Flight experiments for measurement of aircraft noise using "Tunnel-In-the-Sky" display

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Keywords: aircraft noise, directivity, flight experiment

1. Introduction
With the maturation of aerospace technology in recent decades, research objectives as well as public concerns and regulations have shifted to flight safety, air pollution from exhaust gas and noise impact. Noise has become the major problem for the public especially in densely populated areas around airports.

A series of flight experiments to measure aircraft noise were conducted using the National Aerospace Laboratory of Japan’s MuPAL-ε research helicopter and MuPAL-α research airplane. In addition to longitudinal flight profiles such as level, climbing and descending flight, steady turns were flown to measure noise in the plane of the main rotor tip-path of the helicopter or in the wing tip direction of the airplane.

In this research, noise directivity patterns are examined, as well as flight paths and their errors to demonstrate the effectiveness of applying “Tunnel-in-the-Sky” display technology to noise measurement flight experiments.

2. Experimental apparatus
2.1 MuPAL-ε
Aircraft position and attitude were measured using a Differential Global Positioning System / Inertial Navigation System (DPGS/INS) sensor. Air data was obtained from an air data sensor installed at the tip of the nose boom. Rotor and blade parameters such as rotor rotational speed and flapping angles were also measured.

2.2 MuPAL-α
Aircraft position, attitude, and air data were measured by systems similar to those of MuPAL-ε. Engine torque was also measured to verify that it was set to the desired value.

2.3 “Tunnel-In-the-Sky” (TIS) display
TIS depicts a three-dimensional flight path as a perspective-view tunnel as shown in Figure 1. A pilot can track a desired flight path by controlling the aircraft so that a flight path predictor symbol is kept coincident with a ghost aircraft symbol.

2.4 Noise measurement system
Microphones placed on top of 1.2m (3.9ft) tripods were used to obtain noise data. Four or six microphones were placed in a straight line perpendicular to the flight track and the noise data were recorded using Digital Audio Tape (DAT) recorders together with GPS time to enable synchronization with on-board measurement data such as aircraft position.

3. Results and discussion
3.1 MuPAL-ε in steady turn
Precise path tracking at prescribed bank angles was afforded by use of a TIS. Figure 2 shows the deviations of lateral position and roll attitude during steady turning flights at an altitude of 90m (260ft), an airspeed of 100 knots and a bank angle of 30 degrees. The absissa indicate time from passing over the microphones. Deviations, mainly caused by the effects of wind, are not so small as to be negligible. However, it is nearly impossible without using a TIS to fulfill requirements such as flying through a fixed point in the air, i.e., over the microphones, while maintaining a prescribed bank angle.

3.2 Noise directivity of MuPAL-α

Figure 1: TIS display image.
Table 1: Flight patterns for MuPAL-α.

<table>
<thead>
<tr>
<th>Case</th>
<th>Pattern</th>
<th>Airspeed</th>
<th>Altitude</th>
<th>Bank angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-A</td>
<td>Level flight</td>
<td>100</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>α-B</td>
<td>Descent</td>
<td>140</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>α-C</td>
<td>Climb</td>
<td>100</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>α-D</td>
<td>Level flight</td>
<td>140</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>α-E</td>
<td>Right turn</td>
<td>100</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>α-F</td>
<td>Left turn</td>
<td>100</td>
<td>250</td>
<td>-30</td>
</tr>
<tr>
<td>α-G</td>
<td>Right turn</td>
<td>100</td>
<td>250</td>
<td>15</td>
</tr>
<tr>
<td>α-H</td>
<td>Left turn</td>
<td>100</td>
<td>250</td>
<td>-15</td>
</tr>
</tbody>
</table>

The flight patterns conducted using MuPAL-α are listed in Table 1. The noise directivity pattern obtained from the measurements is shown in Figure 3. It can be seen that Overall A-weighted Sound Pressure Levels (OASPL) vary widely at the circumferential angles around 30 and 150 degrees and care is required in the modeling of aircraft noise and in designing noise abatement flight paths.

4. Concluding remarks

The noise measurement flight experiments were conducted using a TIS display system installed on NAL’s research aircraft, MuPAL-ε and MuPAL-α. Use of the TIS enabled precise tracking on prescribed flight paths, both steady-state and those involving a dynamic maneuver such as a pull-up. These advantages were used to fly steady turns in order to measure noise in the main rotor tip-path plane of a helicopter and in the wing tip direction of a fixed-wing airplane. As a result, circumferential noise directivity patterns were obtained, and these data are expected to contribute to the design of noise abatement approach paths.

5. References