



# OPEN ROTOR DEVELOPMENT

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GE Aviation

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

FAA Continuous Lower  
Energy, Emissions, and Noise



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



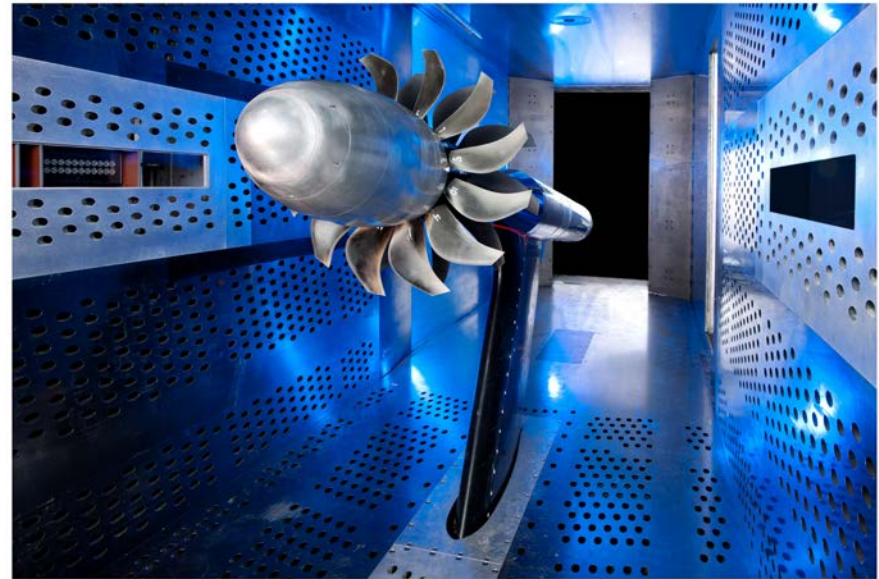
NASA C-2010-3602



National Aeronautics and Space Administration  
Glenn Research Center at Lewis Field

Acoustic characterization  
in GRC 9x15 LSWT

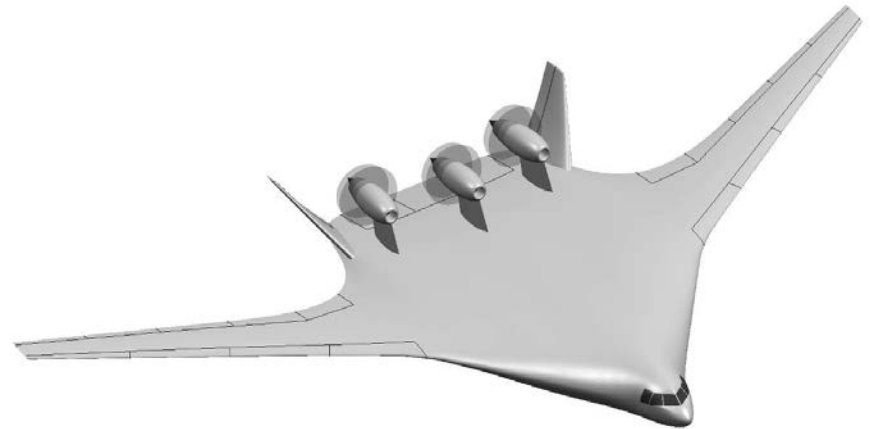
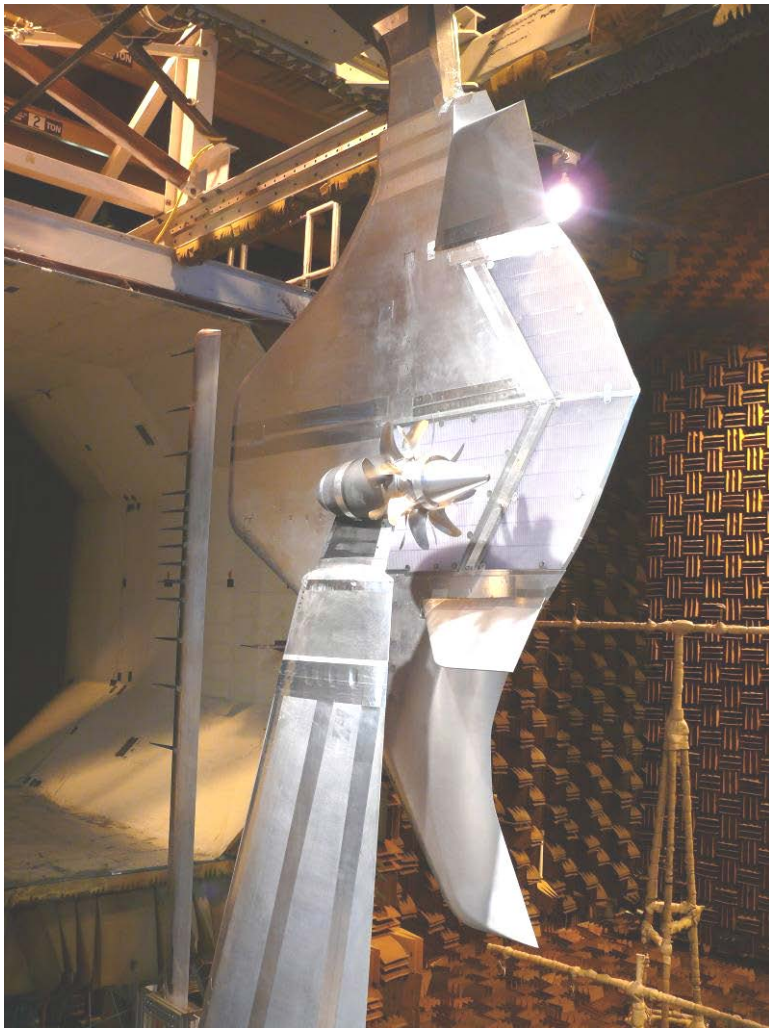
NASA C-2011-622



National Aeronautics and Space Administration  
Glenn Research Center at Lewis Field

Cruise performance test  
in GRC 8x6 SWT

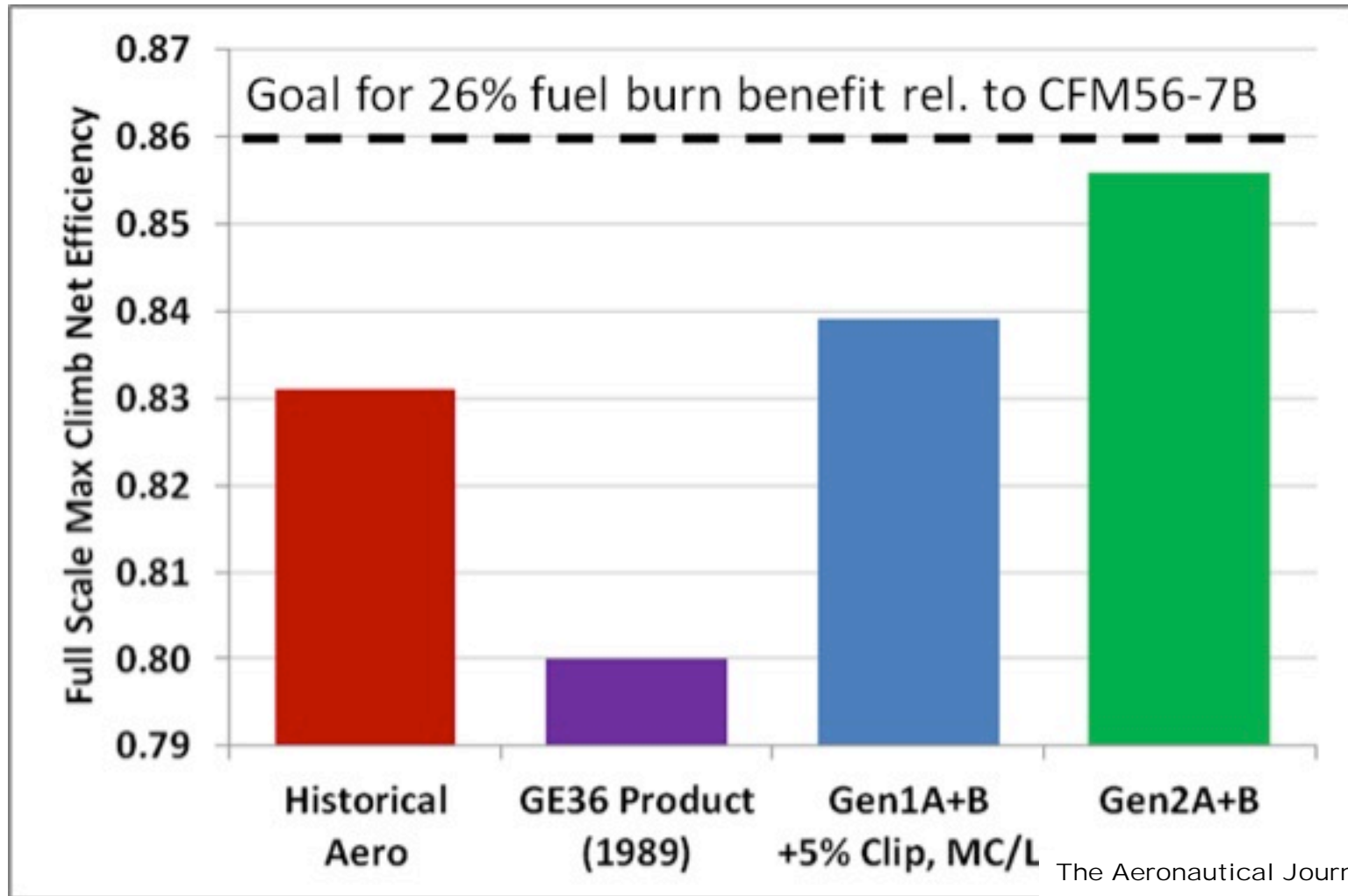
# Isolated and Installed Tests for community noise and cruise performance: 1000+ hours of wind tunnel testing



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

Installation studies at  
Boeing LSAF,  
AIAA-2013-2185

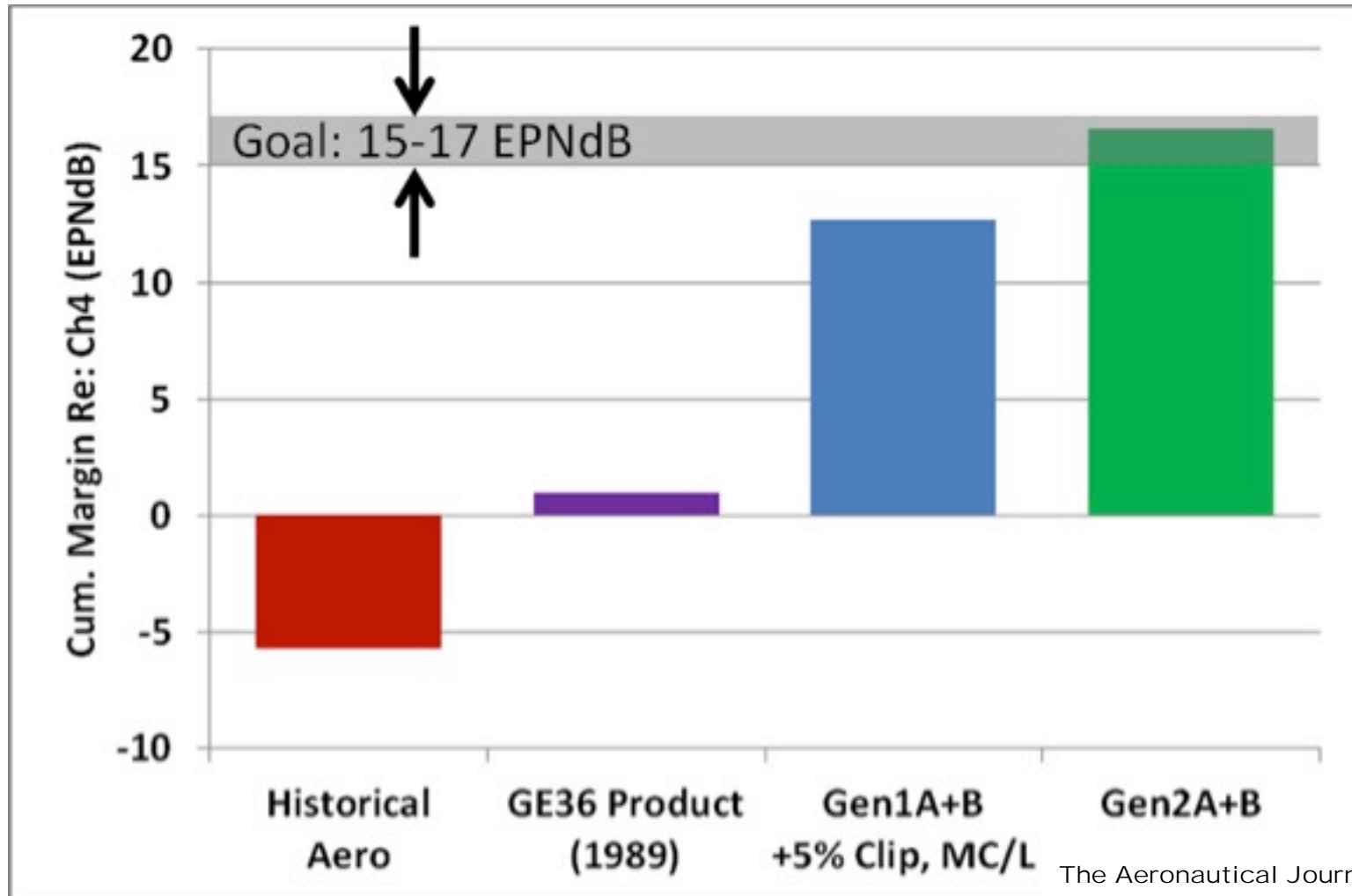
# Aerodynamic performance



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

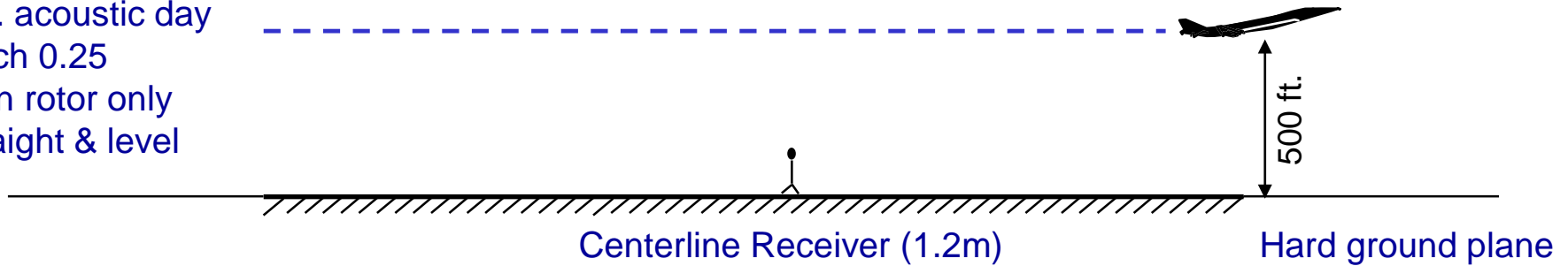


The Aeronautical Journal, Oct 2014

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

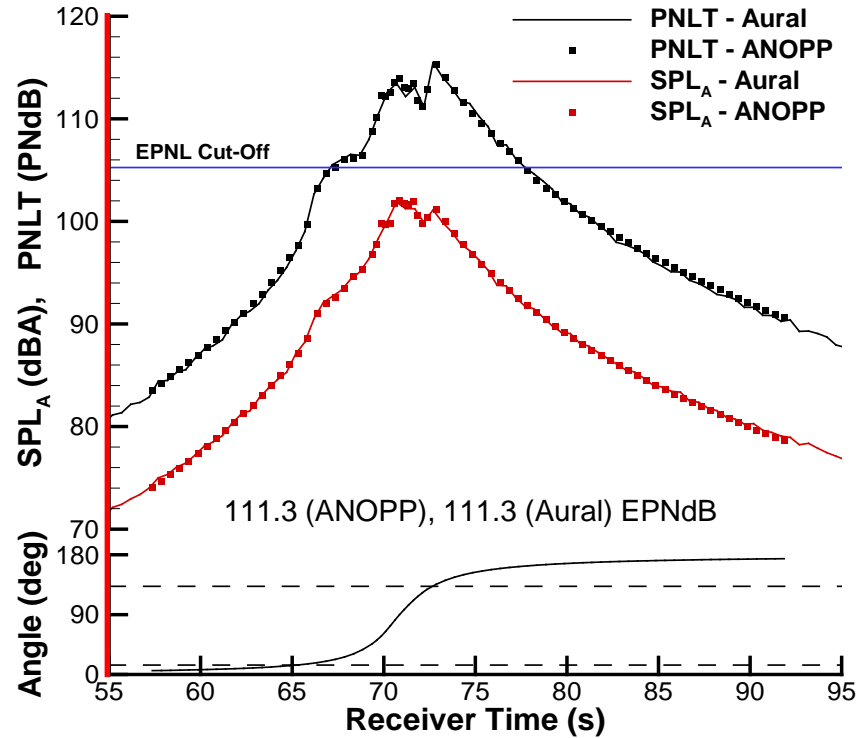
Reading Number	Blade Set	Installation	Full-Scale Thrust (lbf)	$\alpha_{Inflow}$ (deg)	Forward BPF (Hz)	Aft BPF (Hz)
359	F31/A31	Pylon	13741	0	258	215
361	F31/A31	Pylon	14650	0	264	220
470	F31/A31	Isolated	13609	0	260	217
480	F31/A31	Isolated	13566	3	260	217
488	F31/A31	Isolated	13686	8	260	217
Gen-2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

## Configuration Effects

- Effect of thrust level
- Effect of installation type
- Effect of rotor inflow angle
- Effect of blade set

\*GE Proprietary Data

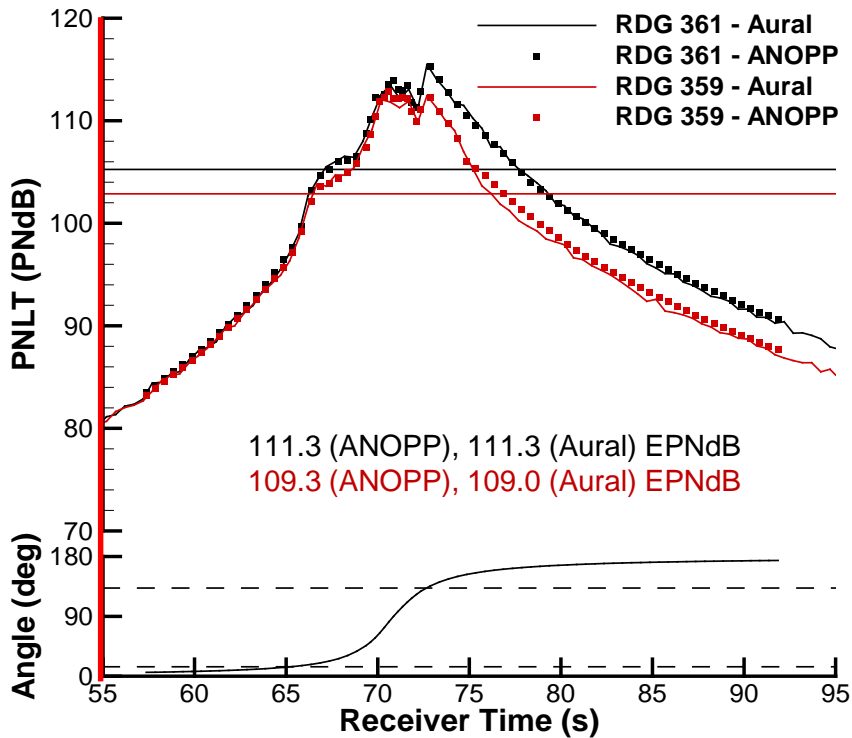
# Historical Blade Set (RDG 361)



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

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- 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/>**

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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

