
ROTORCRAFT AEROMECHANICS BRANCH

In-Flight Rotorcraft Acoustics Program



Introduction

A key part of NASA's aeronautics research is reducing noise to make helicopters and tiltrotors more acceptable to the public. The objective of the In-Flight Rotorcraft Acoustics Program (IRAP) is to acquire rotorcraft noise data in flight for comparison to wind tunnel data. The type of noise of concern is "blade-vortex-interaction," or BVI, noise. Microphones on the wing tips and tail fin of the quiet NASA YO-3A Acoustics Research Aircraft measure BVI noise while the YO-3A descends in close formation with the helicopter or tiltrotor emitting the noise. The data acquired through IRAP is needed to validate wind-tunnel test results, or, where the results cannot be validated, to provide researchers with clues as to how to improve testing methods.

Links to related pages:

- A description of the [YO-3A](#).
- A discussion of flight- and wind-tunnel acoustic [test techniques](#).
- A list of [references](#) to technical reports on BVI and related aspects of acoustics theory and testing.
- Links to individual flight test programs are given in the [history](#) section.

BVI noise. During certain rotorcraft flight operations, particularly forward descents such as landing approaches, each rotor blade can run into the tip vortex shed by a preceding blade. The resulting "blade-vortex interaction," or BVI, causes a distinctive type of noise: the annoying "blade-slap" of helicopters with slow-turning rotors, or a sharp fluttering noise for rotorcraft with fast-turning rotors. A comprehensive review of rotorcraft noise is given in Schmitz's 1991 summary, listed on the [references](#) page. In-flight measurement of BVI noise is the primary effort of IRAP.

History. In-flight measurements of BVI noise were undertaken in the mid-1970s with a Bell UH-1H "Huey" as the test helicopter and an OV-1 Mohawk as the microphone platform (Schmitz, 1991). By 1979, the OV-1 had been replaced by the much quieter YO-3A, which was used to measure BVI from a UH-1H and two models -- AH-1S and AH-1G -- of Bell Cobra helicopters (Boxwell and Schmitz, 1980; Cross and Watts, 1984). The Army further used the YO-3A to test a variety of helicopters, including the UH-60, YUH-61, YAH-63, and AH-64 (Cross and Watts, 1984). There were also flight tests with a McDonnell Douglas MD 500D.

Drawing on this experience with in-flight acoustics testing, the In-Flight Rotorcraft Acoustics Program (IRAP) was established in 1991 for the specific purpose of acquiring measurements of rotor noise in flight for comparison to wind-tunnel data. IRAP is managed by the Rotorcraft Aeromechanics Branch at NASA Ames Research Center. The YO-3A has been used for all IRAP tests, four of which have been carried out to date:

Sikorsky S-76C (1991 and 1992)
MBB BO 105 (1993)
Sikorsky UH-60A (1993-94)
Bell XV-15 (1995)

Follow the links for details of each flight test. Each discussion of a flight test program includes links to hypertext descriptions of associated wind tunnel tests.

Related Publications:

Boxwell, D. A., and Schmitz, F. H. "Full-Scale Measurements of Blade-Vortex Interaction Noise." 36th Annual Forum of the American Helicopter Society, Washington D.C., May 1980.

Cross, J. L. and Watts, M. E. "In-Flight Acoustic Testing Techniques Using the YO-3A Acoustic Research Aircraft." NASA TM-85895, February 1984.

McCluer, M. and Dearing, M. "Measuring Blade-Vortex Interaction Noise Using the YO-3A Acoustics Research Aircraft." 22nd European Rotorcraft Forum, Brighton, UK, September 1996.

Schmitz, F. H. "Rotor Noise." Acoustics of Flight Vehicles: Theory and Practice. Vol. 1: Noise Sources. H. H. Hubbard, ed. NASA RP-1258, WRDC TR-90-3052, August 1991.

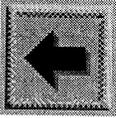
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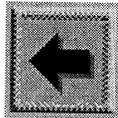
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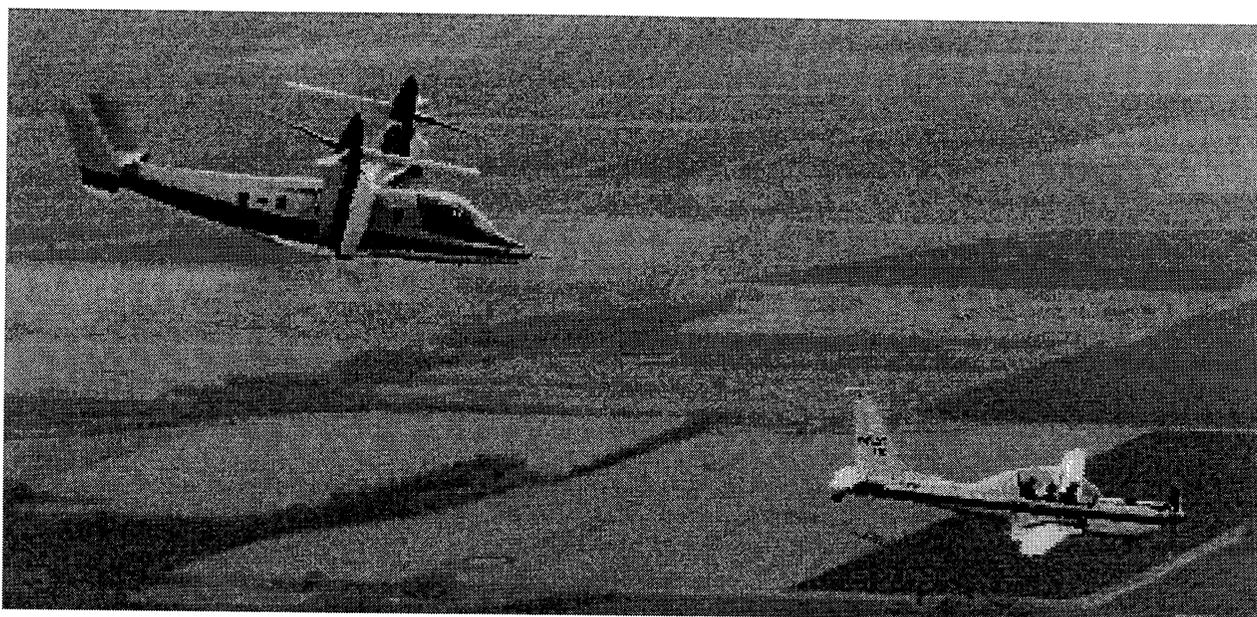
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In-Flight Rotorcraft Acoustics Program

XV-15 Flight & Wind Tunnel Tests



The XV-15 following the YO-3A in formation flight.

Background. Under NASA's Short Haul Civil Tiltrotor (SHCT) program, an extensive amount of acoustic measurements will be acquired from model and full-scale tiltrotors in wind tunnels. Tiltrotor blades are more highly twisted and loaded than conventional helicopter blades and therefore have different performance and noise characteristics. The wind tunnel tests are critical for understanding the aeroacoustics of tiltrotors.

One of the planned wind tunnel tests includes a full-scale rotor from the XV-15 tiltrotor. A single XV-15 rotor is being tested in the 80- by 120-ft test section of the National Full-Scale Aerodynamics Complex (NFAC), with the rotor mounted on the Rotor Test Apparatus (RTA). Although the rotors are identical, the RTA is very different from the actual aircraft, hence limited acoustic measurements of the XV-15 in flight were necessary to provide a validation of the wind tunnel measurements. Therefore, acoustic data were acquired prior to the wind tunnel test using the YO-3A flying in formation with the XV-15 aircraft.

Flight Test. IRAP tests were performed with the YO-3A and XV-15 flying from the Bell Helicopter Flight Test Center in Arlington, Texas. Four flights were performed with the YO-3A and XV-15 flying in close formation, as shown in the photo. The flight conditions and microphone location were chosen to measure the most prominent BVI noise. The starboard wingtip microphone of the YO-3A was positioned 20 degrees below the right rotor hub at a rotor azimuth of 150 degrees. The distance between the starboard wingtip microphone and the rotor hub was three rotor diameters (75 feet). Target flight conditions included tip Mach number of 0.69, advance ratios of 0.156 and 0.185 (hence, 70-85 knots airspeed), rotor weight coefficient of 0.0111,

and descent rates of 300-1100 ft/min, all with the XV-15 nacelles at 90 degrees (helicopter mode), where BVI is expected to be maximum. (In the photo shown here, the nacelles are at 80 degrees for convenience during the photo session.)

Wind-tunnel test. The results of the flight test were used to determine appropriate test conditions for a test of the XV-15 rotor in the 80- by 120-ft NFAC test section. A microphone was placed in a location geometrically identical to the relative position of the YO-3A starboard microphone and XV-15 rotor during flight. Rotor test conditions -- including forward airspeed, tip speed, rotor torque, angle of attack, and gimbal angle (equivalent to tip-path-plane angle) -- were all measured in real time during the IRAP flights and were duplicated during the wind-tunnel tests. Hence, the rotor state at each wind-tunnel test point matched that at the equivalent flight condition as closely as is possible for a wind tunnel test. The comparison between flight and wind tunnel acoustic data is currently in progress.

More information on the XV-15 wind-tunnel test can be found [here](#). Detailed information on the 80- by 120-ft wind tunnel and RTA can be found [here](#).

Related Publications:

McCluer, M. and Dearing, M. "Measuring Blade-Vortex Interaction Noise Using the YO-3A Acoustics Research Aircraft." 22nd European Rotorcraft Forum, Brighton, UK, September 1996.

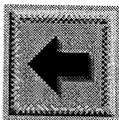
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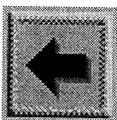
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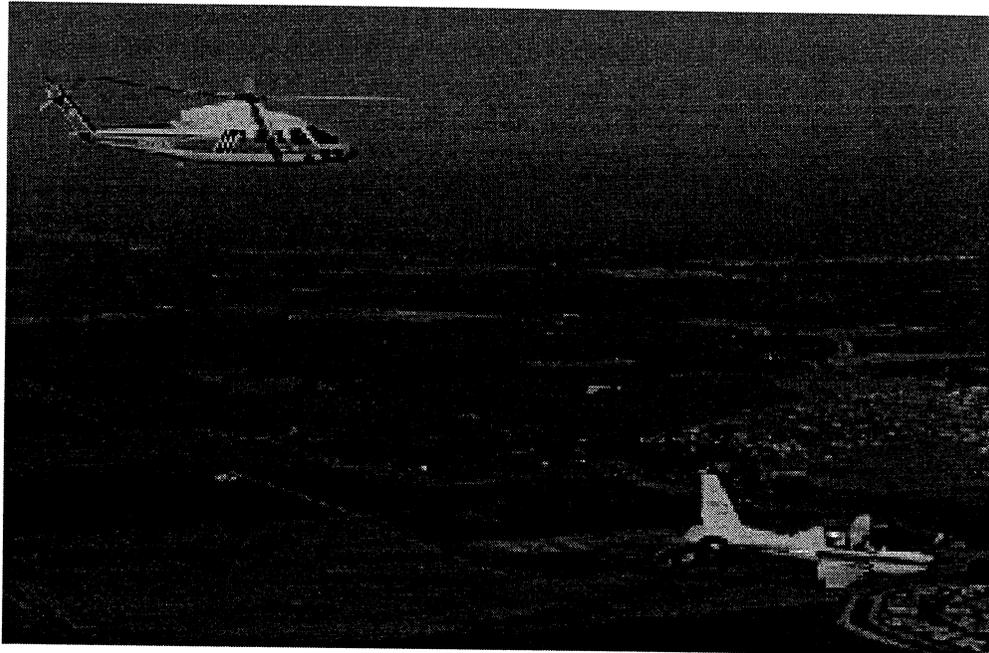
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In-Flight Rotorcraft Acoustics Program

S-76 Flight Tests



The S-76C in formation with the YO-3A.

Measurements of S-76C BVI Noise

Acoustic measurements of a Sikorsky S-76C helicopter in flight were compared with acoustic measurements of a full-scale S-76 rotor tested in the 80- by 120-Foot Wind Tunnel at NASA Ames Research Center (Yamauchi, et al., 1993). The flight data were acquired using the NASA Ames YO-3A Acoustics Research Aircraft. Flight and wind tunnel data were compared for three conditions. For the low and moderate advance ratio conditions (figs. 1 and 2, respectively), the BVI pulse widths of the flight and wind tunnel data were very similar, indicating the conditions were well-matched. Comparisons between the flight and wind-tunnel data waveforms for the high advance ratio case (μ near 0.25) were poor (see fig. 3). For this condition, the wind tunnel data showed greater blade-to-blade and revolution-to-revolution variability than the flight data.

Effects of tip-path-plane angle and advance ratio on the BVI flight data were also analyzed. The flight data showed the BVI peaks increased with increasing tip-path-plane angle until reaching a maximum angle, which varied with flight condition. Further increases in the tip-path-plane angle resulted in reduced BVI peaks. Increasing advance ratio increased the magnitude of the BVI noise for the flight conditions tested.

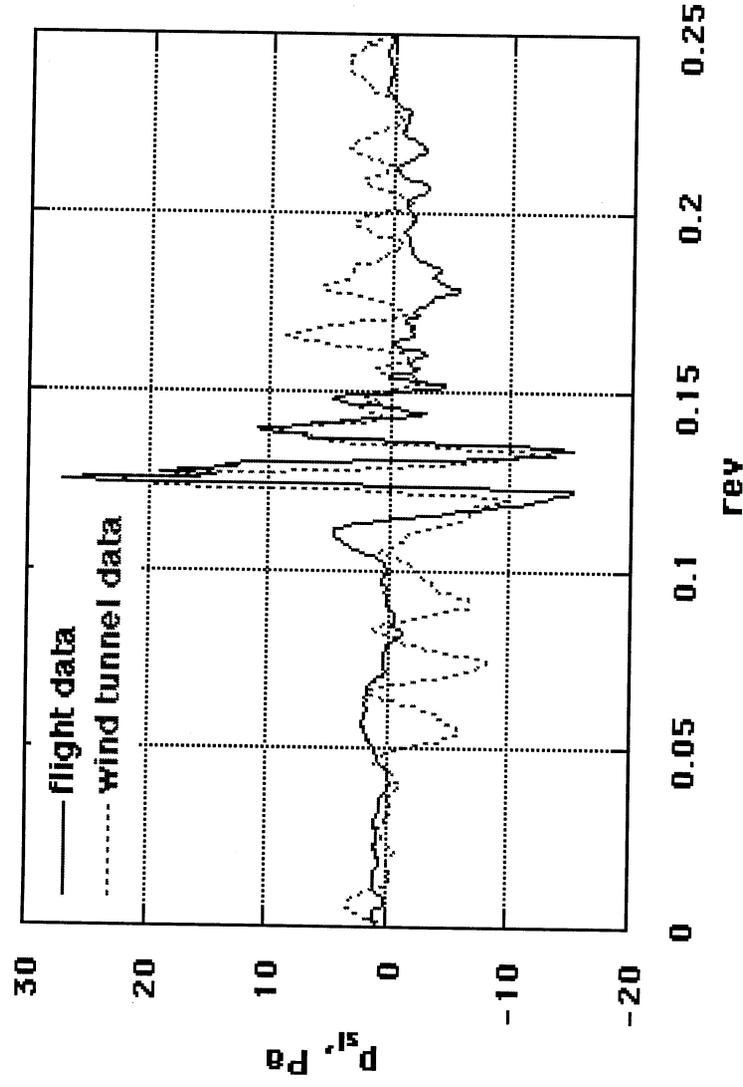


Figure 1. Flight and wind tunnel data comparison (averaged time histories, 1/4 revolution). Test conditions: Flight pt. 203: $C_T=0.00778$, $M_{tip}=0.603$, $\mu=0.164$, $\alpha_{tip}=5.6$ deg. W/T run 39_24: $C_T=0.00753$, $M_{tip}=0.605$, $\mu=0.173$, $\alpha_{tip}=5.0$ deg. (Ref. Yamauchi et al., 1993)

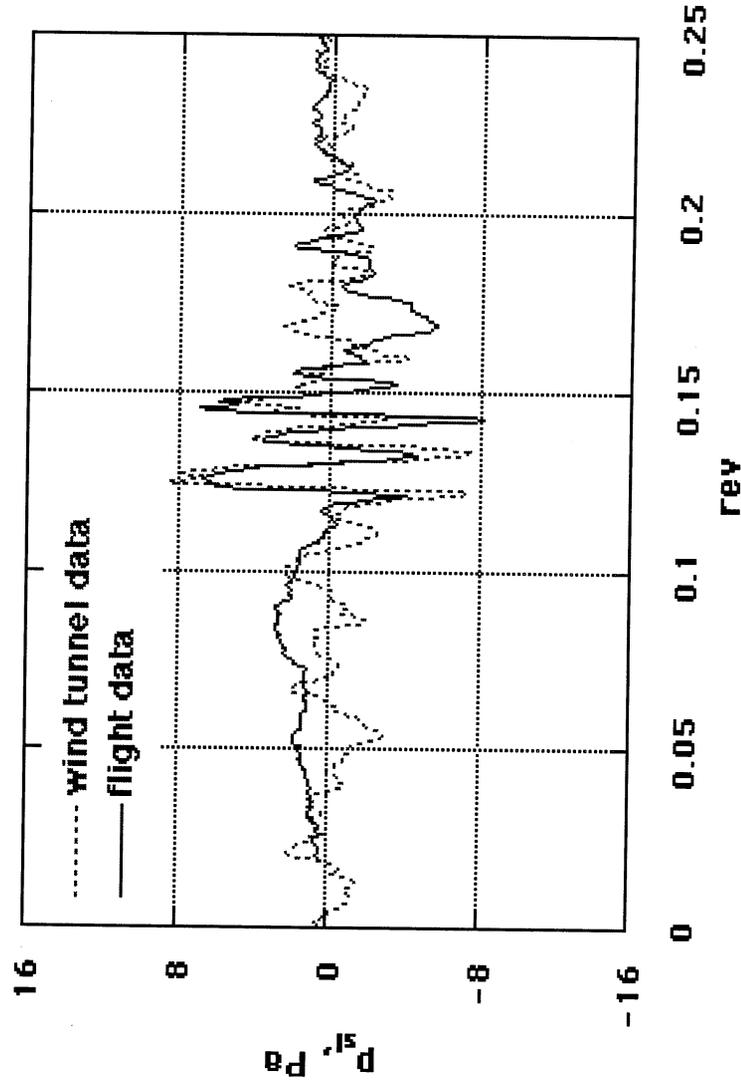


Figure 2. Flight and wind tunnel data comparison (averaged time histories, 1/4 revolution). Test conditions:
 Flight pt. 307: $C_T=0.00605$, $M_{tip}=0.606$, $\mu=0.203$, $\alpha_{tpp}=0.5$ deg.
 W/T run 48_19: $C_T=0.00599$, $M_{tip}=0.605$, $\mu=0.200$, $\alpha_{tpp}=0.0$ deg.
 (Ref. Yamauchi et al., 1993)

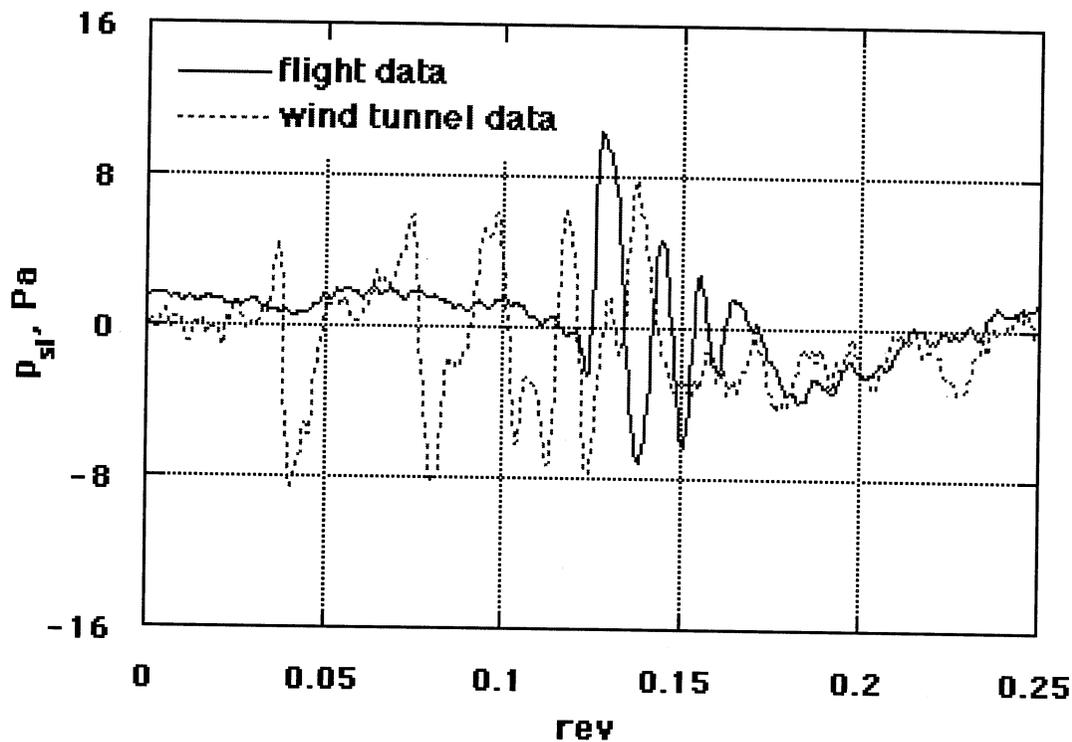


Figure 3. Flight and wind tunnel data comparison (averaged time histories, 1/4 revolution). Test conditions:
 Flight pt. 315: $C_T=0.00600$, $M_{tip}=0.606$, $\mu=0.245$, $\alpha_{tpp}=0.4$ deg.
 W/T run 48_18: $C_T=0.00597$, $M_{tip}=0.605$, $\mu=0.251$, $\alpha_{tpp}=0.0$ deg.
 (Ref. Yamauchi et al., 1993)

Links to related pages:

[YO-3A info](#) | [IRAP overview](#) | [Other IRAP tests](#) | [S-76 wind-tunnel tests](#)

Related Publications:

Yamauchi, G. K., Signor, D. B., Watts, M. E., Hernandez, F. J., LeMasurier, P., "Flight Measurements of Blade-Vortex Interaction Noise Including Comparisons with Full-Scale Wind Tunnel Data." 49th Annual Forum of the American Helicopter Society, St. Louis, MO, May 1993.

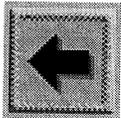
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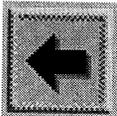
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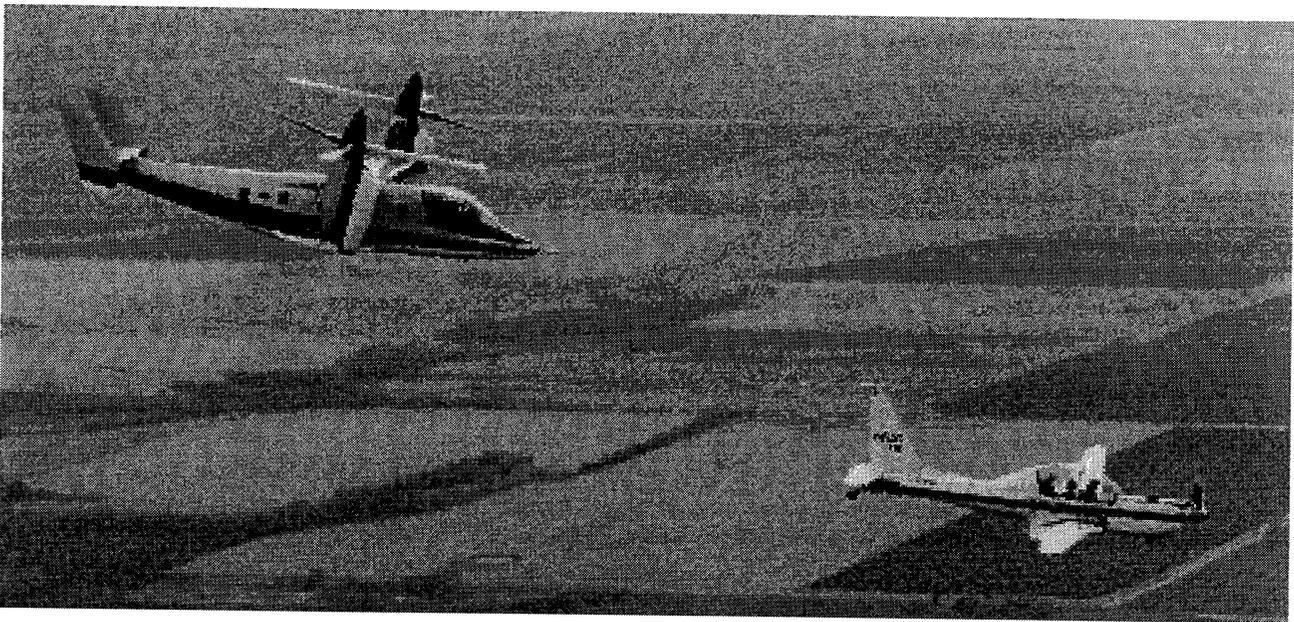
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Experimental Techniques

Why Flight Test?

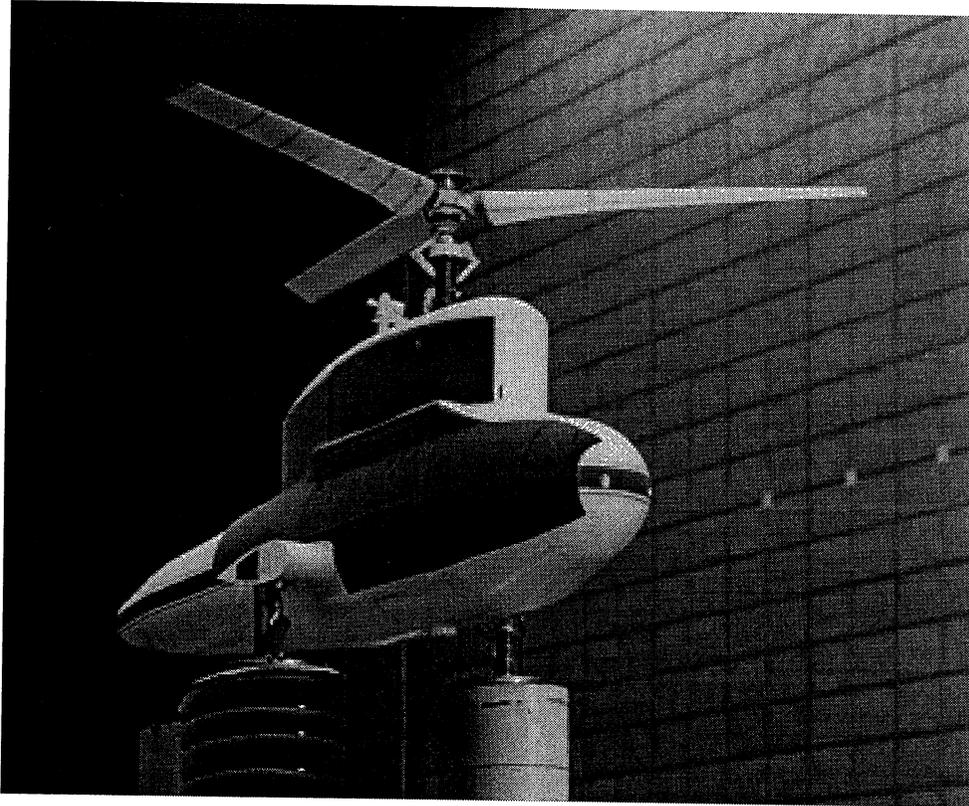
Flight vs. Wind-Tunnel Tests



The most recent IRAP test was with the XV-15 tiltrotor.

Why Flight Test? Wind-tunnel tests provide precise, repeatable control of rotor operating conditions, but accurate noise measurements are difficult for several reasons:

1. Wall effects prevent the rotor wake from developing exactly as it does in free flight. This is crucial because an important contributor to rotor noise is the interaction between the rotor and its own wake (such as blade-vortex interaction).
2. In many wind-tunnel tests, the rotor test stand is not the same shape as the helicopter fuselage, hence aerodynamic interference between the test stand and rotor is different than in flight.
3. The wind-tunnel walls cause reflections that may corrupt the acoustic signals.
4. The wind tunnel has its own background noise, caused by the wind-tunnel drive and by the rotor test stand. (The YO-3A aircraft is actually quieter than many wind tunnels.)
5. The wind tunnel turbulence level is rarely the same as in flight.
6. The rotor is frequently trimmed differently in a wind-tunnel test than in flight.



The XV-15 rotor on the Rotor Test Apparatus (RTA).

Methods of reducing or compensating for these effects are available, but they are not always effective and remain under development. It is important to verify that the wind-tunnel data match flight data. One approach is to fly the rotorcraft over a microphone placed on the ground, so that it measures what a human hears. However, such data are non-steady because the distance and angle from the rotor to the microphone is constantly changing, whereas in a wind tunnel the geometry is fixed. Hence, averaged fly-over data must be corrected before comparisons can be made with wind-tunnel data.

There remains a need to validate the data-correction methods. The solution used by IRAP is to put microphones on a quiet airplane flying in formation with the rotorcraft. The measurement geometry can be matched to that in the wind tunnel, permitting direct comparison with wind-tunnel data. NASA's YO-3A acoustics research aircraft was modified explicitly for this purpose. Once the wind-tunnel data for a few critical test conditions are verified with flight test data, the rotor is tested in the wind tunnel over a wide variety of operating conditions with greater confidence in the noise measurements.

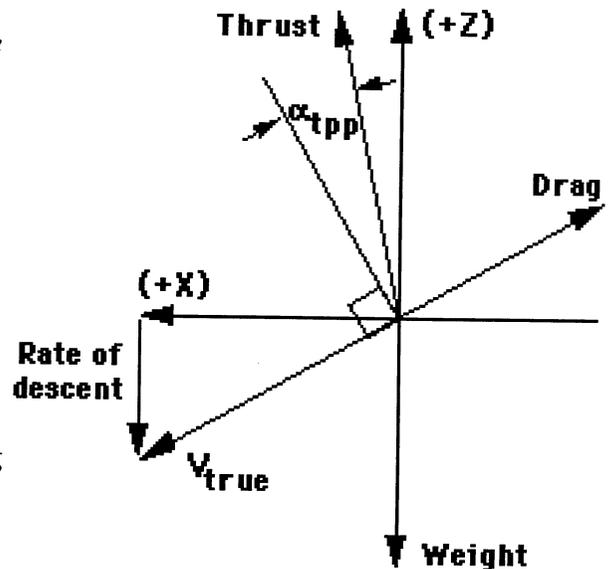
Flight vs. Wind-Tunnel Tests

Test conditions are controlled differently in flight than they are in wind tunnels. Some parameters that are easily controlled in flight cannot be controlled at all in a wind tunnel, and vice versa. For IRAP, flight test conditions must be closely comparable to wind tunnel test conditions. The major issues involved in simultaneously planning flight and wind tunnel tests are briefly discussed here.

Airspeed, rotor speed, and rotor thrust are easily controlled in a wind tunnel, and can be set to values not possible in flight. For IRAP flights, the lower airspeed limit is set by YO-3A stall (obviously, helicopters have no lower limit). Some helicopters, and all tiltrotors, are actually faster than the YO-3A, so the upper limit is often set by the YO-3A's flight envelope. The upper limit has not been important to date because BVI noise

Most helicopters can easily adjust their rotor speed, but only within a very narrow range. Thrust must always match weight -- adjusted for download, drag, etc. -- in trimmed flight, and the thrust will vary as fuel is burned off. Tiltrotors and compound helicopters have wings that share lift with the rotor, but the total lift must still match the total weight in unaccelerated flight. In contrast, a rotor in a wind tunnel need not produce any particular amount of thrust nor turn at flight rotor speed.

Forces acting on a rotor. In trimmed flight, thrust must balance the vector sum of drag and weight; this determines the tip-path-plane angle. (Vectors are not to scale.) (See also Signor, et al., 1994.)



Altitude is readily controlled in flight, although altitude changes may require considerable time. IRAP test altitudes range from about 2000 to 10,000 feet; a reduced range is normal for reasons of safety and efficiency. Very few wind tunnels, however, can control altitude (i.e., pressure): the effective altitude is usually determined by the weather -- temperature and barometric pressure -- at the time of the test. Also, the effective altitude in a wind tunnel may change during the test as the air in the circuit heats up.

Fortunately, these four parameters -- airspeed, altitude, rotor speed, and thrust -- can be chosen such that flight and wind-tunnel test conditions match the physical flow phenomena of interest, thereby allowing the data to be directly compared. Instead of matching rotor speed, tip Mach number is matched, which automatically compensates for temperature. Instead of matching airspeed, advance ratio -- the ratio of forward speed to rotor tip speed -- is matched at the chosen tip Mach number. Instead of matching thrust and altitude, thrust coefficient is matched; the thrust coefficient is the thrust adjusted for density, rotor speed and rotor disk area. In flight, altitude is adjusted to compensate for fuel burn-off; in the wind tunnel, thrust is adjusted to compensate for temperature.

Rate of descent -- or descent angle -- is easily adjusted in flight. The upper limit is set by YO-3A handling qualities: 1000 feet per minute is roughly the maximum practical value. In the wind tunnel, rate of descent is simulated by tilting the rotor test stand backwards, so that the airflow has an upwards component relative to the rotor.

For acoustics measurements, control -- or at least knowledge -- of rotor **tip path plane** is important. Tip-path-plane angle is the angle between the rotor disk and the resultant velocity vector; hence, it is the effective angle of attack of the rotor as a whole. In flight, the angle is determined by trim and cannot be independently controlled. In a wind tunnel, directly controlling tip path plane is not always practical; the rotor is usually trimmed to zero flapping. If set to zero flapping, or otherwise limited by loads or controls setup, tip path plane would then be determined by the test-stand pitch chosen to simulate rate of descent.

Note that tiltrotors are a special case because pylon (or rotor nacelle) tilt changes the tip path plane. Pylon tilt also affects trim, so it is not a completely independent control. There is no equivalent adjustment, independent of shaft tilt, for an isolated-rotor test in a wind tunnel. Only purpose-built tiltrotor models have both pylon tilt and shaft tilt.

Another test parameter important for IRAP is **microphone angle**: the angle between the rotor hub and the microphone measuring BVI noise. In flight, the achievable angle is limited by visibility: the helicopter pilots following the YO-3A must be able to clearly see the YO-3A in order to safely maintain formation. At very high angles, the YO-3A is not visible over the helicopter instrument panel. Below that limit, the microphone angle is easily adjusted in flight by adjusting the relative positions of the two aircraft.

In the wind tunnel, microphone position is typically fixed, hence the angle to the rotor varies slightly with test-stand pitch. There is no practical barrier to remotely controlling the microphone position in the vertical (X-Z) plane to compensate, but this has yet to be implemented for any IRAP-related test.

The final test parameter to be considered is **microphone distance**: the distance from the center of the rotor hub to the microphone. In flight, the separation distance is typically set at two or three rotor diameters and is measured by a laser rangefinder. Although workload is high, pilots can control formation distance to within a few feet.

In the wind tunnel, the microphone is usually fixed and the distance varies slightly with test-stand pitch. The distance could in principle be controlled with an adjustable microphone mount, but this has not yet been done for purposes of matching IRAP data. (Note that acoustic traverses are commonly used in wind tunnels to move one or more microphones in the horizontal plane, thereby scanning a large area under a rotor. These changes in microphone position are much larger than what would be required to compensate for test-stand pitch.)

Related Publications:

Signor, D. B., Watts, M. E., Hernandez, F. J., and Felker, F. F., "Blade-Vortex Interaction Noise: A Comparison of In-Flight, Full-Scale, and Small-Scale Measurements." American Helicopter Society Aeromechanics Specialists Conference, San Francisco, CA, January 1994.

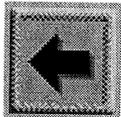
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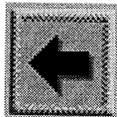
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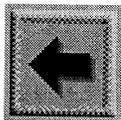
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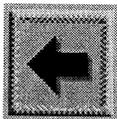
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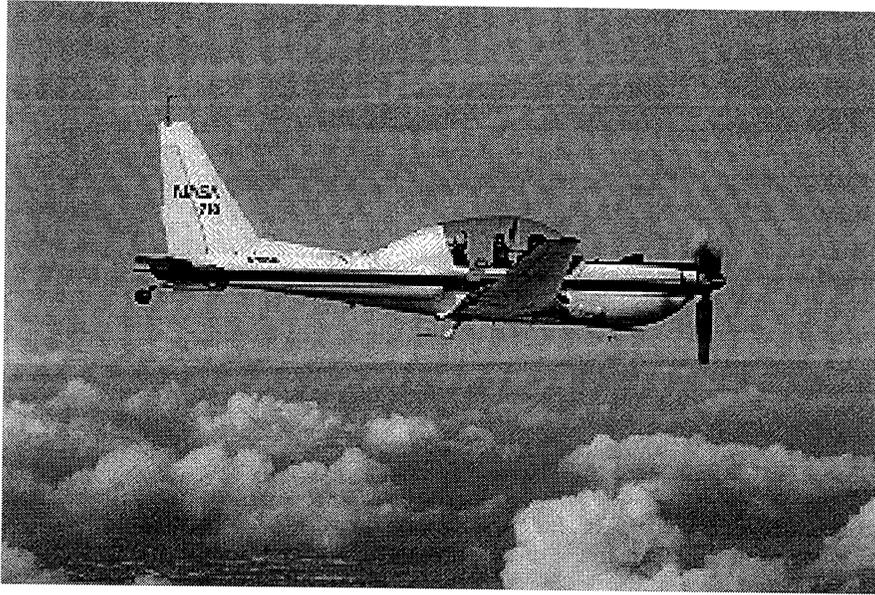
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ROTORCRAFT AEROMECHANICS BRANCH

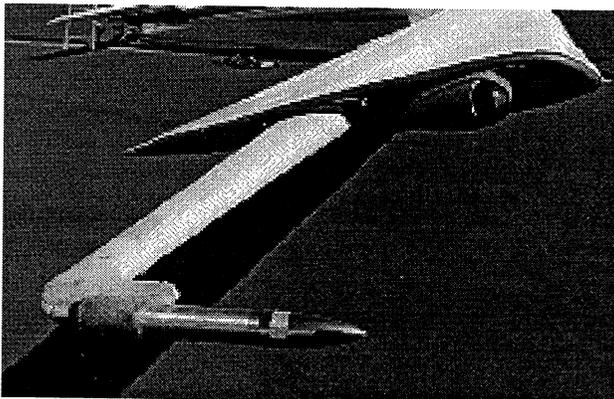
In-Flight Rotorcraft Acoustics Program

The YO-3A



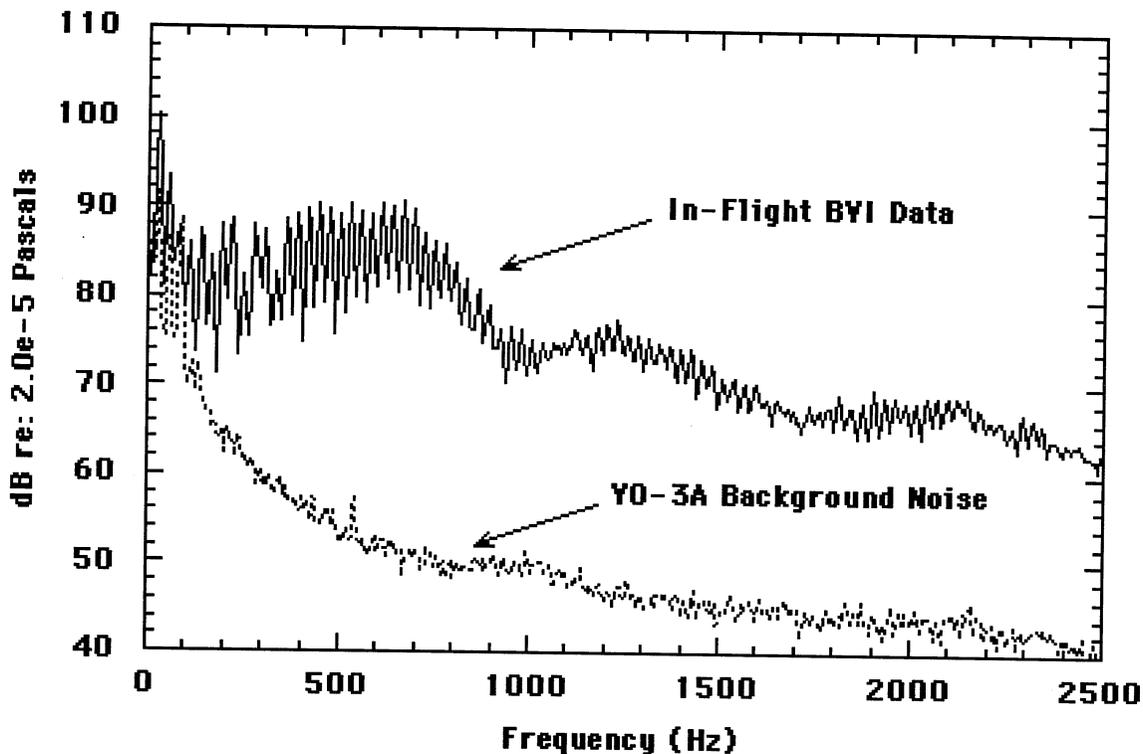
The YO-3A Acoustics Research Aircraft. The tail microphone is at the top of the YO-3A's tail fin.

Originally built as a miniature, ultra-quiet spy plane, the Lockheed YO-3A was converted into a noise research platform. NASA, in cooperation with the Army, added microphones on the wing tips and tail fin, along with a data-recording system. An air-data boom was installed under the left wing. The sailplane wing, muffled engine, and slow-turning, belt-driven propeller keep the noise extremely low -- enough so as to allow accurate measurement of rotor noise from a nearby helicopter or tiltrotor.



A close-up of the starboard wingtip microphone. The light-colored band just behind the bullet nose is a perforated screen that surrounds the microphone diaphragm.

The YO-3A has a condenser microphone mounted at each wing tip and one mounted at the top of the vertical tail. The microphones have a 0.5-inch diameter and are fitted with bullet-shaped nose cones. Each bullet fairing has a porous screen that allows the acoustic signal to reach the microphone diaphragm. The fairings are pointed forwards to minimize local flow separation and consequent background noise.



YO-3A background noise compared to typical BVI data. (Signor, et al., 1994)

For IRAP tests, the YO-3A flies below and ahead of the aircraft being tested, where BVI noise is typically loudest. BVI occurs primarily during descending forward flight, so the YO-3A establishes a steady descent and the helicopter or tiltrotor follows it down. To help set up and maintain formation, the helicopter copilot uses a hand-held laser rangefinder to continuously measure distance from the YO-3A.

For helicopters that do not have full suites of flight test instrumentation, NASA developed a portable, on-board data system to complement the YO-3A's acoustic-data system. The portable system measures and records fuselage attitude together with the distance measurements from the laser rangefinder. The data recorders in the YO-3A and the test helicopter both record a synchronization signal (1/rev pulse) once each rotor revolution; a transmitter broadcasts the synchronization signal and an IRIG-B time code from the test aircraft to the YO-3A.

IRAP tests have been carried out with Sikorsky S-76C, MBB BO 105, and Sikorsky UH-60A helicopters, and most recently the Bell XV-15 tiltrotor. In addition to IRAP tests, the YO-3A was used for earlier acoustics tests with a Bell UH-1H "Huey," two models -- AH-1S and AH-1G -- of Bell Cobras, McDonnell Douglas AH-64 Apache and MD 500 helicopters, and the YUH-61 and YAH-63 prototype military helicopters. (See the [history](#) section.) The YO-3A was also used to measure sonic booms from an [SR-71](#) "Blackbird."

Related Publications:

"YO-3A Acoustic Research Aircraft Fact Sheet." NASA Information Bulletin, December 1983.

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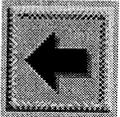
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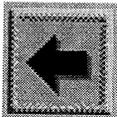
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ROTORCRAFT AEROMECHANICS BRANCH

In-Flight Rotorcraft Acoustics Program

BO 105 Flight Tests

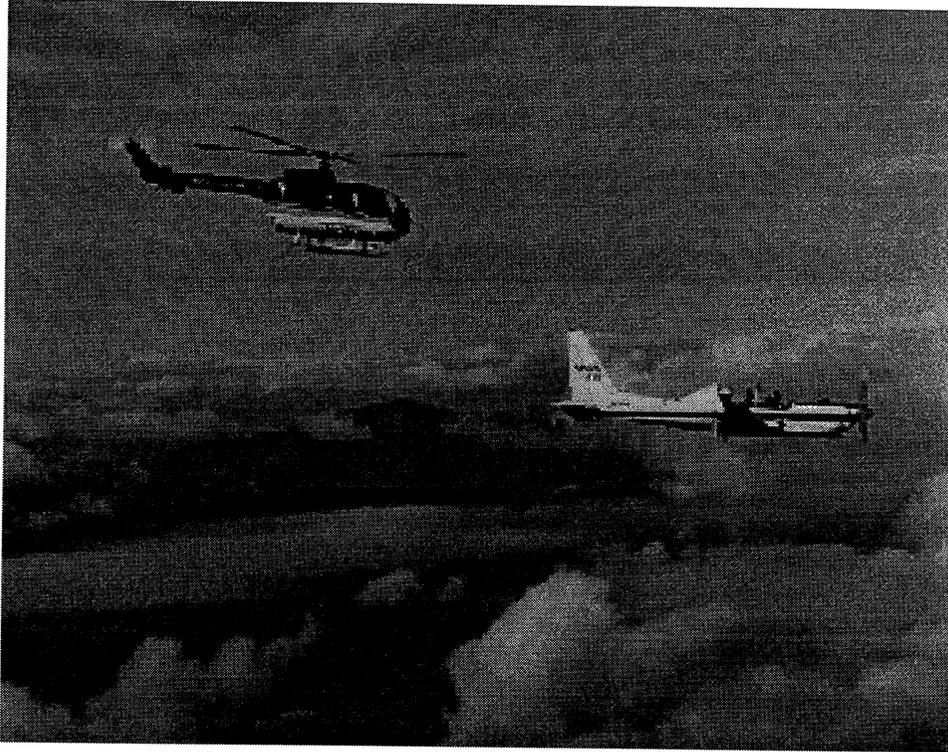


Fig. 1 The BO 105 in formation with the YO-3A.

Measurement of BO 105 BVI Noise

Acoustic measurements of a Messerschmitt-Bölkow-Blohm (MBB) BO 105 helicopter in flight were compared with acoustic measurements of a full-scale BO 105 rotor tested in the 40- by 80-Foot Wind Tunnel at NASA Ames Research Center and with acoustic measurements of a small-scale BO 105 rotor tested in the Deutsch-Niederländischer Windkanal (DNW) (Signor et al., 1994). Significant differences were seen in both the magnitude and shape of the blade-vortex interaction (BVI) events in the 40- by 80-Foot Wind Tunnel data and DNW data, as compared to the flight data. The rotor wakes in the 40- by 80-Foot Wind Tunnel and DNW were concluded to be different from the rotor wake occurring in flight. The differences in the respective wakes were primarily attributed to different trim conditions, wind tunnel wall effects, different shaped bodies underneath the rotors, and wind tunnel turbulence levels.

Test Summary

The NASA Ames YO-3A fixed wing aircraft was flown in formation with a production MBB BO 105 helicopter, as shown in Figure 1. The YO-3A tail-mounted microphone was located below and in front of the helicopter, to measure the BVI noise generated on the advancing side of the rotor.

Acoustic measurements of a full-scale BO 105 rotor were made in the 40- by 80-ft test section of the National Full-Scale Aerodynamics Complex (NFAC). All four production rotor blades used in the wind tunnel tests had various instrumentation installed (strain gages, surface pressure taps and accelerometers). The BO 105 rotor, Rotor Test Apparatus (RTA), and microphone as installed in the 40- by 80-ft test section are shown in Figure 2. The microphone was the same type used in flight (0.5 in pressure-type condenser microphone, frequency response of 5 Hz to 20 kHz) and was mounted on an acoustically treated and faired stand, hard-mounted to the wind tunnel floor.

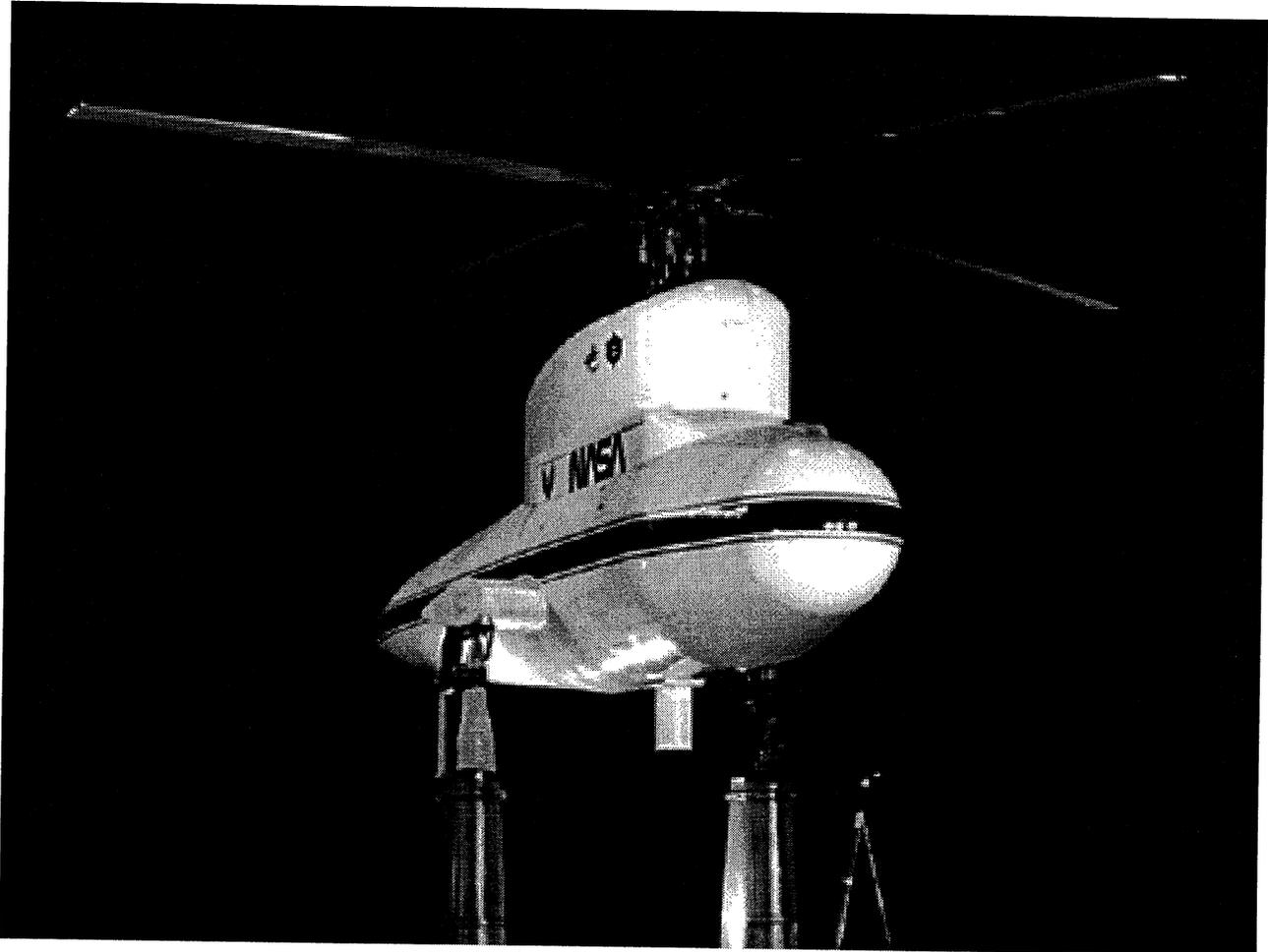


Fig. 2 The BO 105 rotor on the RTA.

Acoustics data were acquired in two separate test entries in the DNW. The same 0.4058-dynamically scaled BO 105 rotor and similar test set-ups were used in both tests (rotor radius = 6.54 ft). The tests were conducted in the open jet, anechoic test section configuration. The microphone was the same type used in flight. The microphone location was nominally the same as in the 40- by 80-Foot Wind Tunnel and flight.

Results

Examples of acoustic pressure (Sound Pressure Level, SPL) time histories from flight are presented in Figure 3. The vertical scale of each SPL time history, in Pascals, is identical: -25 Pa to +45 Pa. A half revolution is shown in each time history. Tip-path-plane angle variations were achieved by varying rate of descent while all other parameters were held constant; effective tip-path-plane angle is shown on the vertical bar next to the data

plots. The dramatic change in the shape of the acoustic waveform as BVI reaches a maximum is clearly visible.

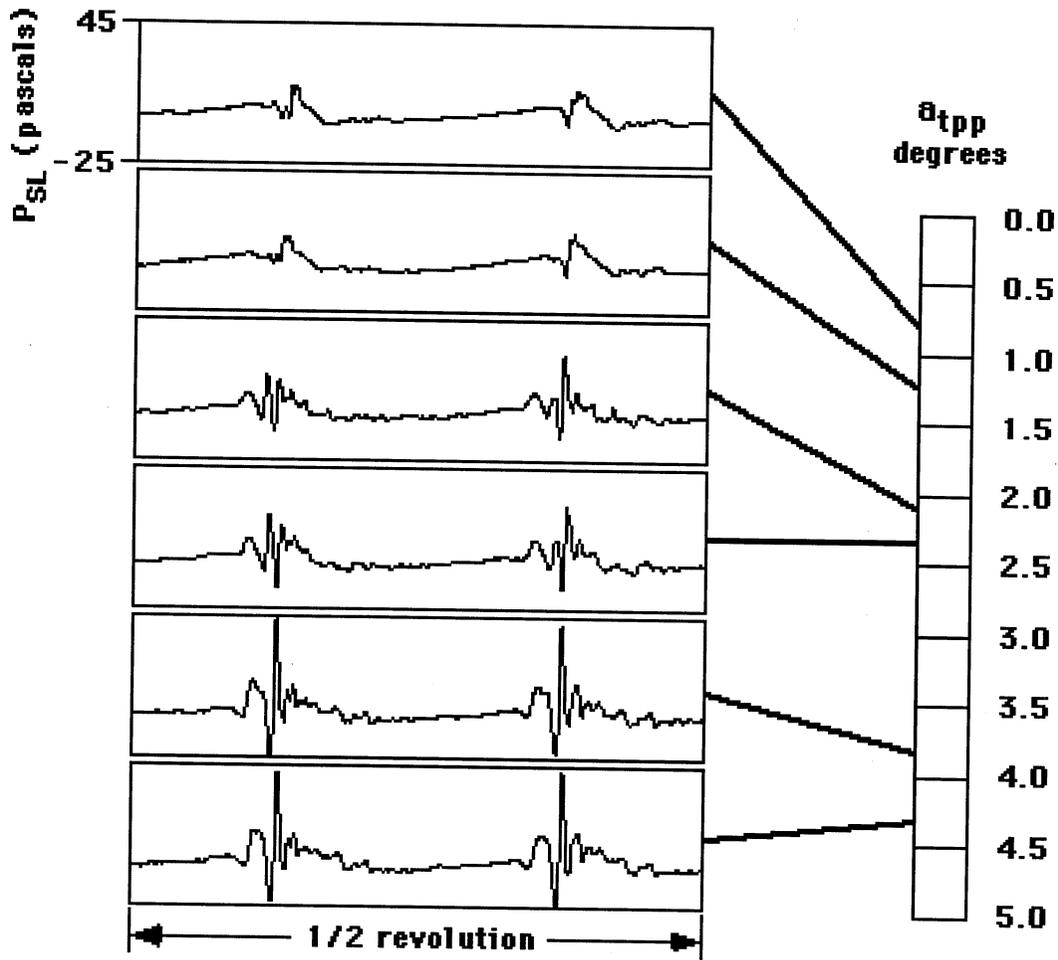


Fig. 3 Flight acoustic pressure time histories vs. α_{tpp} .
Test conditions: $\mu \approx 0.175$, $C_w \approx 0.00500$, $M_{tip} \approx 0.64$.
(Ref. Signor et al., 1994)

Acoustic pressure time histories from flight, the 40- by 80-Foot Wind Tunnel and the DNW for the same test conditions are compared in Figure 4. Significant differences in the waveforms are evident. Although these adverse results do not occur for all acoustics data, the inability to consistently match flight and wind-tunnel data remains the primary motivation for further research under IRAP.

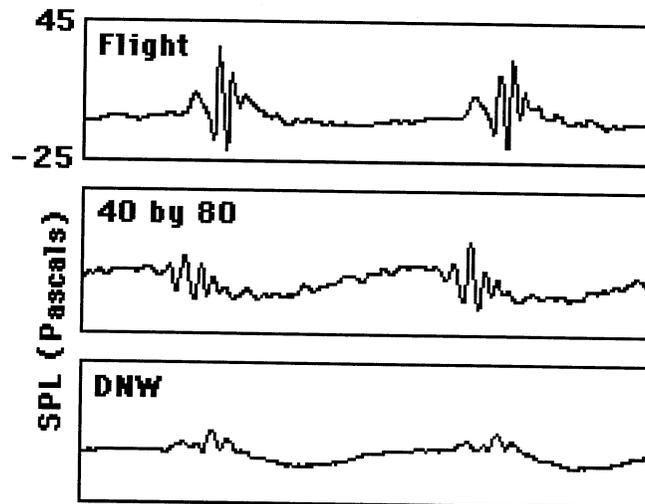


Fig. 4 Acoustic pressure time histories for flight vs. wind tunnel.
 Test conditions: $\alpha_{tip} \approx 2.4$ deg., $\mu \approx 0.185$, $C_w \approx 0.00465$, $M_{tip} \approx 0.64$.
 (Ref. Signor et al., 1994)

Effects of trim of BO 105 BVI Noise

A concern arising from this initial comparison between the flight and wind tunnel data was whether the differences in rotor trim were a major contributor to differences in the BVI noise waveforms. During the 40-by 80-Foot Wind Tunnel test, the rotor was trimmed to zero flapping; during the flight, the rotor was trimmed to balance moments on the helicopter.

The effect of rotor trim on BVI noise was investigated in a subsequent test of the BO 105 rotor in the 40- by 80-Foot Wind Tunnel by setting up on flight trim conditions. Small longitudinal and lateral cyclic excursions about the flight trim condition were input to the rotor to account for small trim variations which occur in flight. No significant effects on measured BVI noise were observed. In addition, during the latest testing of the small-scale BO 105 rotor in the DNW, the measured BVI noise time histories were very similar to those acquired in the 40- by 80-Foot Wind Tunnel. Trim variations were also performed during this test, with no observable effect of trim on BVI noise.

The differences between the BVI noise measured in the wind tunnel and flight, for the BO 105 rotor, cannot be reliably attributed to differences in rotor trim. Further research is needed to understand the effects of trim on BVI noise for full-scale rotors (For small-scale effects, see Burley & Martin, 1988.)

For a different perspective on these issues, see the discussion of BO 105 blade-pressure differences in Heller,

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Heller, H., Buchholz, H., Schultz, K.-J., Ahmed, S. R., and Spletstoesser, W. "Helicopter Rotor Blade Aeroacoustics: A Comparison of Model-Scale Wind Tunnel and Full-Scale Flight Test Results." ICAS-96-1.8.1, 20th ICAS Conference, Sorrento, Italy, September 1996.

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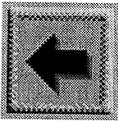
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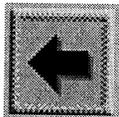
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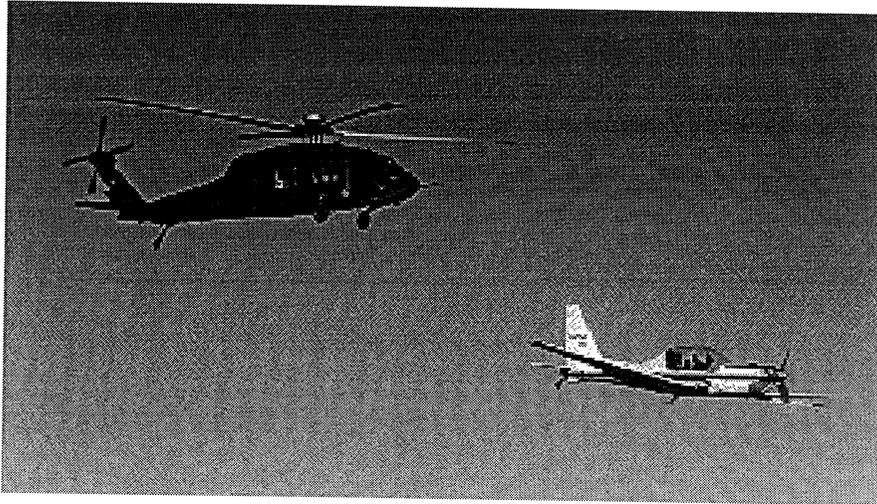
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In-Flight Rotorcraft Acoustics Program

UH-60 Flight Tests



The UH-60 helicopter in formation with the YO-3A.

A comprehensive series of tests are in progress for the Sikorsky UH-60 Black Hawk helicopter. The series includes flight tests, including tests under the In-Flight Rotorcraft Acoustics Program (IRAP), plus full- and small-scale wind-tunnel testing of the rotors. The IRAP flight tests are described here, with links to descriptions of the wind-tunnel tests. The IRAP tests were a joint effort with the NASA/Army UH-60 Airloads Project, which used a heavily instrumented UH-60A to acquire a wide variety of research data in flight.

The immediate objective of the IRAP tests was to measure blade-vortex interaction (BVI) noise from the UH-60 in flight. These measurements will be compared with similar wind-tunnel measurements in order to better understand BVI noise, with the ultimate goal of learning how to minimize BVI noise from helicopters.

Links to related pages:

[UH-60 Airloads Project](#) | [YO-3A info](#) | [IRAP overview](#) | [Other IRAP tests](#)

Measurement of UH-60 BVI Noise

During the IRAP tests, the NASA Ames YO-3A fixed-wing aircraft used a wingtip-mounted microphone to acquire BVI noise generated by the UH-60 Airloads helicopter. The simultaneous acquisition of both in-flight

acoustic and airloads data will allow the BVI noise to be examined in great detail. Six flights were performed with the YO-3A and UH-60 flying in close formation. The photo above shows a 3/4 side view of the flight formation. The starboard wingtip microphone of the YO-3A was positioned 22 deg below the rotor hub at a rotor azimuth of 150 deg. The distance between the starboard wingtip microphone and the rotor hub was 1.5 rotor diameters (80.5 ft). Target flight conditions included advance ratios from 0.175-0.250, tip Mach numbers of 0.636 and 0.66, rotor thrust coefficients of 0.0058 and 0.0071, and descent rates of 200-900 ft/min.

A subset of these flight conditions match conditions tested previously in the Deutsch-Niederländischer Windkanal (DNW). During the DNW test, acoustic and blade pressure data from a 1:5.73 scale model of the UH-60 rotor were acquired. To complete the acoustic data base of the UH-60 rotor, preparations are underway to test the UH-60 Airloads blades in the NASA Ames 40- by 80-Foot Wind Tunnel using the Large Rotor Test Apparatus (LRTA). Acoustic and blade pressure data will be acquired for conditions matching the flight and DNW tests. Because the rotor was heavily instrumented in flight, the in-flight rotor state can be accurately duplicated in the wind tunnel.

Related Publications:

Kufeld, R., Balough, D. L., Cross, J. L., Studebaker, K. F., Jennison, C. D., and **Bousman, W. G.** "Flight Testing of the UH-60A Airloads Aircraft." 50th Annual Forum of the American Helicopter Society, Washington, D.C., May 1994.

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Adapted from "Flight and Wind Tunnel Investigations of Blade-Vortex Interaction Noise," in Research and Technology 1994, NASA TM-108858.

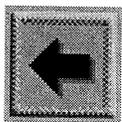
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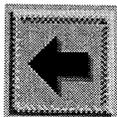
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