tion of precise autonomous station keeping. The second phase, also completed, involved mapping of the effects of leading-airplane-generated vortices on a evaluation of the performances of a highly accurate relative-position-sensing system and of a data-link system. The primary goal of the project — demonstration of integrated system performance, including a sustained 10-percent reduction in fuel consumption in close, autonomous formation flight — will be reached in the third phase. The results of this phase will be applicable to commercial and military cargo and passenger transport aircraft, unpiloted aircraft, increasing the ranges of aircraft in general, aerial refueling and resupply, and formation flying of satellites.

The AFF project is developing the first system for highly accurate in-flight relative positioning of two aircraft to incorporate differential-carrier-phase Global Positioning System (GPS) and inertial measurement information with an extended Kalman filter in a moving-base-station scenario. This system is expected to yield relative-position measurements accurate to within 0.5 ft (0.15 m). Flight tests will enable evaluation of control-system approaches and performance, validation of mathematical models for predicting vortex effects, quantification of reductions of drag, and evaluation of operational effectiveness. The flight tests will provide insight into such phenomena as effects of multipath propagation on GPS measurements and data communications and the dynamics of (including interactions between) vortices that cannot be adequately identified through simulation or ground test.

During the first phase of the program, two F/A-18 airplanes were outfitted with identical GPS receivers and an air-to-air telemetry system as a data link between the airplanes. In addition, the trailing airplane was equipped with an airborne research test system (ARTS) and a research flight-control computer. The ARTS hosted a precise autopilot control system, which received GPS and inertial measurement data from the leading airplane and computed stick commands to place the trailing airplane at the desired relative position. The research flight-control computer received and used the stick commands from the ARTS while engaged, but reverted to the production F-18 flight control system for the remainder of the mission. An interactive display was installed in the back seat of the airplane to enable the flight crew to control the flight experiment. Lateral and vertical position errors were displayed to the pilot by use of instrument-landing-system needles.

A standard test block of six maneuvers was repeated for each of four different autopilot gain sets. These maneuvers included five-minute steady-state tracking tests and 30-ft (≈9-m) commanded step inputs in each axis. The dynamic response of the system was observed in maneuvers in which the leading airplane performed heading sweeps of a few degrees and altitude sweeps of several hundred feet (≈100 m).

A total of 167 tests points was reached in 11 research flights. The experiment met all project objectives. The formation autopilot maintained relative position to within 2 ft (0.61 m) [see Figure 2] for all four gain sets during straight and level flight with turbulence levels ranging from nonexistent to light chop. An additional position error of up to 3 ft (0.91 m), due to GPS navigation errors, brought the total formation position error to less than 5 ft (1.52 m). Accurate, predictable tracking was observed during the step and dynamic maneuvers.

This work was done by Gerard S. Schkolnik and Brent Cobleigh of **Dryden Flight Research Center**. *For more information on the AFF project contact Gerard S. Schkolnik, AFF Project Manager, gerard.schkolnik@dfrc.nasa.gov, (661) 276-3055 or Brent Cobleigh, AFF Chief Engineer, brent.cobleigh@dfrc.nasa.gov, (661) 276-2249.*
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Expandable Purge Chambers Would Protect Cryogenic Fittings

Flowing dry nitrogen would prevent accumulation of ice or airborne particles.

John F. Kennedy Space Center, Florida

Expandable ice-prevention and cleanliness-preservation (EIP-CP) chambers have been proposed to prevent the accumulation of ice or airborne particles on quick-disconnect (QD) fittings, or on ducts or tubes that contain cryogenic fluids. In the original application for which the EIP-CP chambers were conceived, there is a requirement to be able to disconnect and reconnect the QD fittings in rapid succession. If ice were to form on the fittings by condensation and freezing of airborne water vapor on the cold fitting surfaces, the ice could interfere with proper mating of the fittings, making it necessary to wait an unacceptably long time for the ice to thaw before attempting reconnection. By keeping water vapor away from the cold fitting surfaces, the EIP-CP chambers would prevent accumulation of ice, preserving the ability to reconnect as soon as required.

Basically, the role of an EIP-CP chamber would be to serve as an enclosure for a flow of dry nitrogen gas that would keep ambient air away from QD cryogenic fittings. An EIP-CP chamber would be an inflatable device made of a fabric-like material. The chamber would be attached to an umbilical plate holding a cryogenic QD fitting. The chamber would include inner and outer subchambers that would be inflated with gaseous nitrogen through separate supply tubes. The outer subchamber would resemble a small tire tube. The inner chamber would be perforated on its innermost circle to allow nitrogen to flow onto and around the QD surfaces. When deflated, the EIP-CP would be about 1 in. (≈2.5 cm) thick.

When not in use, the EIP-CP would be kept deflated, flat against the umbilical plate. Before disconnecting the QD fitting, the two subchambers of the EIP-CP would be pressurized with nitrogen. As disconnection proceeded, the pressurized outer tube would expand to follow the moving umbilical plate of the mating fitting, up to a maximum axial thickness (corresponding to a tire width) of about 6 in. (≈15 cm). The subchambers would be shaped so that once maximum expansion was reached and the chamber could no longer seal against the receding umbilical plate of the mating fitting, the opening on the exposed end of the chamber would narrow to a small hole. The purge flow of nitrogen would keep ambient air out of the chamber.

To prepare for reconnection, the umbilical plate of the mating fitting would be brought into contact with the EIP-CP chamber and the supply of nitrogen would be turned off. Then a vacuum pump would be used to deflate the nitrogen from the outer chamber, so that the chamber could be pressed flat against its umbilical plate and the mating QD connectors pushed together.

This work was done by Ivan I. Townsend III of Dynacs, Inc., For further information contact the Technology Programs and Commercialization Office at (321) 867-8130 for **Kennedy Space Center**.
KSC-12460

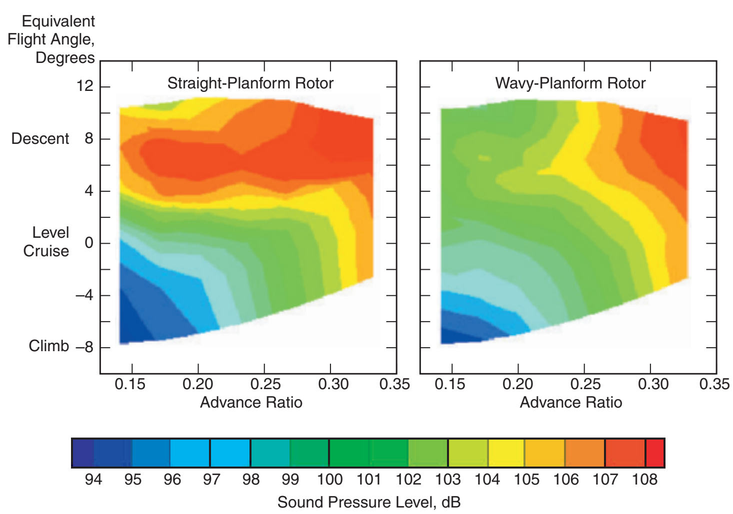
Wavy-Planform Helicopter Blades Make Less Noise

Improved designs reduce strengths of BVI-noise and thickness-noise sources.

Langley Research Center, Hampton, Virginia

Wavy-planform rotor blades for helicopters have been investigated for the first time in an effort to reduce noise. Two of the main sources of helicopter noise are blade/vortex interaction (BVI) and volume displacement. (The noise contributed by volume displacement is termed thickness noise.) The reduction in noise generated by a wavy-planform blade, relative to that generated by an otherwise equivalent straight-planform blade, affects both main sources: (1) the BVI noise is reduced through smoothing and defocusing of the aerodynamic loading on the blade and (2) the thickness noise is reduced by reducing gradients of thickness with respect to listeners on the ground.

Wavy-Planform Rotor on Model Helicopter in Wind Tunnel



Wavy-Planform Rotor Blades on a model helicopter in a reverberant wind tunnel were found to generate less noise than did rectangular-planform blades.

Noise tests were performed in a reverberant wind tunnel on a model helicopter (see photo). In the tests, sound-pressure levels were measured over a range of flight angles and advance ratios (the advance ratio is defined as the ratio between the horizontal speed of a helicopter and the speed of the tip of a rotor blade). Sound-pressure levels were also measured under the same conditions using a baseline rotor that had a rectangular-planform blade with linear twist.

The figure presents color contour plots of some of the data from the tests. These plots show that during descent (landing) flight conditions, which are most strongly dominated by BVI noise, sound-pressure levels of the wavy-planform blades were more than 4 dB below those of the rectangular planform blades. Some mild reduction in noise was also found for other flight conditions of climb and level cruise over all frequency ranges. Further testing and analysis of data will be needed to farther quantify reduction of noise, vibration, and performance benefits, leading eventually to refinements in the designs of wavy-planform blades.

This work was done by Thomas F. Brooks of **Langley Research Center**. *For further information, contact the Langley Commercial Technology Office at (757) 864-3936.*
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