OPEN ROTOR DEVELOPMENT

DALE E. VAN ZANTE
ERA PROJECT ENGINEER FOR PROPULSION

STEPHEN A. RIZZI
NASA LANGLEY RESEARCH CENTER

GE Aviation

NASA Subsonic Fixed Wing
NASA Environmentally Responsible Aviation
NASA Aeronautical Sciences
NASA Aeronautics Test Program

FAA Continuous Lower
Energy, Emissions, and Noise
Isolated and Installed Tests for community noise and cruise performance: 1000+ hours of wind tunnel testing

Acoustic characterization in GRC 9x15 LSWT

Cruise performance test in GRC 8x6 SWT
Isolated and Installed Tests for community noise and cruise performance: 1000+ hours of wind tunnel testing

Installation studies at Boeing LSAF, AIAA-2013-2185

Conceptual a/c design, Boeing OREIO, NASA/CR–2011-217303
Aerodynamic performance

Current blade designs have higher efficiency than the best designs of the 1980s. Blade designs maintain the high efficiency to 0.8 cruise Mach (no need to fly slow).
Contemporary blade designs have substantial margin to the current noise regulations (and are predicted to be quieter than many a/c in the current single aisle fleet)
Auralization Results

Uniform atmosphere
Std. acoustic day
Mach 0.25
Twin rotor only
Straight & level

Centerline Receiver (1.2m) 500 ft. Hard ground plane

Open Rotor Test Conditions

<table>
<thead>
<tr>
<th>Reading Number</th>
<th>Blade Set</th>
<th>Installation</th>
<th>Full-Scale Thrust (lbf)</th>
<th>$\alpha_{\text{inflow}}$ (deg)</th>
<th>Forward BPF (Hz)</th>
<th>Aft BPF (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>359</td>
<td>F31/A31</td>
<td>Pylon</td>
<td>13741</td>
<td>0</td>
<td>258</td>
<td>215</td>
</tr>
<tr>
<td>361</td>
<td>F31/A31</td>
<td>Pylon</td>
<td>14650</td>
<td>0</td>
<td>264</td>
<td>220</td>
</tr>
<tr>
<td>470</td>
<td>F31/A31</td>
<td>Isolated</td>
<td>13609</td>
<td>0</td>
<td>260</td>
<td>217</td>
</tr>
<tr>
<td>480</td>
<td>F31/A31</td>
<td>Isolated</td>
<td>13566</td>
<td>3</td>
<td>260</td>
<td>217</td>
</tr>
<tr>
<td>488</td>
<td>F31/A31</td>
<td>Isolated</td>
<td>13686</td>
<td>8</td>
<td>260</td>
<td>217</td>
</tr>
<tr>
<td>Gen-2</td>
<td>Gen-2</td>
<td>Pylon with mitigation</td>
<td>14472</td>
<td>0</td>
<td>n/a*</td>
<td>n/a*</td>
</tr>
</tbody>
</table>

*GE Proprietary Data

Configuration Effects
Effect of thrust level
Effect of installation type
Effect of rotor inflow angle
Effect of blade set
Historical Blade Set (RDG 361)

A-weighted SPL & PNLT (flush receiver)
Effect of Thrust Level and Blade Set

Effect of Thrust Level
(RDG 359 vs RDG 361 - 6.6% higher)

Effect of Blade Set
Gen-2 vs RDG 361

100.5 (ANOPP), 100.2 (Aural) EPNdB – Gen-2 Flush
97.6 (ANOPP), 97.5 (Aural) EPNdB – Gen-2 Elevated

PNLT for two flyovers
(flush receiver)
Concluding Remarks

• Current open rotor designs are more efficient and substantially quieter than legacy blades.

• Method for auralizing full scale flyover noise using model scale open rotor test data has been developed.

• Thrust level, propulsor installation, & rotor inflow angle affected forward & aft radiated noise and produced audible differences.

• Gen-2 blade set demonstrated to be substantially (11 EPNdB) quieter than historical baseline blade set at comparable thrust level.

• Perception-influenced designs now possible which meet noise certification requirements and simultaneously have desirable sound quality attributes.
Thank You.

Selected sound files are available for download at:

http://stabserv.larc.nasa.gov/flyover/

This work performed with support from the NASA Environmentally Responsible Aviation, Fixed Wing and Aeronautical Sciences projects. GE open rotor blade design and testing performed under support of FAA CLEEN program.
