



Single- and Contra-Rotating Propeller Noise Prediction

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**NASA Langley Research Center
Fall Acoustics Technical Working Group Meeting
Hampton, VA**

October 23-25, 2012



Outline

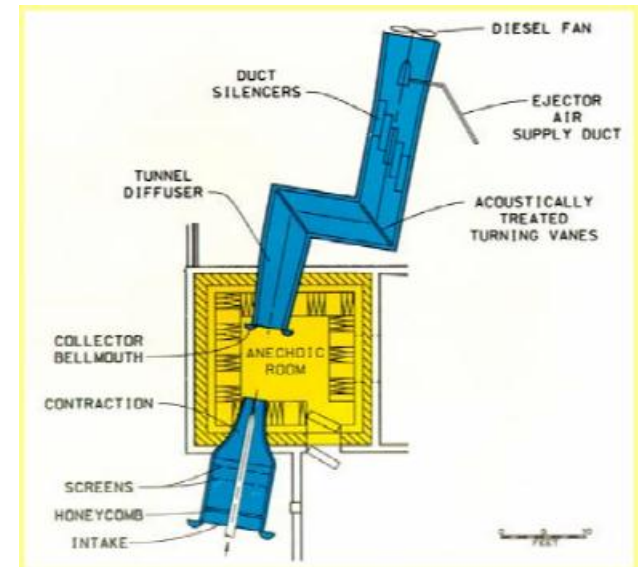
- **Single-Rotation Propeller (SRP) Noise**
 - GTRI Measurements
 - Prediction Approach
- **Contra-Rotation Propeller (CRP) Noise**
 - Prediction Approach (F31A31 Historical Baseline Blade Set)
- **Acoustic Scattering Prediction**
- **Concluding Remarks**



Isolated SRP Measurements

GTRI Phase 1 Measurements

- 8 COTS “Zinger Pro” Propellers
 - 16” diameter
 - 3–5 blades
 - 6”, 10”, and 14” Pitch ($\beta_{3/4} \sim 9^\circ, 15^\circ, 20^\circ$)
- Flight Speeds
 - 3 forward speeds (30, 60, 90 knots)
- Propeller RPM
 - 4000 - Max (tip speeds up to $M \sim 0.66$)
- 2 COTS “Zinger” Square tip Propellers also tested to assess tip geometry effects



GTRI PI: Russell Young

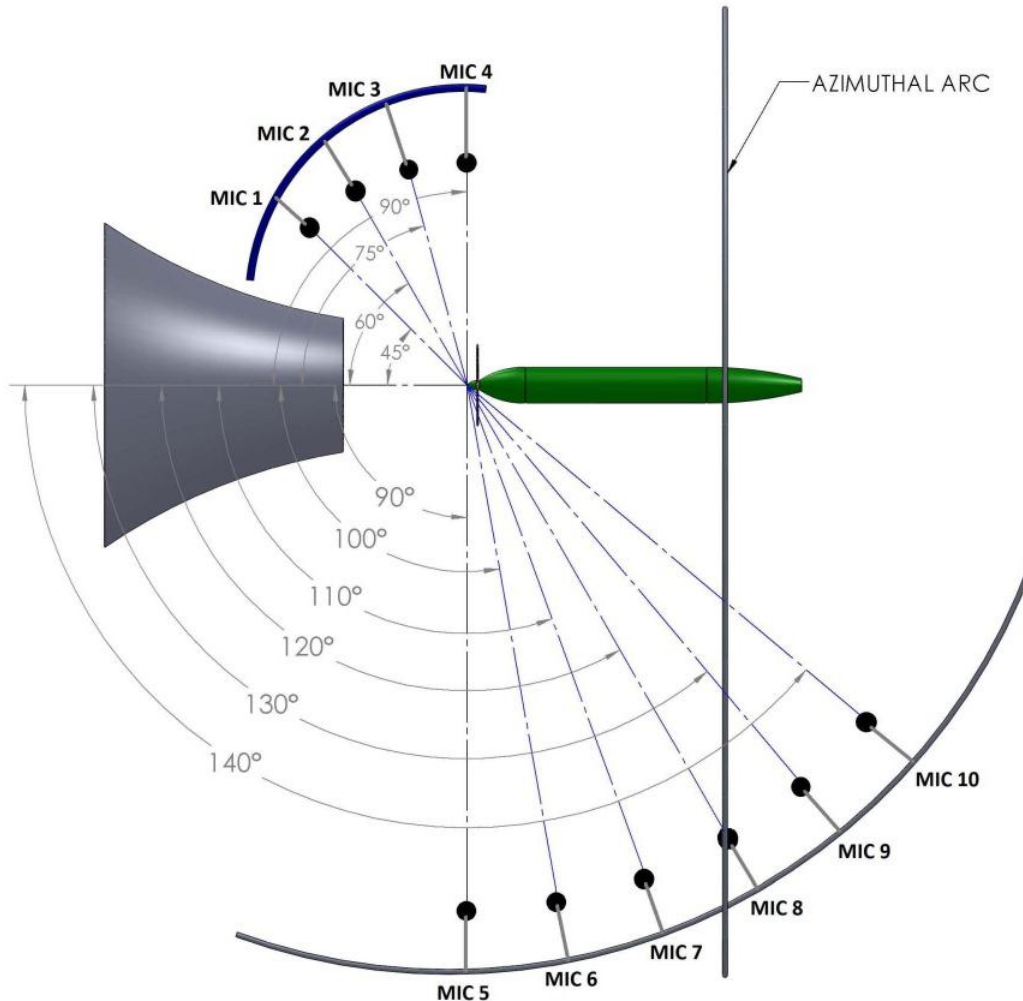
GTRI Anechoic Flight Simulation Facility



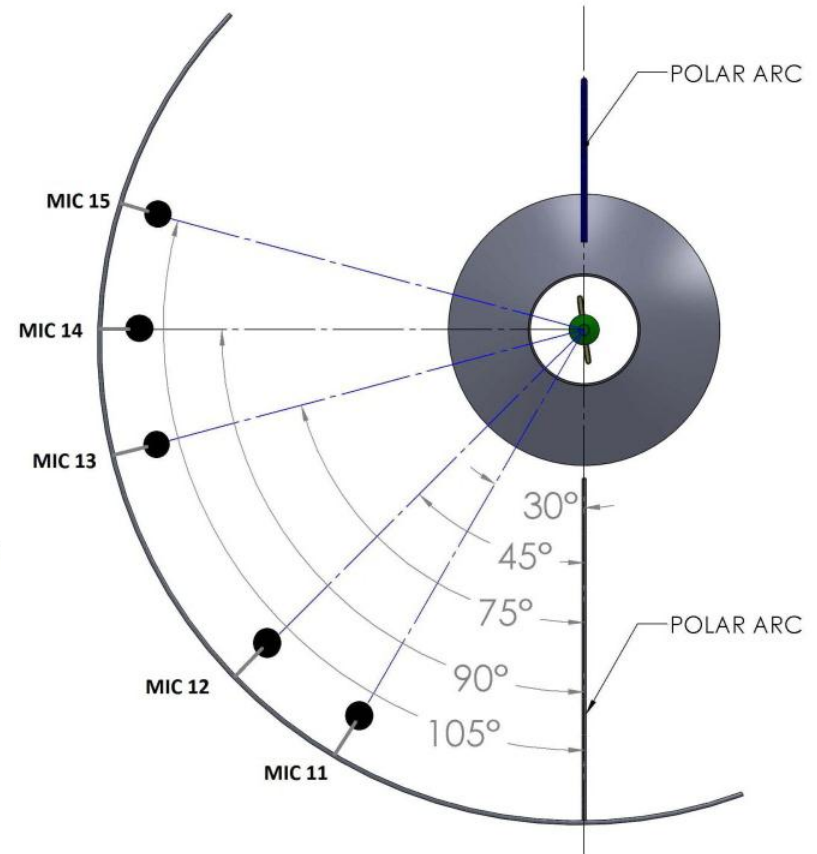
Isolated SRP Measurements

GTRI Measurement Locations

Polar Plane



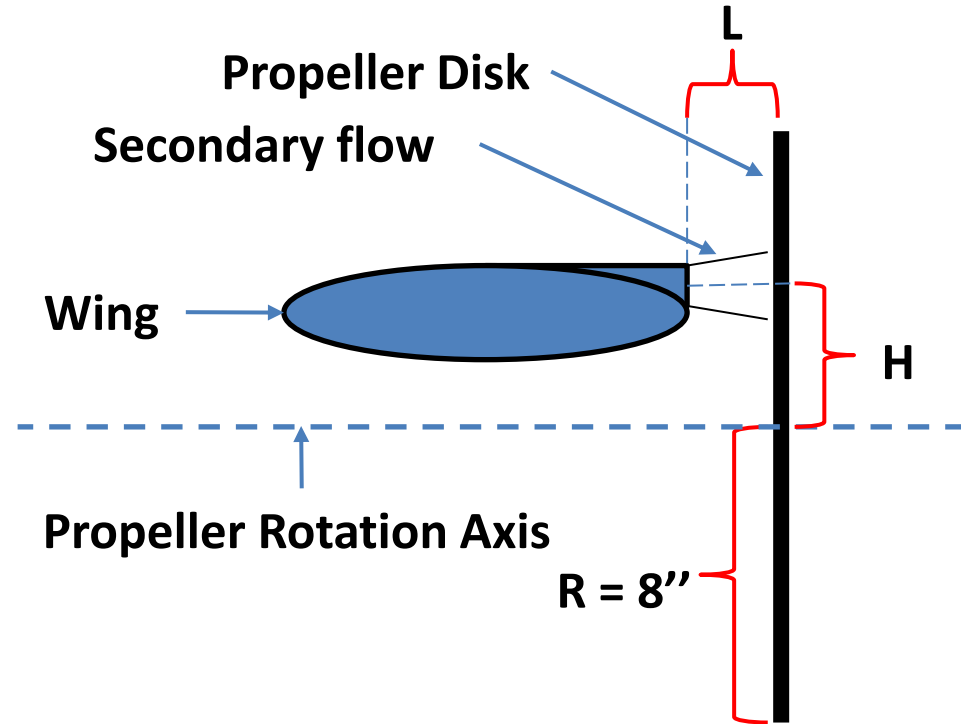
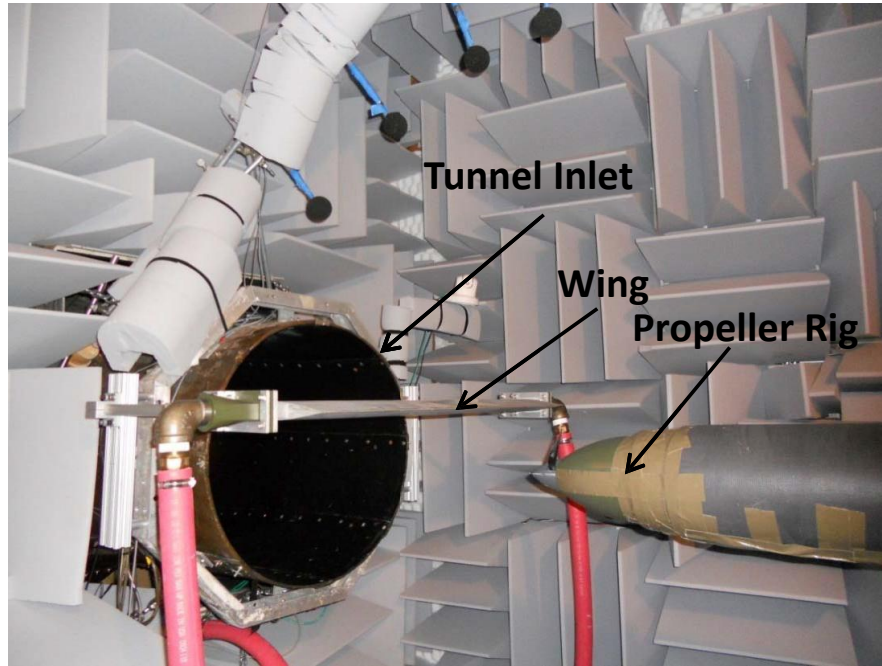
Azimuthal Plane



(GTRI: Young, Nance)



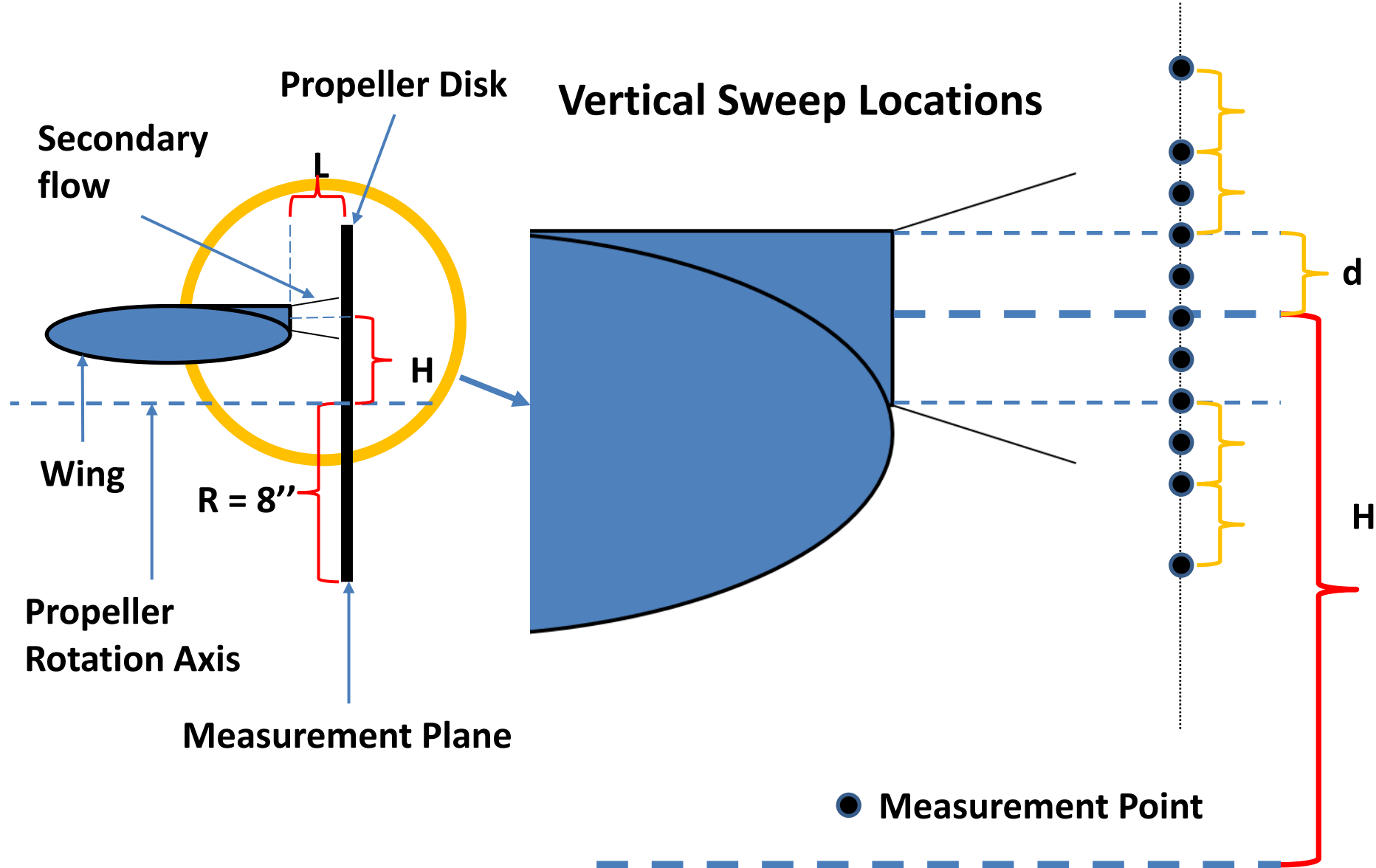
Installed SRP Measurements



Propeller Type	Number of Blades	Propeller RPM Range	Tunnel Flow Speed (Knots)	Secondary Flow Speed (knots)	L	H
16x14 Pro	3,4,5	4000 - Max	30, 60, 90	0, 150	0.75R	0.33R
16x14 Pro	3,4,5	4000 - Max	30, 60, 90	0,150	0.75R	0.75R
16x10 Pro	3,4,5	4000 - Max	60	0, 150	1.0R	0.33R
16x10 Pro	3,4,5	4000 - Max	60	0, 150	1.0R	0.75R

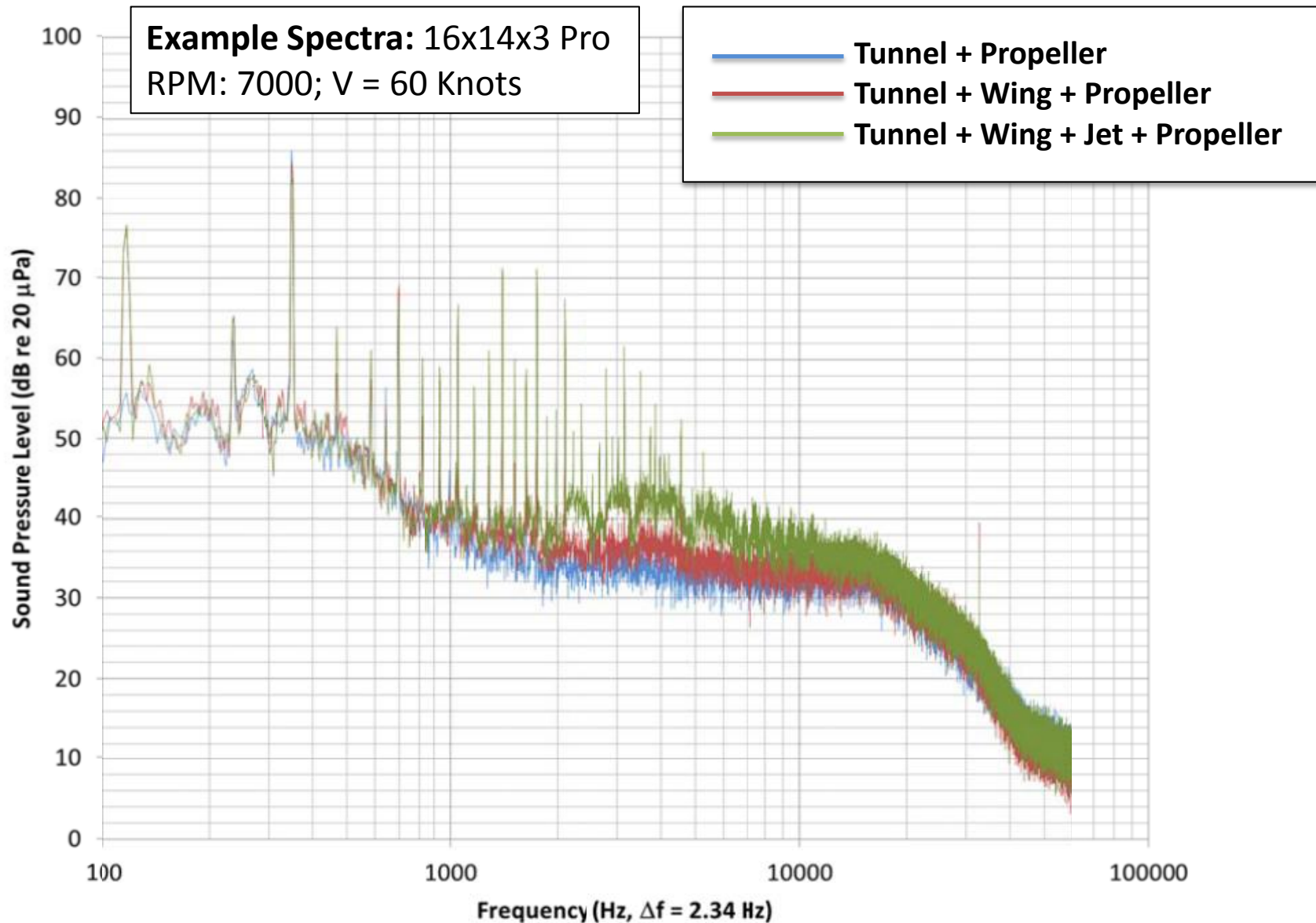


Installed SRP Measurements





Sample SRP Measurement





Isolated SRP Predictions

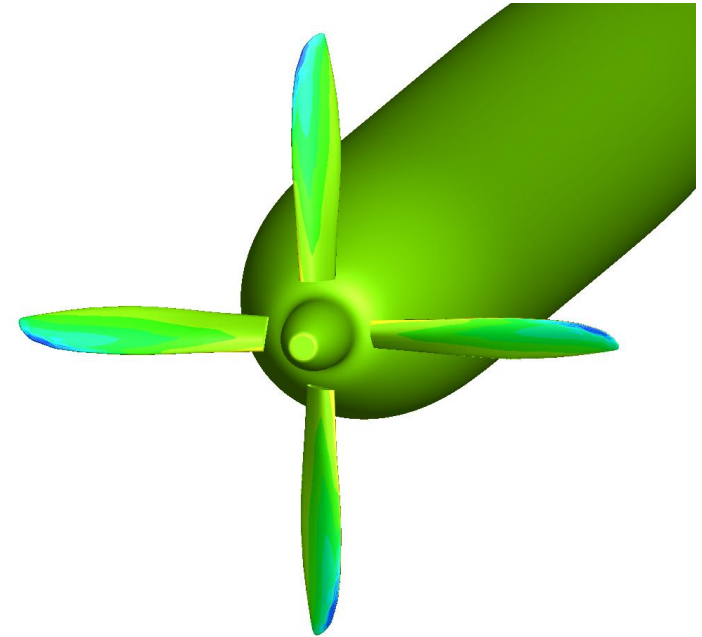
- **Blade scans complete**

- **Blade Loading**

- PAS
- SBAC
- OVERFLOW

- **Acoustics**

- PAS
- ASSPIN
- PSU-WOPWOP
- F1A



OVERFLOW Performance Predictions

Propeller Type D/P/B/Tip	Propeller RPM	T_{measured} (lbs)	τ_{measured} (ft-lbs)	η_{measured}	$T_{\text{predicted}}$ (lbs)	$\tau_{\text{predicted}}$ (ft-lbs)	$\eta_{\text{predicted}}$
16x10x3 Pro	9000	14.6	2.5	0.62	14.3	2.3	0.67
16x10x3 Square	9000	17.5	2.7	0.69	16.3	2.5	0.70
16x14x3 Pro	8000	20.6	4.0	0.62	19.9	3.8	0.63
16x14x4 Pro	7000	18.9	3.9	0.66	18.1	3.7	0.66



Installed SRP Predictions

Blade Loading

- UBAC
- OVERFLOW

Steady Blade Aerodynamics Code (SBAC)

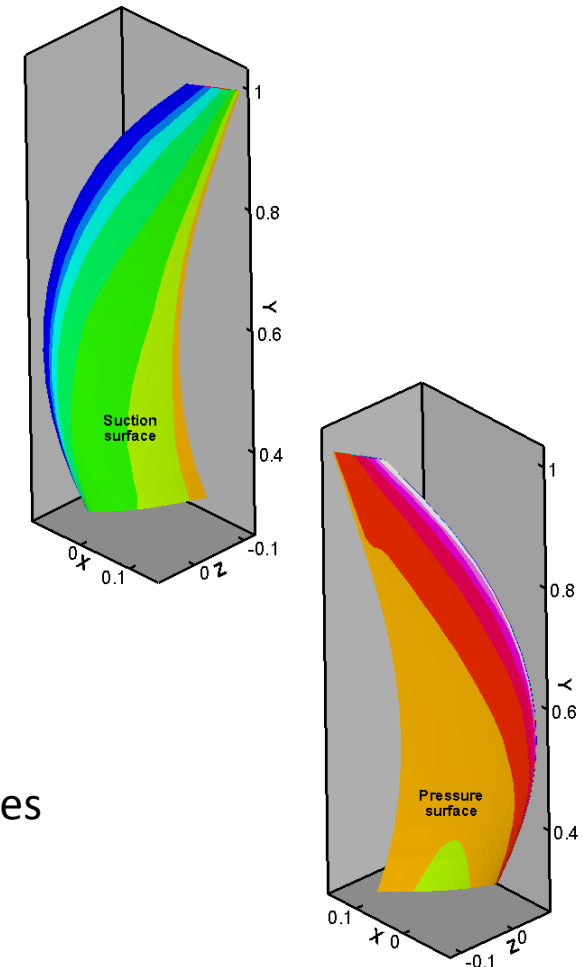
- Coupled blade element theory calculations and 2-D airfoil aerodynamics code are coupled

Unsteady Blade Aerodynamic Code (UBAC)

- Computes blade section response to periodic gusts
- Method based on thin airfoil perturbation theory of Sears
- Section unsteady lift coefficients written as Fourier time series

Acoustics

- ASSPIN
- PSU-WOPWOP
- F1A



Tinetti, AIAA 2012-2217



Isolated CRP Predictions

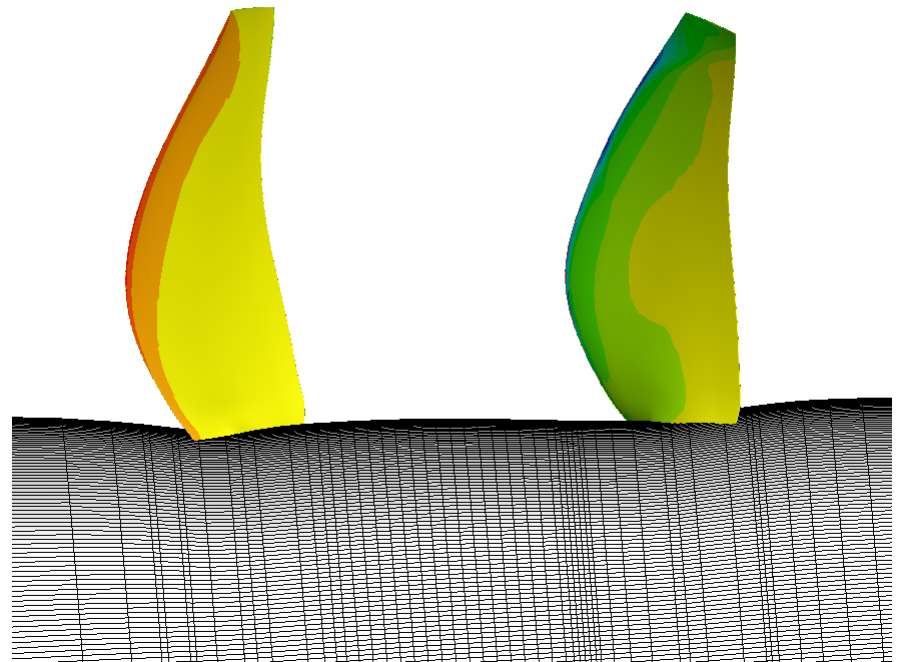
F31A31 Historical Baseline Blade Set

Blade Loading

- TURBO prediction courtesy Ed Envia
- FUN3D
- OVERFLOW

Acoustics

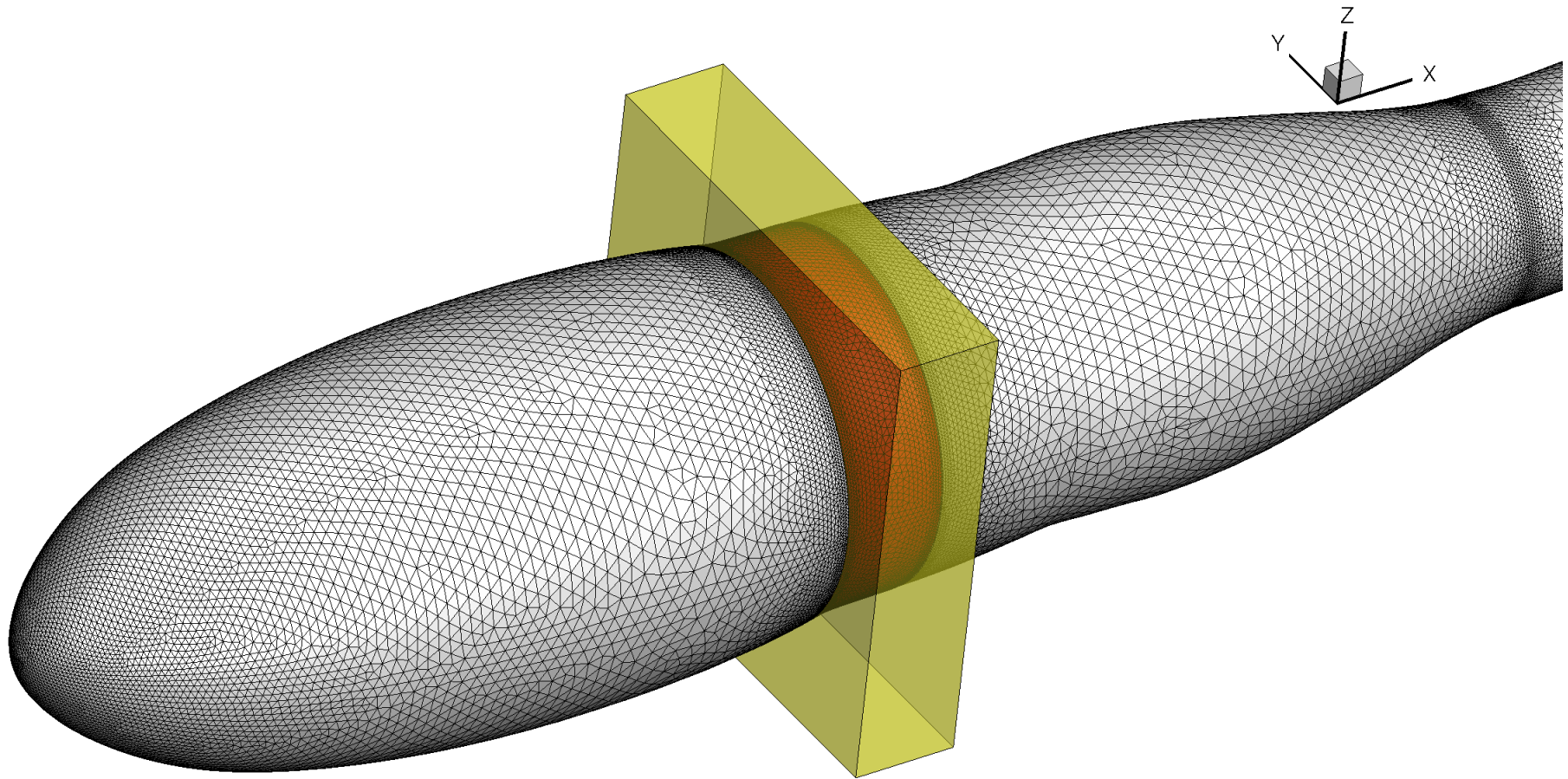
- F1A
- PSU-WOPWOP
- CRPFAN2/CRPCLD2





Isolated CRP Predictions

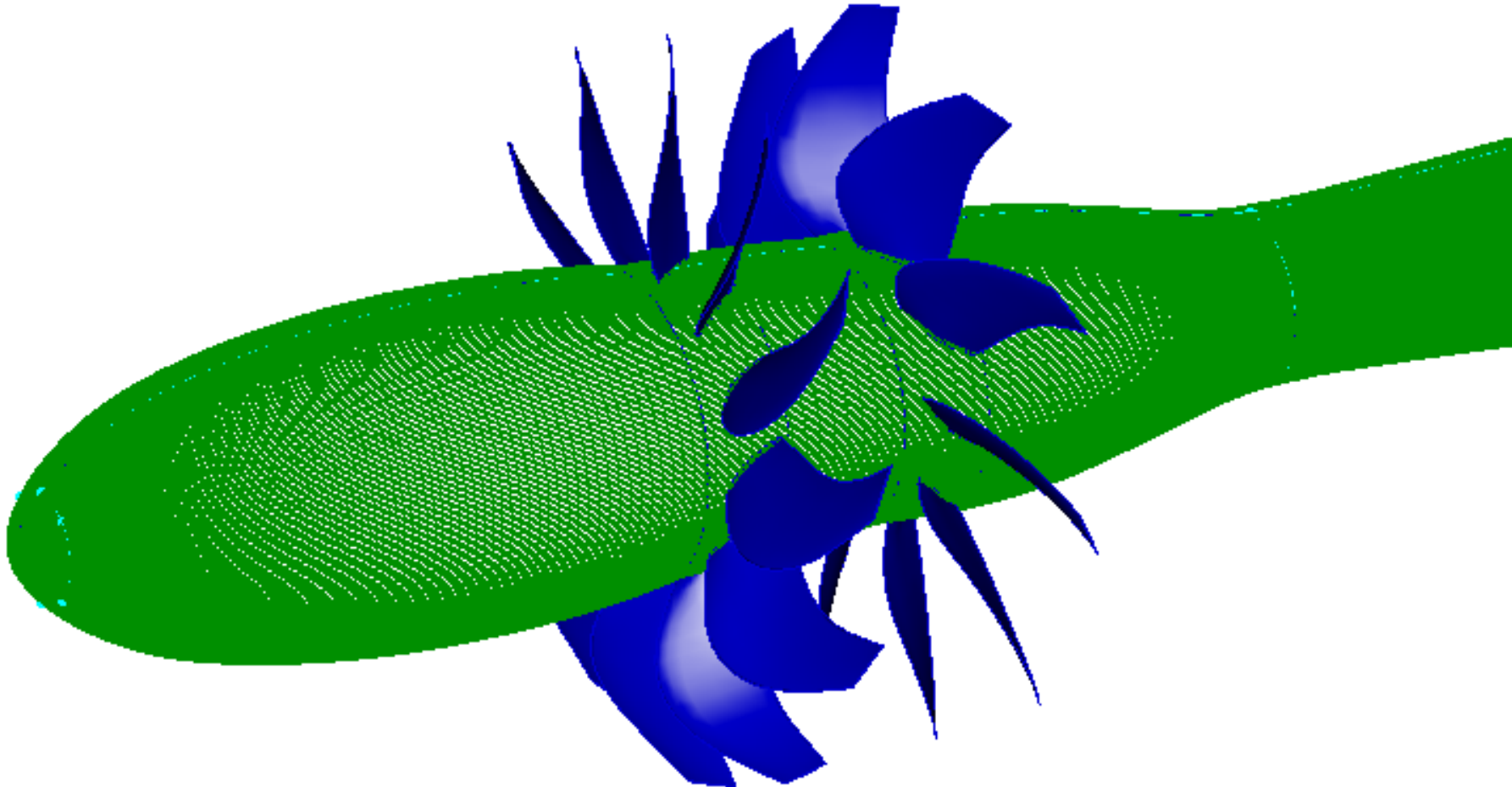
FUN3D Aerodynamic Predictions





Isolated CRP Predictions

OVERFLOW Aerodynamic Predictions



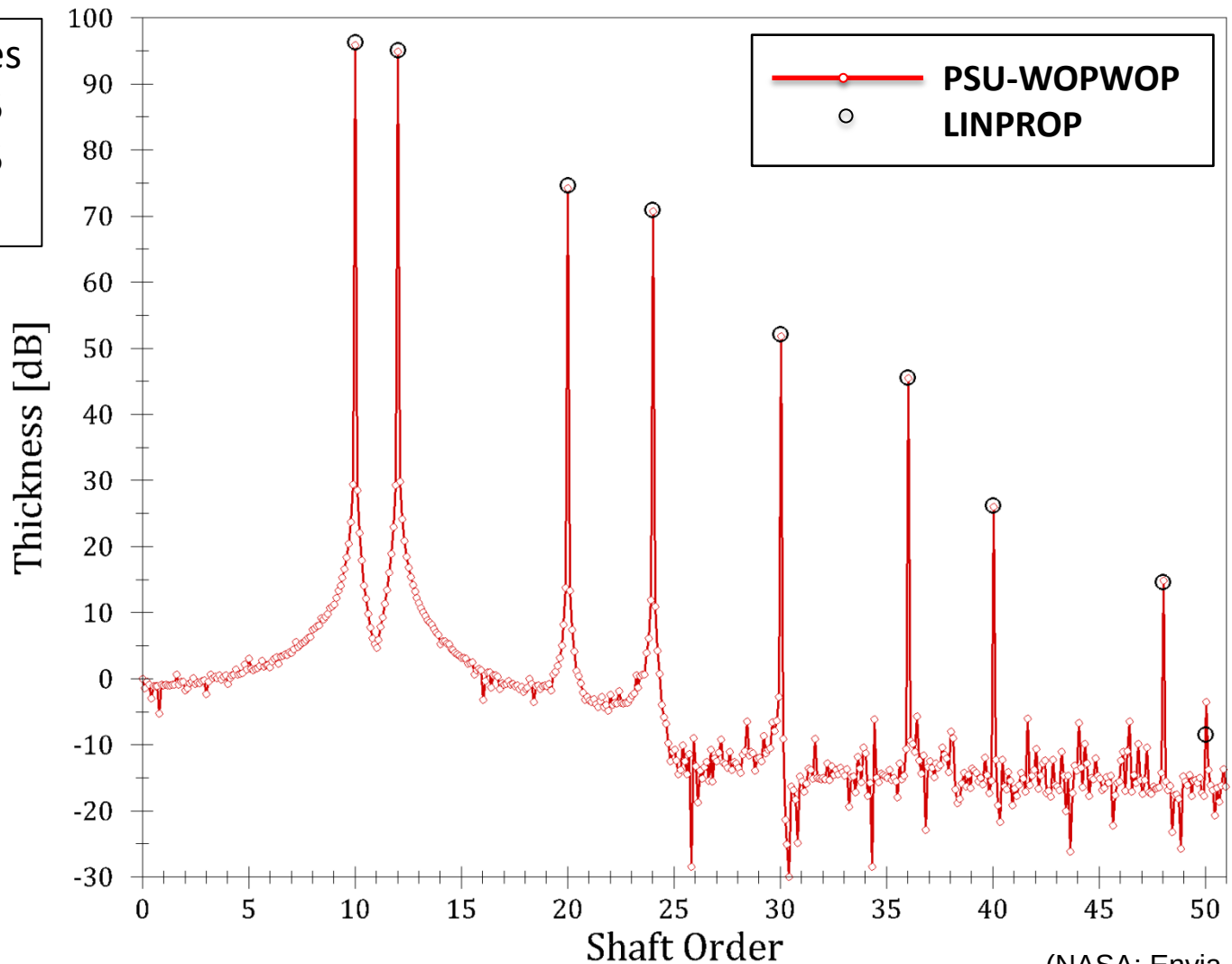
(NASA: Boyd, Nark)



Isolated CRP Predictions

Thickness Noise Predictions

12x10 Blades
RPM1: 6625
RPM2: 6625
 $M = 0.2$



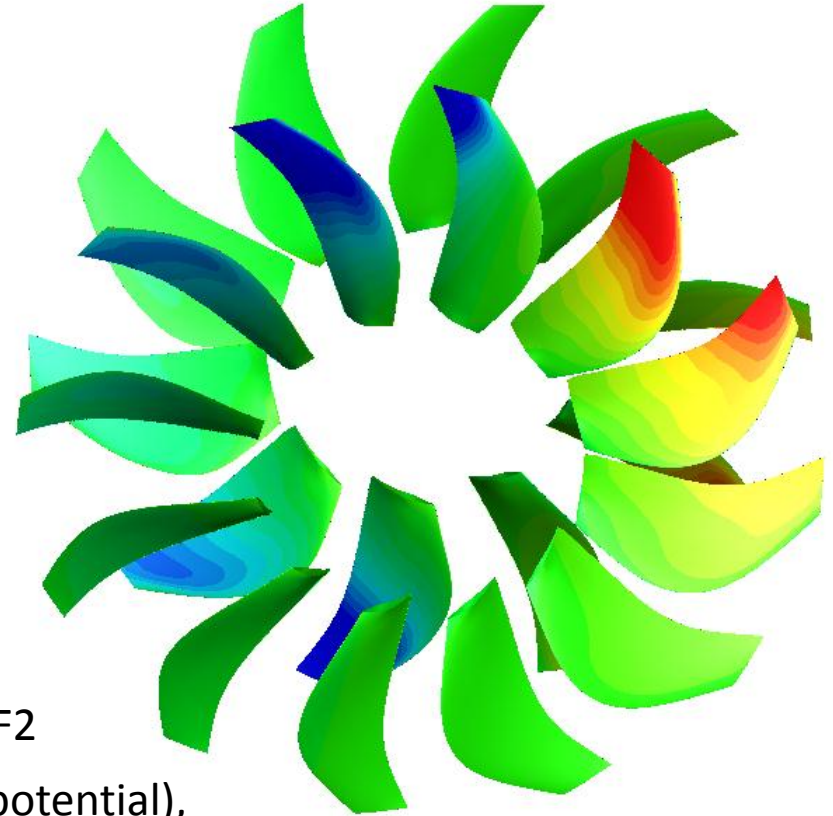
(NASA: Envia, Nark)



Isolated CRP Predictions

ANOPP2-F1A Module

- **Integral part of ANOPP2**
 - Farassat's Formulation 1A
 - Distributed with ANOPP2
 - Several options for efficiency and accuracy
 - Permeable and Impermeable surfaces
 - Deforming and Non-Deforming surfaces
 - Metadata Files for Analysis and Debugging
- **Plans for Suite of Formulations**
 - F1, G1, F1A (subsonic-tau), G1A (gradient), F2 (collapsing sphere), F2B (broadband & vel. potential), F3(supersonics-sigma surface)



(F1A Dev: Lopes)



Acoustic Scattering Predictions

Methods: Possible ANOPP2 Incorporation

Fast Scattering Code (FSC) (SFW NRA (end 2012): Dunn, POC: D. Nark)

- Can handle geometric details: i.e. edges, 'corners'
- No frequency restrictions other than resource limitations
- Application/validation on HWB: Broadband Engine Simulator (BENS) predictions
- Review: Wednesday, November 14, 2012 (1:00 PM ET) WebEx information available

Time Domain BEM : TDBEM (SFW NRA (end 2014): Hu, ODU, POC: D. Nark)

- Scattering solutions at all frequencies are obtained within one single computation
- Broadband noise sources and time dependent transient signals
- Review: Wednesday, October 24, 2012 (11:10 AM ET)

DIM2 (based on MIT diffraction integral method) (ERA funded, POC: Burley)

- Flat geometry, creeping ray effect modeled using Geometrical Theory of Diffraction for deep shadow region & wedge diffraction potential (transition region) (April 2012)
- Source (localized) description satisfies Helmholtz equation: spherical functions to define directional source (ex. Fan noise from Heidmann).



Acoustic Scattering Predictions

Fast Scattering Code

Computation Improvements

- Streaming I/O – run time reduction factor: 8
- Memory allocation approach – run time reduction factor: up to 18

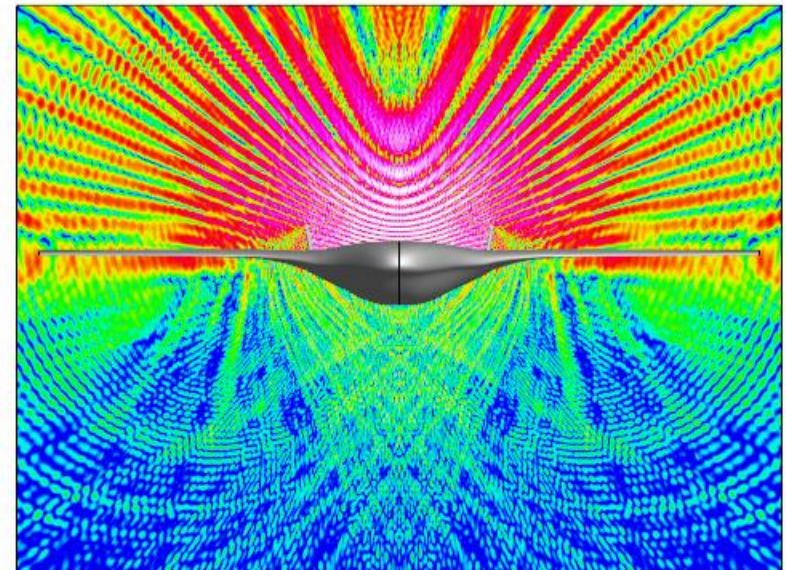
Generation and scattering of broadband noise

- Random-phase, prescribed amplitude
- Based on simple acoustic sources

Predictions for full configurations: N2A-exTE

- Symmetrically placed stationary monopole:
 $f = 20 \text{ kHz}$, $M = 0.0$
- 600 Westmere cores on NAS Pleiades

Plane at fin mid-chord



(FSC Dev: Tinetti, Dunn)

Tinetti, AIAA 2012-2075



Concluding Remarks

- **SRP Predictions**
 - GTRI isolated/installed measurements complete
 - Isolated predictions nearly complete
 - Anticipate technical publications
- **CRP Predictions**
 - Excellent agreement on thickness noise prediction across codes
 - Comparison of total noise underway
 - Initiated FUN3D and OVERFLOW calculations
- **Acoustic Scattering Predictions**
 - Several approaches under investigation
 - Validation through benchmark studies (*e.g.*, sphere, NASA TP-1040)
 - Installed SRP predictions provide unique database



Backup Slides



Acoustic Prediction Approach



Geometry &
Operating Condition

Aerodynamic
Simulation

Noise Source
Predictions

Airframe Scattering
& Shielding Prediction

Atmospheric
Propagation
Modeling

Noise Metric
Prediction

Cabin Noise
Prediction

NASA LaRC Code Toolbox

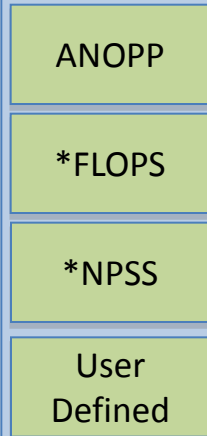
- ASP Tools, FLOPS, NPSS
- ANOPP(2), OVERFLOW, FUN3D, panel methods
- ANOPP(2), jet, fan, core, airframe, duct, rotor, etc
- FSC, TDBEM, DIM2, semi-empirical
- APET (GFPE, Curved Ray), RNM
- ANOPP, APET, RNM/AAM
- SEA/FEM



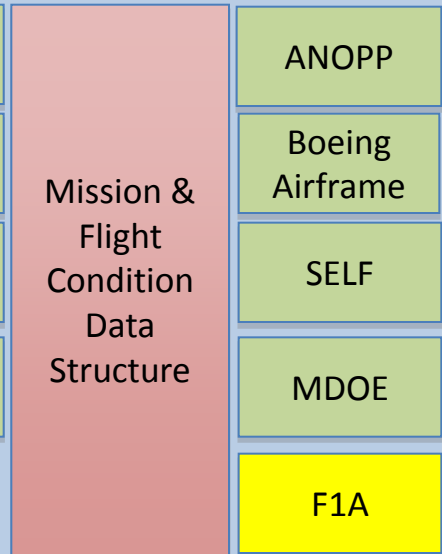
ANOPP2 “Floor Plan”

Command Executive

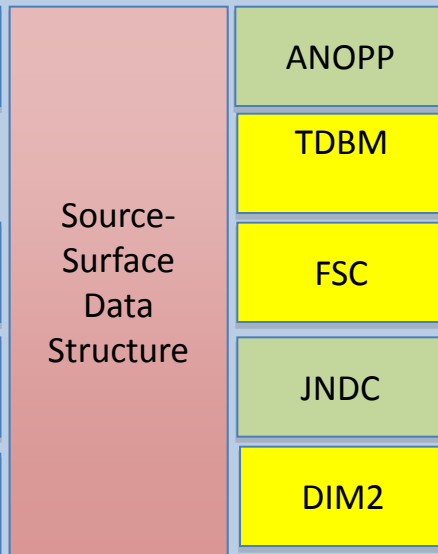
Flight Definition



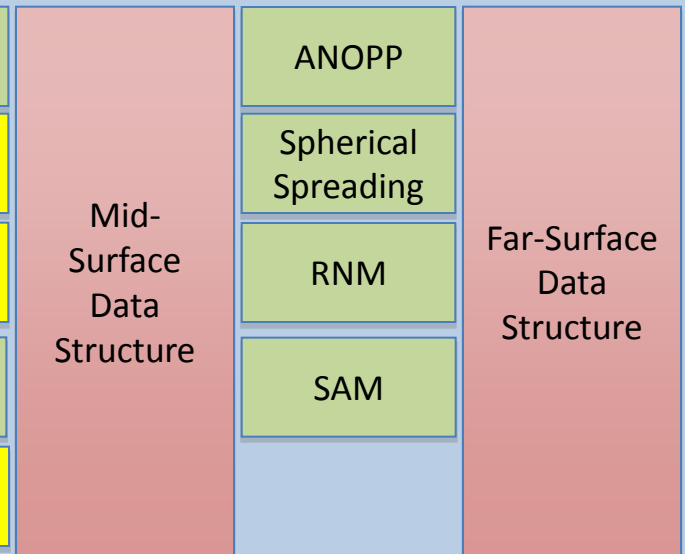
Source Noise



Source-Surface Propagation



Mid-Surface Propagation



Utilities & (APIs)

