various flight profiles, and in-flight structural flexibility. The two ground experiments, completed before the flight experiments began, studied the effect of air inlet structures on the airflow entering the engine and the effect on engine performance when supersonic shock waves rapidly change position in the engine air inlet.

The second phase of research flights entailed further study of the six flight experiments conducted during the first series. Additional instrumentation was installed by Tupolev technicians to assist in acquisition and analysis of data. A new experiment aimed at measurement of in-flight deflections of the wing and fuselage was conducted, and American-supplied transducers and sensors were installed to measure nose boom pressures, angle-of-attack and sideslip angles with greater accuracy. In addition, two NASA research pilots—Robert Rivers of NASA Langley and



Gordon Fullerton of NASA Dryden—assessed the Tu-144LL's handling qualities at subsonic and supersonic speeds during the first three flights in September, 1998. The follow-on series concluded after four data-collection flights in the spring of 1999.

Aircraft Specifications

The modified Tu-144LL Flying Laboratory used for the NASA flight research program has essentially the same dimensions as the Tu-144D model, although the new engines installed for the program give it improved performance. The aircraft has a wingspan of 94 feet, 6 inches, an overall length of 215 feet, 6 inches, and a height of 42 feet 2 inches. Its nose droops up to 12 degrees for better pilot visibility on takeoff and landing, and retractable canards are extended to give the aircraft better pitch control at low airspeeds. Maximum takeoff weight of the Tu-144LL is about 410,000 pounds, including a full load of 224,000 pounds of fuel.

The new Kuznetsov NK-321 turbofan engines, rated at more than 55,000 pounds thrust in full afterburner, give the aircraft a maximum cruising speed above Mach 2.3 (about 1,550 mph). The new engines also give the Tu-144LL a greatly improved range of about 3,500 nautical miles (4,040 statute miles/6,500 km).

Before being upgraded to the "LL" configuration, the Tu-144D was powered by four Koliesov RD-36-51 turbojets which gave it a maximum cruising speed of Mach 2.15 (2.15 times the speed of sound or approximately 1,450 mph) at 59,000 feet altitude. It had a maximum range of less than 2,500 miles and an absolute ceiling of 62,000 feet. The Tu-144D was designed to carry up to 140 passengers, although earlier models used in actual passenger service were configured for only 100 seats.

The Tu-144LL is constructed mostly of a light aluminum alloy. Titanium and stainless steel were used for the leading edges, elevons, rudder and under-surface of the rear fuselage.

Technology Commercialization

Data collected from the flight and ground experiments during the NASA-funded Tu-144LL flight research program are being used to develop the technology base for a proposed future second-generation American-built supersonic jetliner. Although development of an advanced SST is currently on hold, commercial aviation experts estimate a market for up to 500 such aircraft could develop by the third decade of the 21st century.

Among the technological goals set for the aircraft is that it must be environmentally acceptable in the areas of noise generation and pollution control, i.e., the engine exhaust must not contribute to the depletion of the ozone layer in the stratosphere. At the same time, it must be economically viable, that is, be able to carry larger payloads for longer distances and at cheaper costs than first-generation SST's. Among the targets are a 300 passenger capacity (three times that of first-generation SST's), a range of 5,000 nautical miles (twice that of first-generation SST's), and an efficiency which would allow fares to be set at no more than 20 per cent above subsonic jetliner fares on the same routes.

Project Management

The Tu-144LL supersonic research program was conducted as part of NASA's High Speed Research (HSR) program, managed by NASA Langley Research Center, Hampton, Va. The Tu-144LL project established direct working relationships between American and Russian aircraft manufacturers and enhanced the relationship between U.S. and Russian aeronautical agencies.

The project was enabled by an agreement signed in June 1994 by U.S. Vice President Al Gore Jr. and Russian Prime Minister Viktor Chernomyrdin. The Langley Research Center subsequently contracted with the Boeing Commercial Airplane Group which in turn contracted with the Russian aerospace firm for use of the modified Tu-144D jetliner to conduct the flight experiments. In addition to Boeing, the American industry team for the Tu-144LL project included engine manufacturers Pratt & Whitney and General Electric. NASA's Dryden Flight Research Center, Edwards, Calif., provided instrumentation and data processing support as well as management of the actual flight test project. IBP, Ltd., London, UK, assisted with contract management.