Open Rotor Development

Dale E. Van Zante
ERA Project Engineer for Propulsion

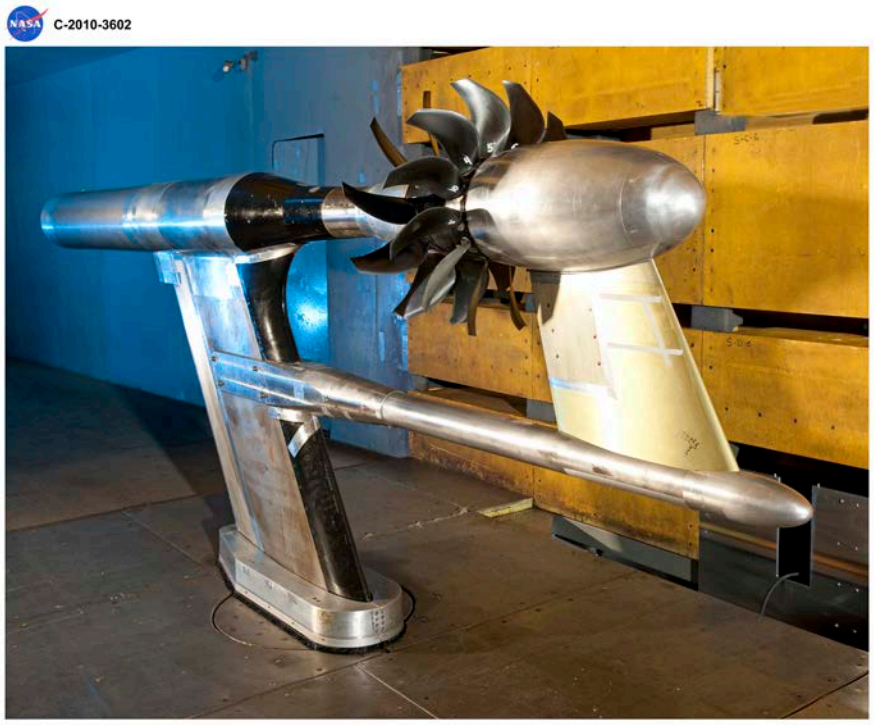
Stephen A. Rizzi
NASA Langley Research Center

GE Aviation

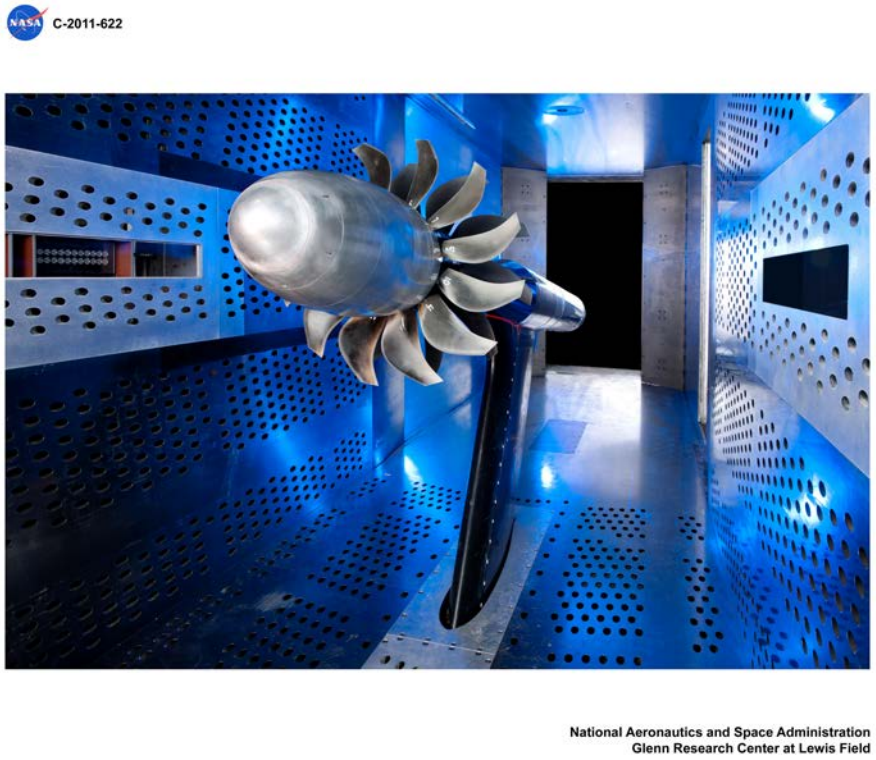
NASA Subsonic Fixed Wing
NASA Environmentally Responsible Aviation
NASA Aeronautical Sciences
NASA Aeronautics Test Program

FAA Continuous Lower
Energy, Emissions, and Noise

Isolated and Installed Tests for community noise and cruise performance: 1000+ hours of wind tunnel testing

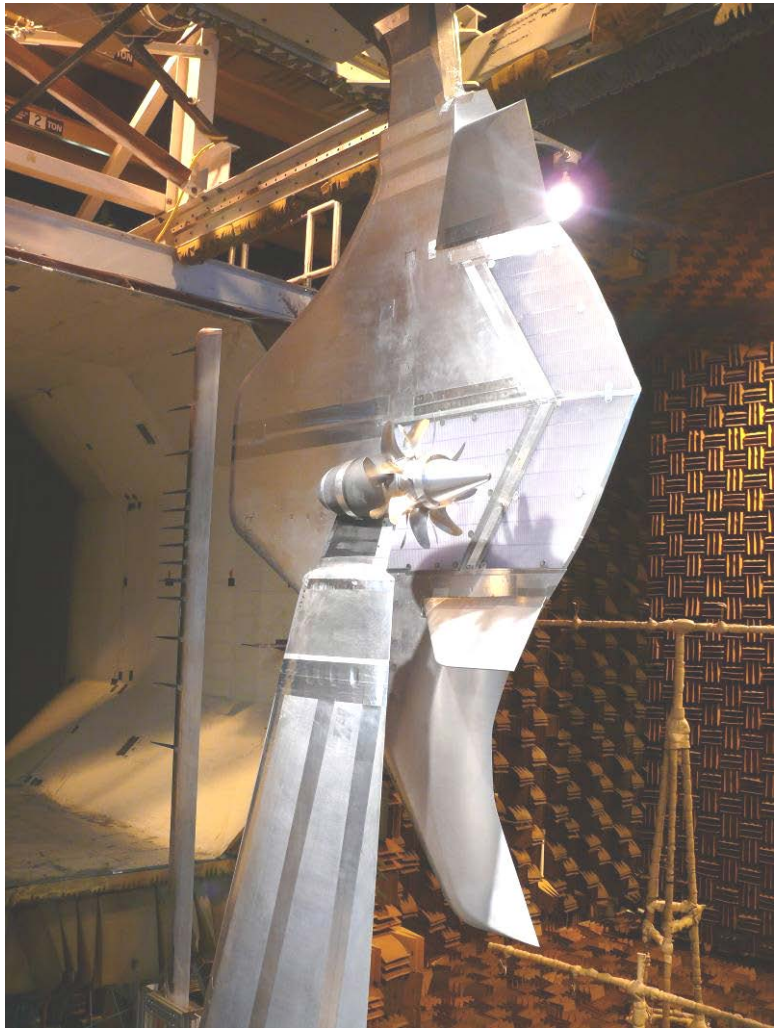


Acoustic characterization in GRC 9x15 LSWT

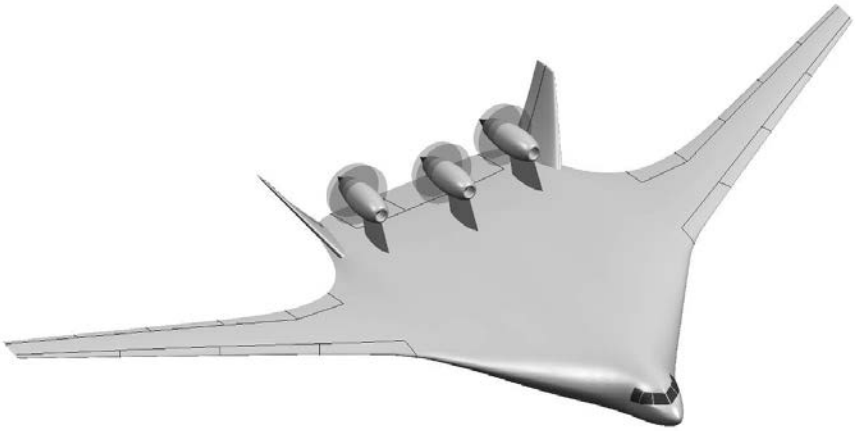


Cruise performance test in GRC 8x6 SWT

Isolated and Installed Tests for community noise and cruise performance: 1000+ hours of wind tunnel testing

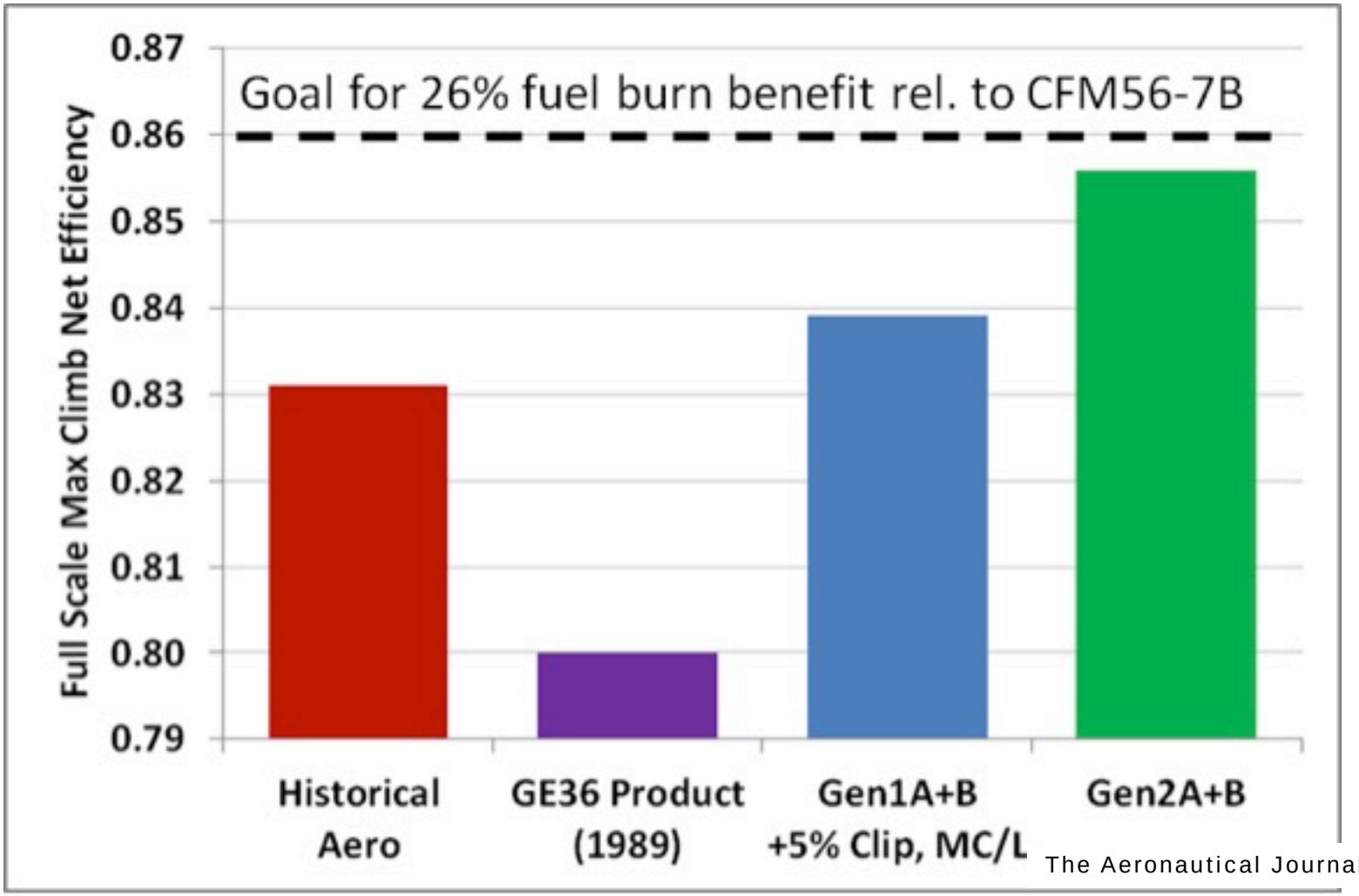


Installation studies at
Boeing LSAF,
AIAA-2013-2185



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

Aerodynamic performance

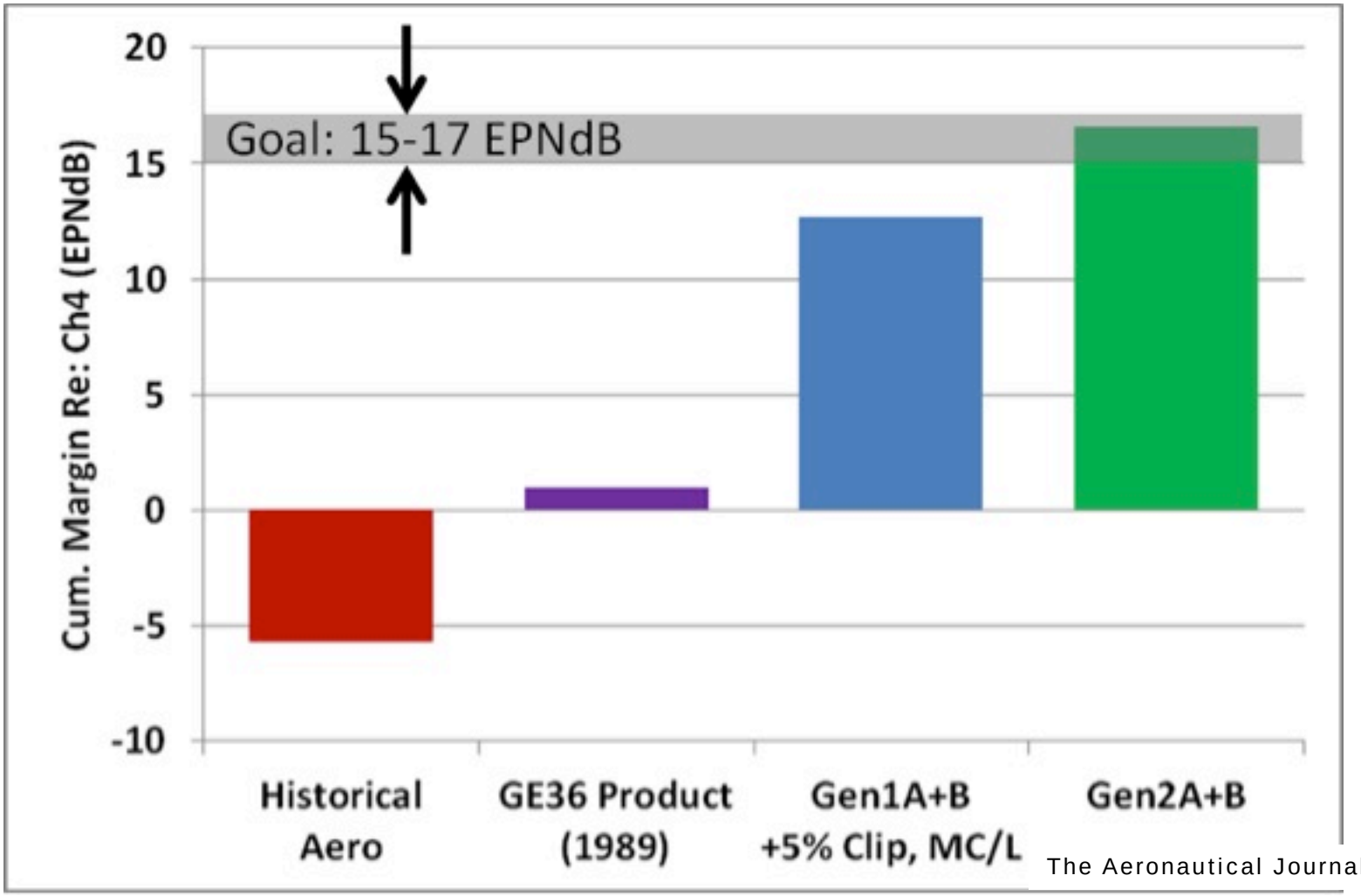


The Aeronautical Journal, Oct 2014

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).

Acoustic performance

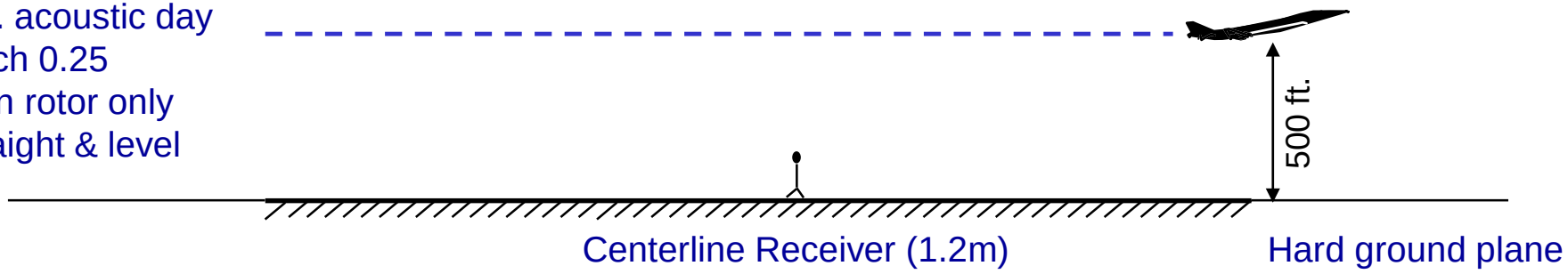


The Aeronautical Journal, Oct 2014

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



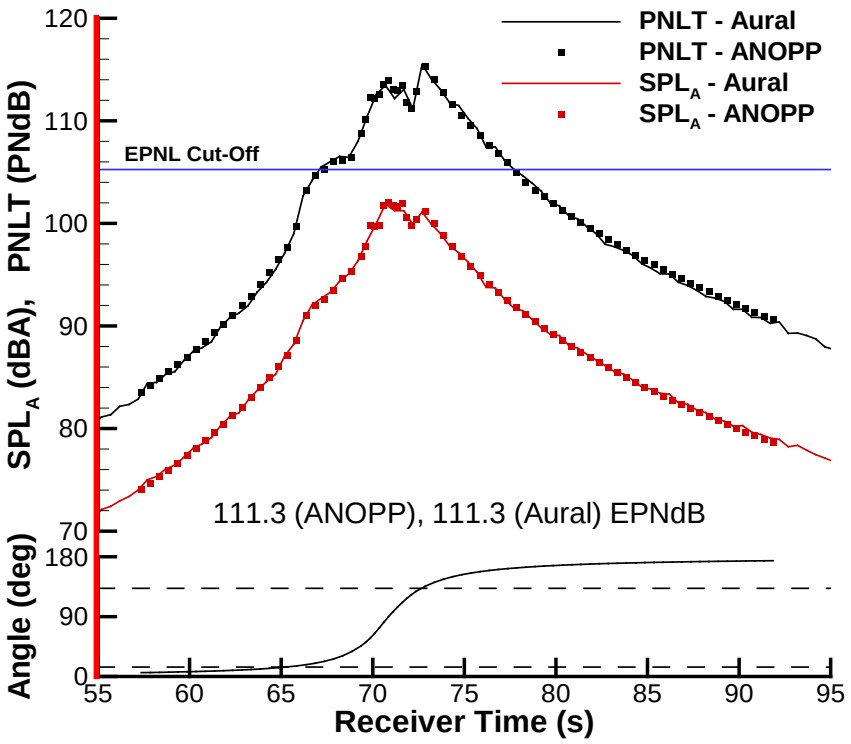
Open Rotor Test Conditions

Reading Number	Blade Set	Installation	Full-Scale Thrust (lbf)	α_{Inflow} (deg)	Forward BPF (Hz)	Aft BPF (Hz)
359	F31/A31	Pylon	13741	0	258	215
361	F31/A31	Pylon	14650	0	264	220
470	F31/A31	Isolated	13609	0	260	217
480	F31/A31	Isolated	13566	3	260	217
488	F31/A31	Isolated	13686	8	260	217
Gen-2	Gen-2	Pylon with mitigation	14472	0	n/a*	n/a*

*GE Proprietary Data

Configuration Effects
Effect of thrust level
Effect of installation type
Effect of rotor inflow angle
Effect of blade set

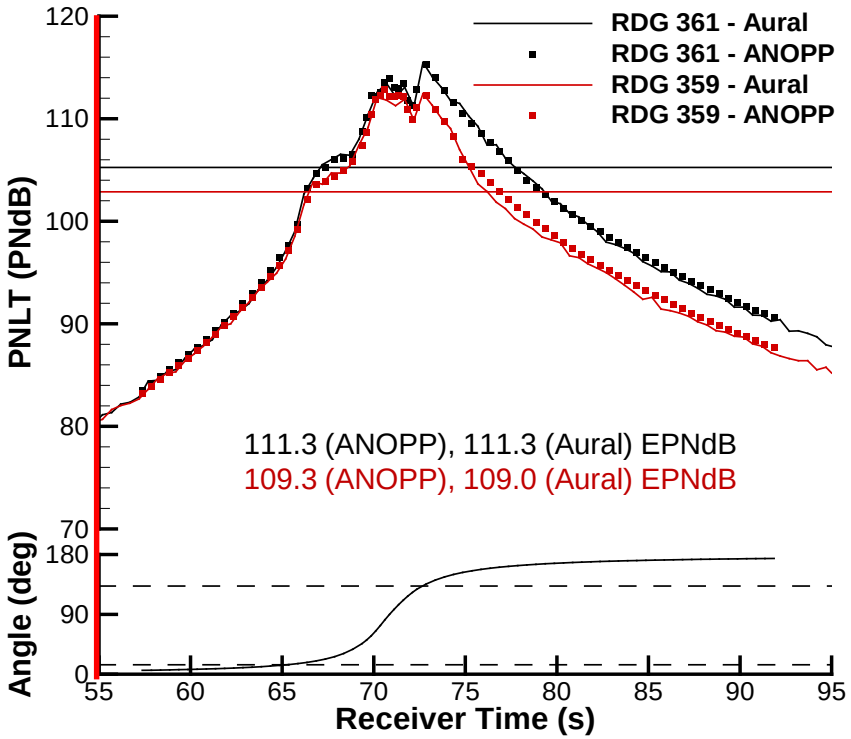
Historical Blade Set (RDG 361)



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)



PNLT for two flyovers (flush receiver)

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

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.

Ref: Stephen A. Rizzi, David B. Stephens, Jeffrey J. Berton, Dale E. Van Zante, John P. Wojno, and Trevor W. Goerig. "Auralization of Flyover Noise from Open-Rotor Engines Using Model-Scale Test Data", Journal of Aircraft, Vol. 53, No. 1 (2016), pp. 117-128.
doi: 10.2514/1.C033223