NASA's Lewis Research Center has been involved in high-speed propeller research since the 1940's. Early research identified the potential for good performance and fuel economy at speeds up to and beyond Mach 0.8 but, with the advent of the jet engine and an abundance of low-cost fuel, propeller research work was shelved in the 1950's. That changed, however, in the mid-1970's when fuel prices soared and uncertain fuel supplies placed a high premium on fuel efficiency. Attention was once again focused on propeller-driven aircraft.

**ATP**

Today, Lewis is managing Advanced Turboprop (ATP) programs that involve the design, fabrication, and testing of advanced propeller systems with high propulsive efficiency at flight speeds and altitudes compatible with today's jet transportation system. Both single rotation and dual counter-rotation multi-bladed propeller systems are being evaluated. Although the technology for each system is distinct, both research efforts are aimed at the "propellerization" of the commercial jet transport, and it now appears that each will find application among the many air transport requirements.

**LAP**

The first large-scale single rotation advanced propfan (LAP) was tested successfully in both the static rig at Wright-Patterson AFB in Dayton, Ohio and in a high-speed wind tunnel in Modane, France. The nine-foot-diameter propfan showed performance and blade stress characteristics that were very close to predicted values. LAP was designed and built by Hamilton-Standard Division of United Technologies Corp. under a contract managed by Lewis.
PTA

The propfan test assessment (PTA) program is a NASA Lewis contract with Lockheed-Georgia for the flight evaluation of the LAP propeller. Ground tests of the propfan, engine and nacelle were conducted in May and June 1986 to assess how well the components worked together. This propulsion system was installed on the left wing of a Gulfstream II test bed aircraft for flight testing in 1987. Testing will include speeds up to and slightly beyond Mach 0.8 (about 530 mph) and altitudes up to 35,000 feet to evaluate the structural integrity of the blades and acoustic characteristics of the advanced propeller during flight. PTA team members include: Lockheed-Georgia Company (prime contractor), Hamilton-Standard Division of UTC, Allison Gas Turbine Division, ROHR Industries, Lockheed-California Company and Gulfstream Aerospace Corporation.

UDF

General Electric Company, under contract with NASA Lewis, has designed and fabricated a unique counter-rotating propfan system called the Unducted Fan (UDF). The UDF is unique in that its counter-rotating propellers are driven directly by a multistage counter-rotating power turbine without the need for a gearbox. Static proof-of-concept testing of a UDF demonstrator engine was conducted at General Electric's Peebles, Ohio test site. In February 1987, General Electric successfully completed a series of flight tests of the UDF mounted on the aft section of a Boeing 727 at their Mojave, California facility.

These and other ATP research projects will be completed before the end of the decade, making it possible for U.S. airplane manufacturers to design and construct commercial aircraft using advanced turboprop technology in the 1990's.

May 1987
NASA RESHAPES TURBOPROPS TO EXTEND FUEL SAVING

In an effort to improve the fuel efficiency of future aircraft, NASA propulsion researchers are taking the turboprop of the 1950s and 1960s and reshaping it for the 1980s and beyond.

The new turboprop — a cross between early propeller concepts and the turbofan engines of modern jet transports — is evolving from NASA's Aircraft Energy Efficiency program studies begun in response to the 1973 oil embargo and sharply rising fuel prices. These studies identified possible aeronautical propulsion technology having a combined potential for improving the fuel efficiency of future aircraft by 50 percent.

Numerous studies and subscale tests of advanced turboprop concepts verified the turboprop's potential to provide a fuel savings of 15 to 30 percent. The advanced turboprops were especially designed to absorb more power and to maintain efficiency up to conventional, subsonic turbofan cruise speeds. At intermediate flight ranges, fuel savings of 15 to 20 percent were identified. Fuel savings were even larger at the long and short flight ranges, reaching 25 to 30 percent for the short routes.

These test results make the advanced turboprop look particularly attractive for short/medium haul markets currently served by the DC-9 and the Boeing 727 and 737 aircraft which have capacities of 120 to 150 passengers. Extending propeller efficiency for flight at the higher speeds of modern jet transports is a major technological hurdle today.

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For example, an aerodynamic effect known as "compressibility" limits the speed at which conventional propellers can operate efficiently. Working with the propeller industry, researchers at Lewis Research Center in Cleveland have taken advantage of several technology advances in propeller blade structure and aerodynamics to dramatically reshape the propeller and thereby delay the onset of compressibility effects.

The researchers' design for an advanced turboprop propulsion system consists of eight or 10 highly swept blades that are about one half as thick as conventional propeller blades on a single engine shaft. Reducing blade thickness and providing blade sweep at the tips delays the onset of compressibility effects and the attendant drag rise and noise-producing supersonic shock waves. The increased number of these highly "loaded" blades helps keep propeller diameter to a reasonable size and weight. New materials and construction techniques allow the blades to be shaped for near optimum aerodynamic efficiency for flight over the entire speed and altitude range of modern jet transports.

Other technological challenges for the turboprop include reducing engine noise and vibration for passenger comfort, finding the most aerodynamically efficient mating of the engines to the airframe and reducing propeller and engine gearbox maintenance. The newly-shaped, thin, highly swept turboprop blades may lower the noise and vibration levels enough to reduce acoustic treatment weight in the aircraft cabin walls.

In conventional aircraft, the weight of noise absorption materials can be as high as 3,630 to 4,540 kilograms (8,000 to 10,000 pounds) for a medium sized, medium range transport. If propeller noise could be reduced by 10 decibels and improved acoustic treatment could be used, the weight penalty could be as low as 680 kg (1,500 lb.). Reducing aircraft weight also reduces fuel consumption.

The efficient mating of propeller engine and airframe is being accomplished primarily through installation aerodynamic analysis and wind tunnel tests at NASA's
Ames and Langley Research Centers. Considerable effort is devoted to straightening the swirling air streaming from the propeller to achieve maximum propeller thrust and reduce air drag. If unchecked, the interference drag could seriously compromise the fuel savings of the turboprop with its large, exposed propeller system.

NASA plans to award a contract next year to an American airframe manufacturer for research leading to high speed flight tests of a large-scale advanced turboprop. Scheduled for early 1987, the tests will involve mounting a single advanced turboprop on the wing of an existing transport. The flight tests, designed to prove the system's fuel economy and reliability, will offer the first comprehensive large-scale tests of advanced turboprop structural integrity, propeller near- and far-field noise, and cabin noise and vibration.

Meanwhile, NASA continues to work on improved propeller designs, including contra-rotating propellers, cabin noise reduction, installation aerodynamics and alternative configurations, including aft-mounted and pusher propeller arrangements.

Researchers at NASA's three aeronautical centers are working with the U.S. aviation industry in these efforts. The NASA propulsion team has been led by NASA's Lewis Research Center in Cleveland, aided by Langley Research Center, Hampton, Va., and Ames Research Center, Mountain View, Calif.

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(NOTE: NASA-LANGLEY PHOTOGRAPH L-81-10,602 IS AVAILABLE TO ACCOMPANY THIS RELEASE AND WILL BE PROVIDED BY TELEPHONING KEITH HENRY AT AC 804-865-2934/2932. PLEASE SPECIFY BLACK & WHITE OR COLOR.)
ADVANCED TURBOPROP PROPULSION SYSTEM

AREA RULED SPINNER

INTEGRATED NACELLE SHAPE

MODERN TURBOSHAFT ENGINE AND GEARBOX

8 OR 10 THIN SWEPT BLADES (HIGH POWER LOADING)