



Progress on Propeller/Open Rotor Noise Prediction

Douglas M. Nark

**NASA Langley Research Center
Spring Acoustics Technical Working Group Meeting
Cleveland, OH**

April 21-22, 2011



Outline

- Objectives
- Key deliverables and milestones
- Current Tasks
 - Isolated Propeller Noise Measurement/Prediction
 - CRPFAN
 - PyASSPIN
 - Ffowcs Williams-Hawkings (FW-H) Approach
 - Fast Scattering Code
- Concluding Remarks



Key Deliverables and Milestones

Milestone/Deliverables	FY11	FY12	FY13	FY14
Assess and Improve Existing Suite of NASA Open Rotor Noise Prediction Codes				
Validate single rotation isolated propeller noise prediction tools using available benchmark noise data				
Validate single rotation installed propeller noise predictions tools using available noise data				
Improve/Develop installed open rotor component noise prediction codes				
Validate installed propulsion (low speed propellers, open rotor) noise prediction tools using available propeller/open rotor noise data				



Isolated Propeller Noise Measurement

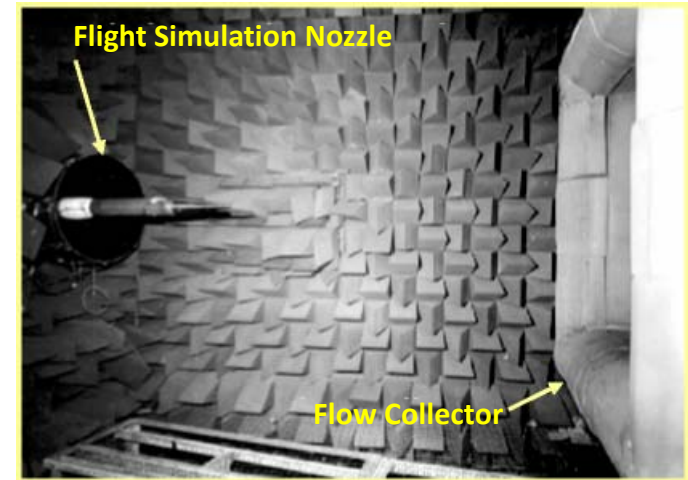
Benchmark UAV Propeller Acoustic Measurements

- Facility currently undergoing upgrade
 - Phase 1: Isolated measurements 8/2011
 - Phase 2: Installed measurements 12/2011

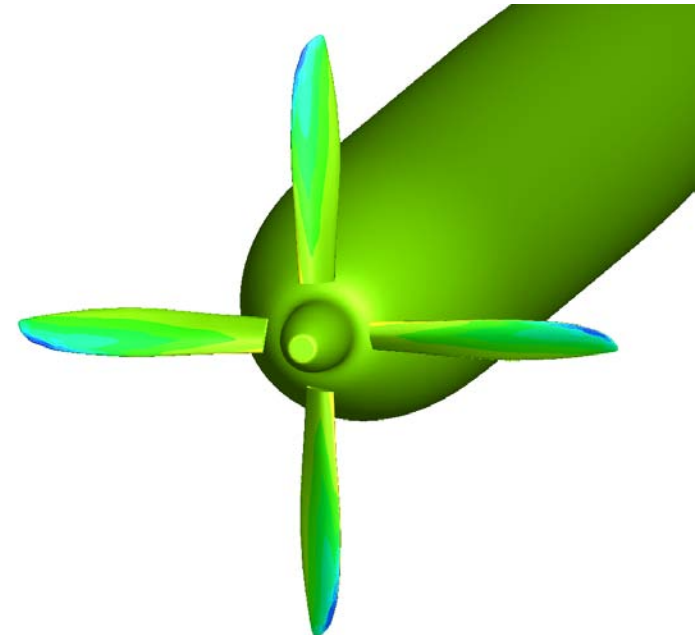
Isolated Propeller Acoustic Predictions

- Five COTS “Zinger” and “Zinger Pro” Propellers
 - 16” diameter
 - 3 and 4 blades
 - 6”, 10”, and 14” Pitch ($\beta_{3/4} \sim 9^\circ, 15^\circ, 20^\circ$)
- Initial blade scans complete
- Initial OVERFLOW calculations complete
- Impermeable/permeable time domain acoustic predictions underway

GTRI: Russell Young, Jeremy Bain



GTRI Anechoic Flight Simulation Facility





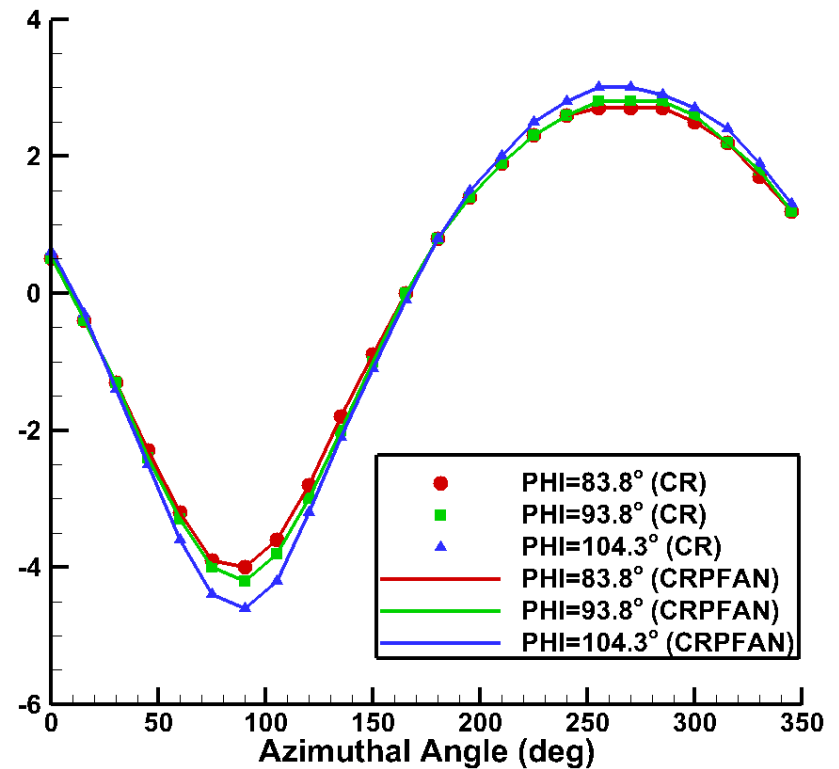
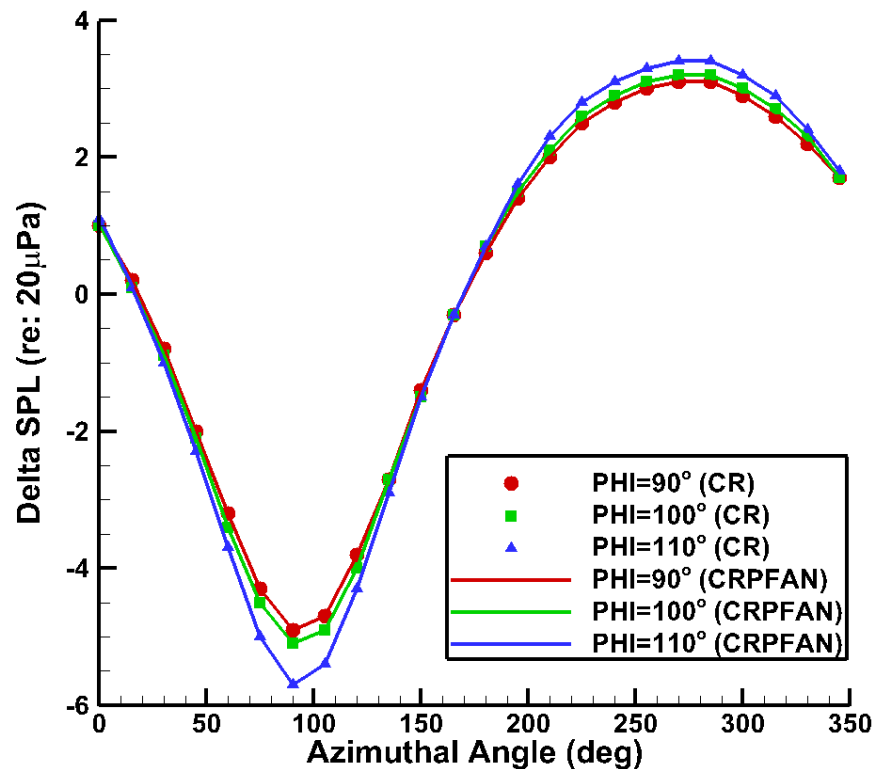
CRPFAN/CRPCLD

- CRPFAN (Counter-Rotation PropFan Noise)
 - Steady loading/thickness noise from fore/aft blades
 - Unsteady loading noise resulting from the interaction of the blades with wakes
 - Installation effects (requires blade section lift and drag coefficients vs. α)
- CRPCLD (Counter-Rotation Propeller Coefficients of Lift and Drag)
 - Blade section lift and drag coefficients vs. α given CRP performance
- Predictions match values documented in NASA CR-185242
- Dependence on IMSL library routines removed
- Integration with ANOPP/ANOPP2 currently being tested



CRPFAN/CRPCLD

Prediction of Installation Effects (CR: Published, CRPFAN: Predicted)

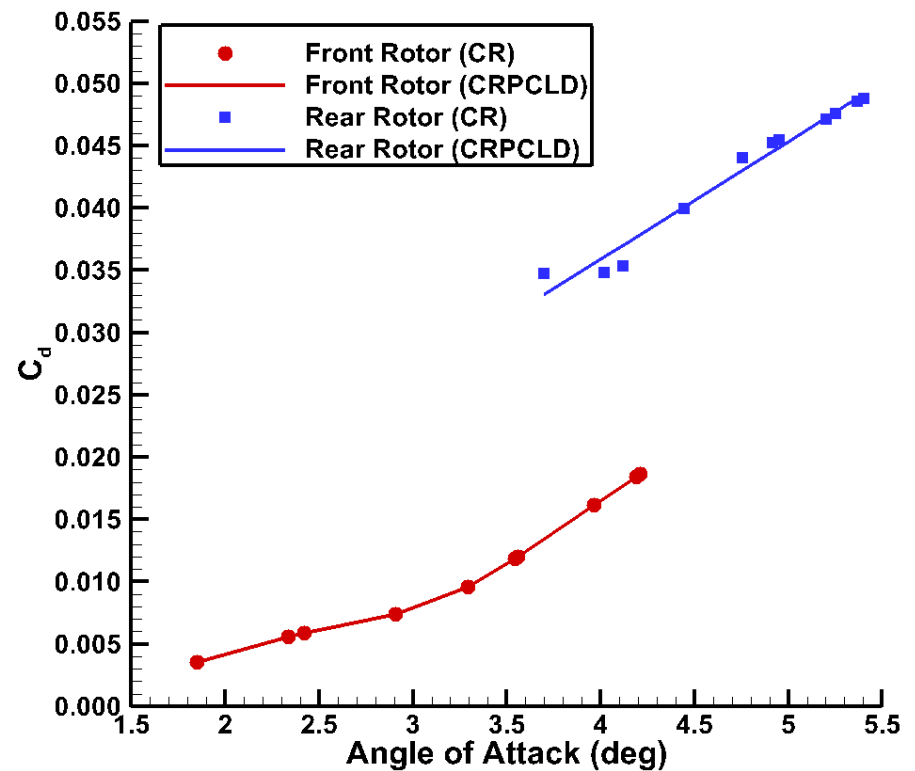
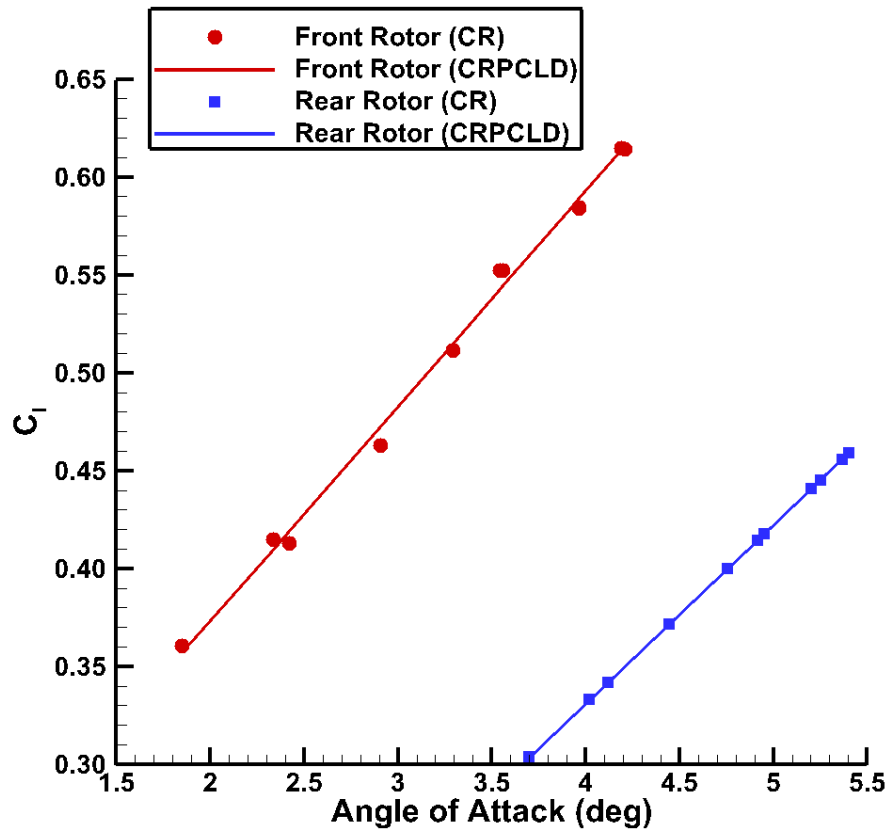


Ref: Whitfield et. al., NASA CR-185242



CRPFAN/CRPCLD

Prediction of Installation Effects (CR: Published, CRPCLD: Predicted)



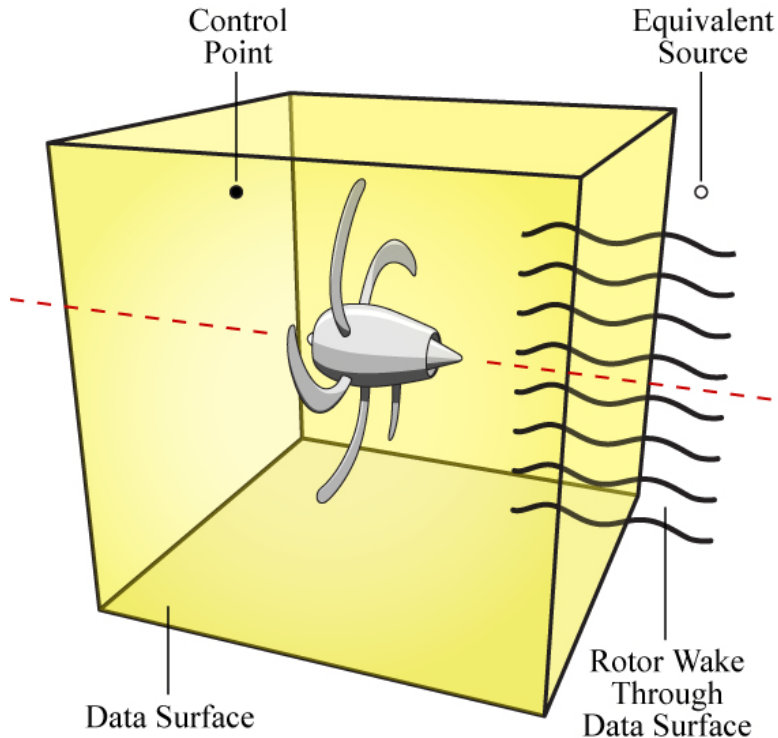
Ref: Whitfield et. al., NASA CR-185242



FW-H Equation

Permeable (Penetrable) Data Surface

$$\square^2 c^2 \rho' \equiv \square^2 p' = \frac{\partial}{\partial t} [\rho_0 U_n] \delta(f) - \frac{\partial}{\partial x_i} [L_i \delta(f)] + \frac{\partial^2}{\partial x_i \partial x_j} [T_{ij} H(f)]$$



$$U_n = \left(1 - \frac{\rho}{\rho_0}\right) v_n + \frac{\rho u_n}{\rho_0}$$

$$L_i = p \delta_{ij} n_j + \rho u_i (u_n - v_n)$$

***u* and *v* refer to the velocity of the fluid and data surface, respectively**

Ref: Farassat et. al., AIAA 2009-3133

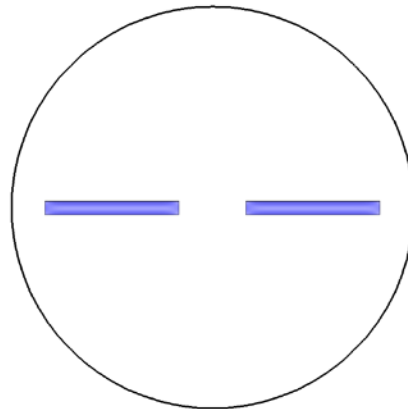


FW-H Equation

Investigation of Spurious Signal Generation

- Isolated two-bladed rotor in hover with permeable data surface
 - “Tuna can” surrounding rotor
 - Observers placed within data surface show non-zero acoustic pressure

Top View

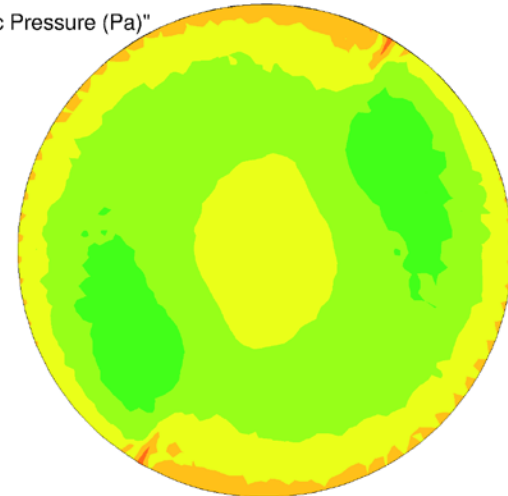
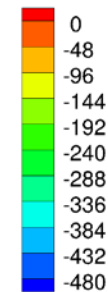


Side View



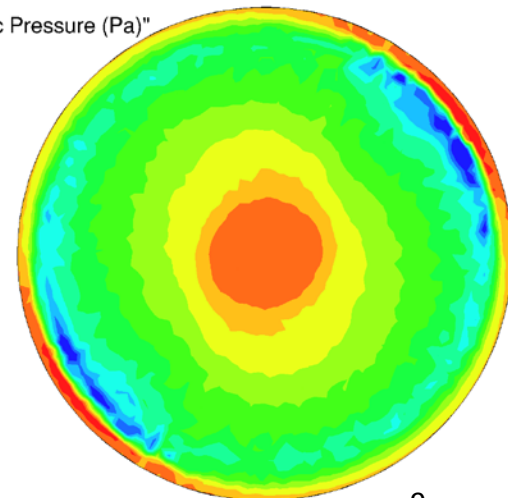
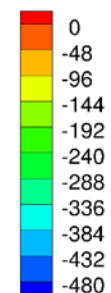
$Z = 0.35$

"Acoustic Pressure (Pa)"



$Z = -0.35$

"Acoustic Pressure (Pa)"



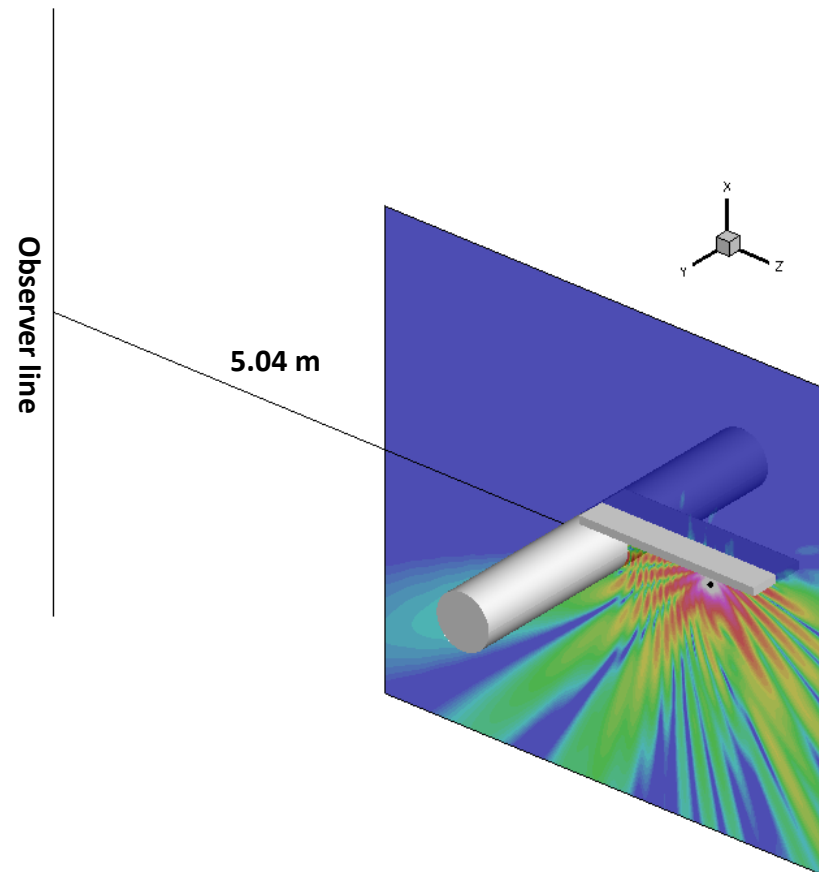
Courtesy: Len Lopes, Doug Boyd



Acoustic Scattering/Shielding

Fast Scattering Code Development and Validation

- Validation for cylinder/plate configuration with monopole source
- New Symmetry Option
 - Exploits bilateral symmetry of geometry
 - No restrictions on location of sound source
- New restart option
 - Uses solution for $f_{n-1} = f_n - \Delta f$ as initial guess for current (fn) solution (Δf is arbitrary)



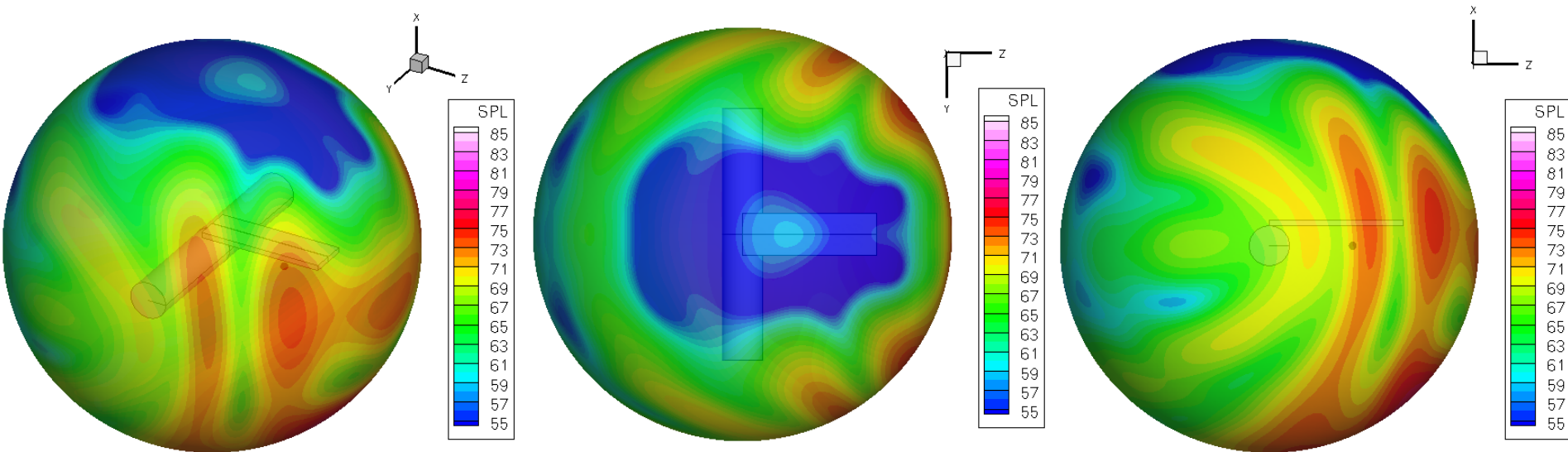
Ref: Ahtye et. al., NASA TP-1004

Courtesy: Dunn, Tinetti (NNL09AA17C)



Acoustic Scattering/Shielding

- Demonstrate suitability for system noise prediction
 - Develop suppression table generation procedure using cylinder/plate
 - Sphere ($r = 2.5$ m) surrounding configuration
 - Allows above/below wing source installation
 - Monochromatic and pink noise



Courtesy: Dunn, Tinetti (NNL09AA17C)



Concluding Remarks

- SRP measurements/predictions progressing
- Multiple CRP noise prediction methods to be assessed
 - Initiating historical baseline grid generation
- Fast Scattering Code (FSC) development progressing
 - Added enhanced source input options
 - Demonstrating suitability for system noise assessment