



AATT Propulsion/Airframe Aeroacoustics Overview

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**Fall Acoustics Technical Working Group Meeting
Cleveland, OH**

October 20-21, 2015



Outline

- Background
- MIT D8.5 Noise Assessment Update
- Research Areas
 - Wake Effects on Shielding/Scattering
 - Propulsion Source Shielding/Scattering
 - External Acoustic Liners
 - Shielding/Scattering Prediction Method Validation
- Concluding Remarks

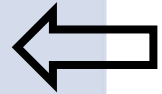


Background

RT 3: Technical Content

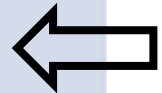
Propulsion

- Propulsor (potentially in distorted inflow)
- Core (combustor & turbine)



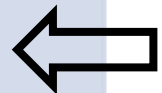
Airframe

- Lifting components
- Landing components



Propulsion/Airframe Aeroacoustics

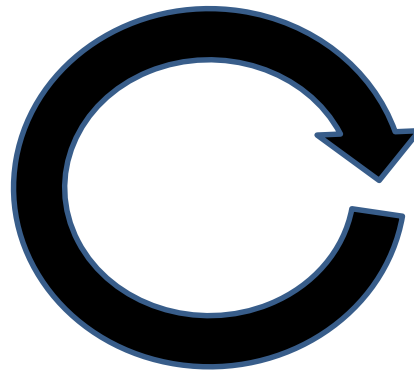
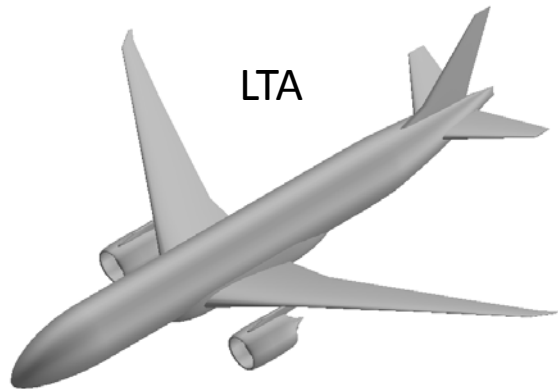
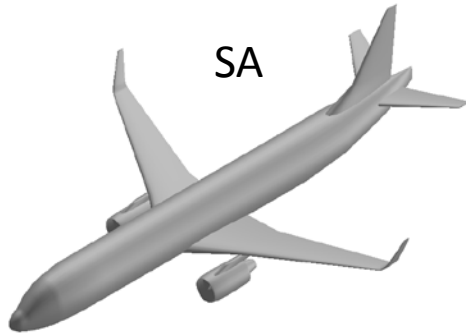
- Installation Effects on Noise Sources
- Shielding/Scattering



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Background

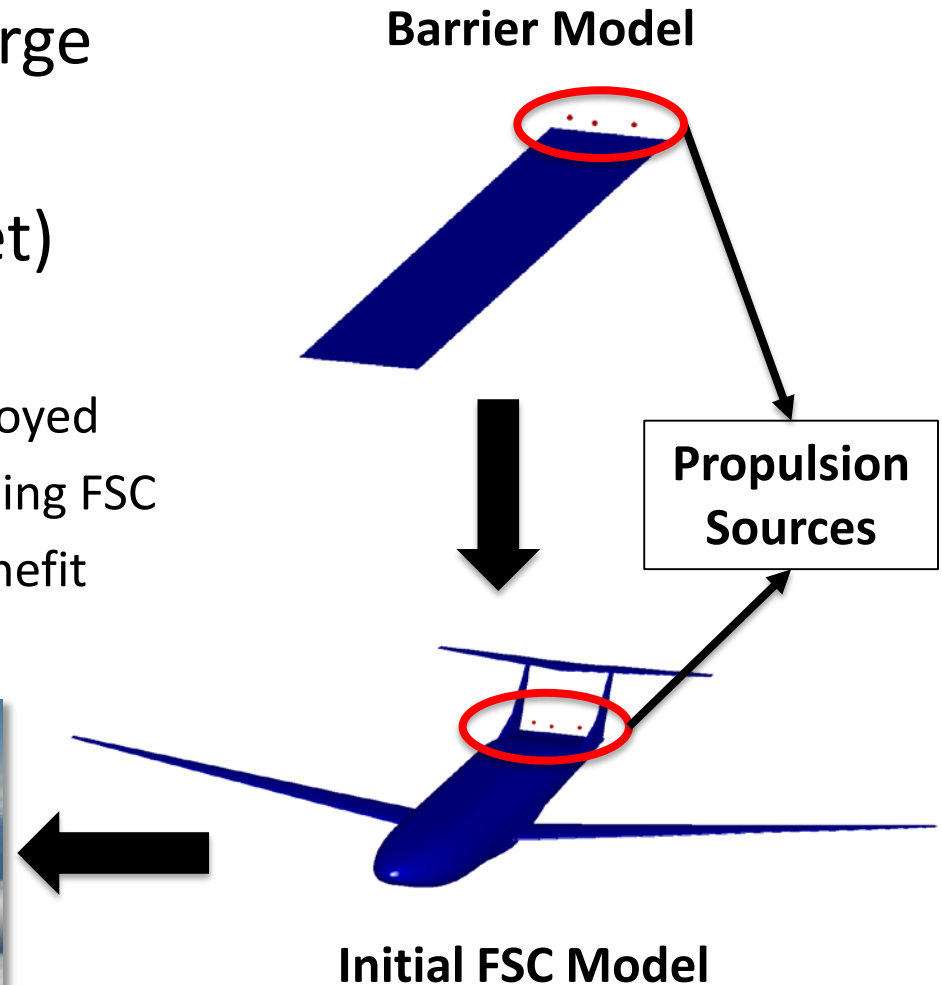


- Develop noise reduction technologies addressing vehicle integration
- Assess system noise impact of component noise reduction technologies



MIT D8.5 System Noise Assessment

- Shielding can constitute a large portion of Stage 4 margin
- Work from initial D8.5 (tri-jet) assessment by Berton
 - ANOPP barrier model initially employed
 - Create ANOPP suppression table using FSC
 - Quantify effect on system noise benefit

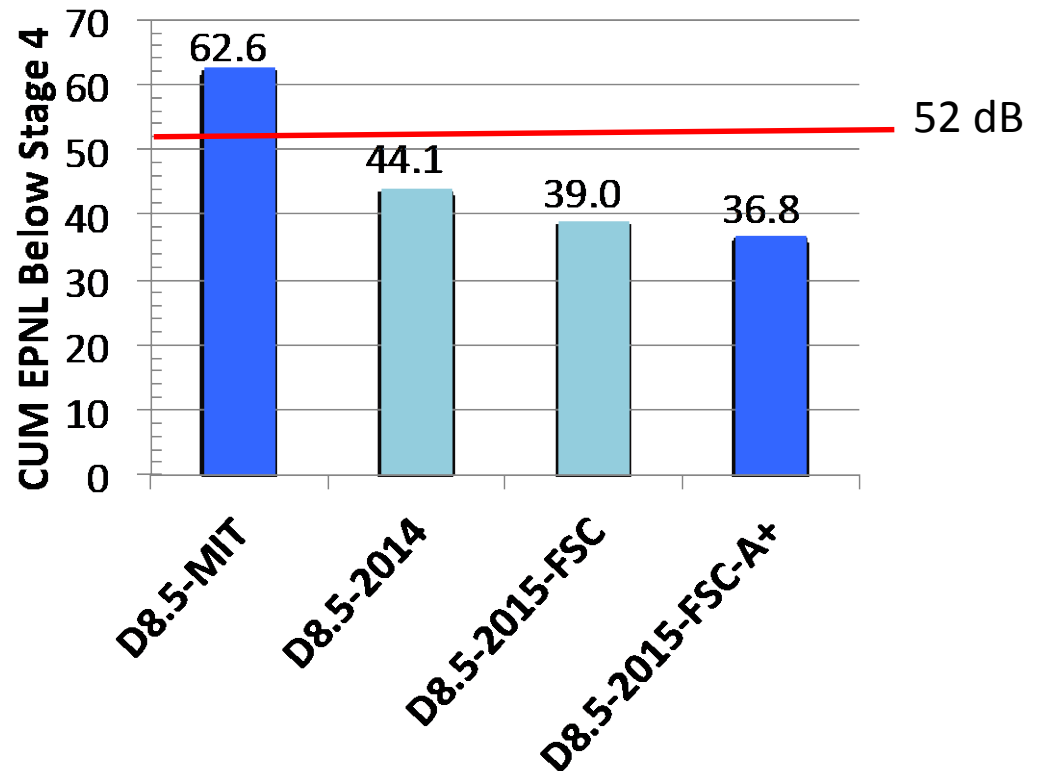
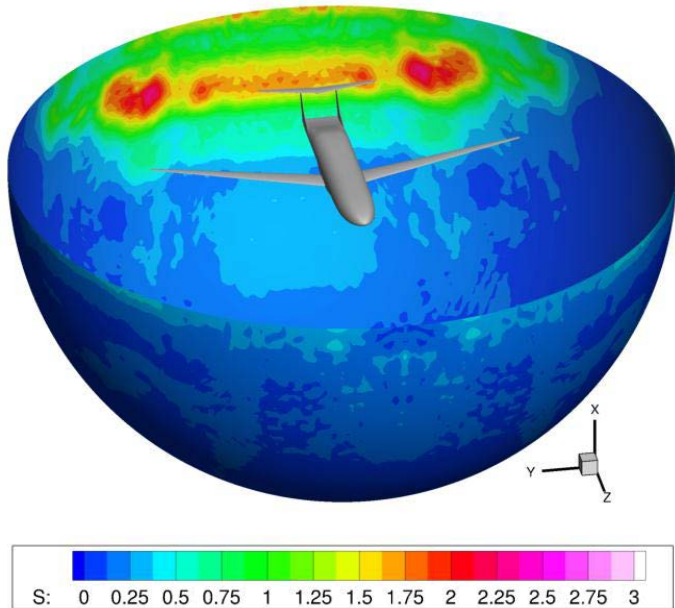




MIT D8.5 System Noise Assessment

NASA systems analysis on the MIT D8.5 configuration - update Sept 2015

- Fast Scattering Code (FSC) for shielding/scattering predictions
- Updated fan and airframe source level predictions



NASA Team: Berton, Burley, Guynn, Nark, Welstead

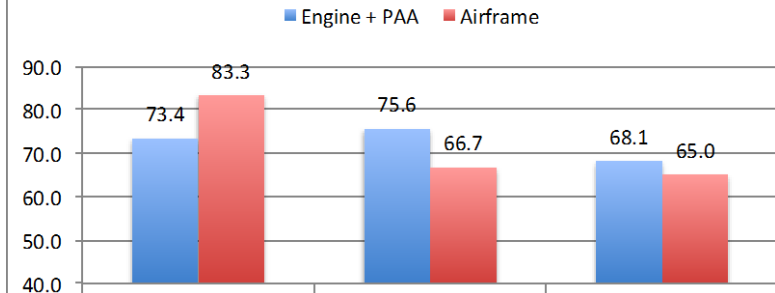


MIT D8.5 System Noise Assessment

Progression

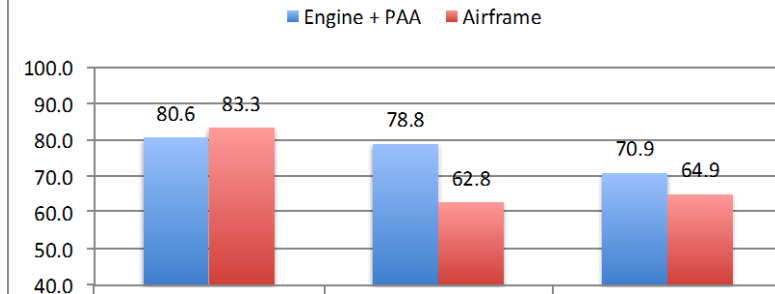
- ANOPP-L30
- Shielding predicted via ANOPP-WING
- Engine and Airframe via simplest ANOPP modules

D8.5-2014-WING



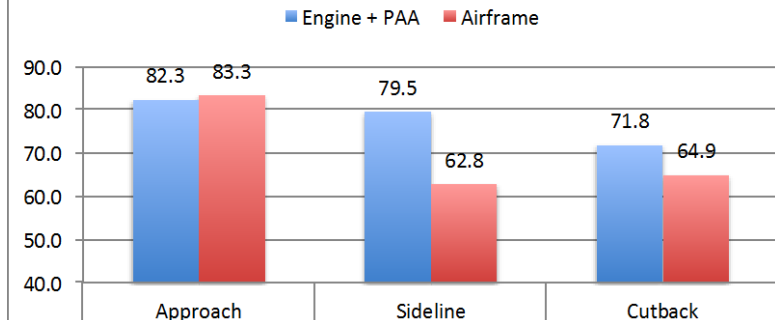
- ANOPP-L31.v1
- Shielding/reflection predicted via FSC and input to GENSUP
- Airframe via higher fidelity ANOPP modules

D8.5-2015-FSC



- ANOPP-L31.v1+
- Shielding/reflection predicted via FSC and input to GENSUP
- Fan via calibrated, higher fidelity ANOPP modules

2015-FSC-A+





System Noise Assessment Remarks

The NASA noise assessment team continues to pursue:

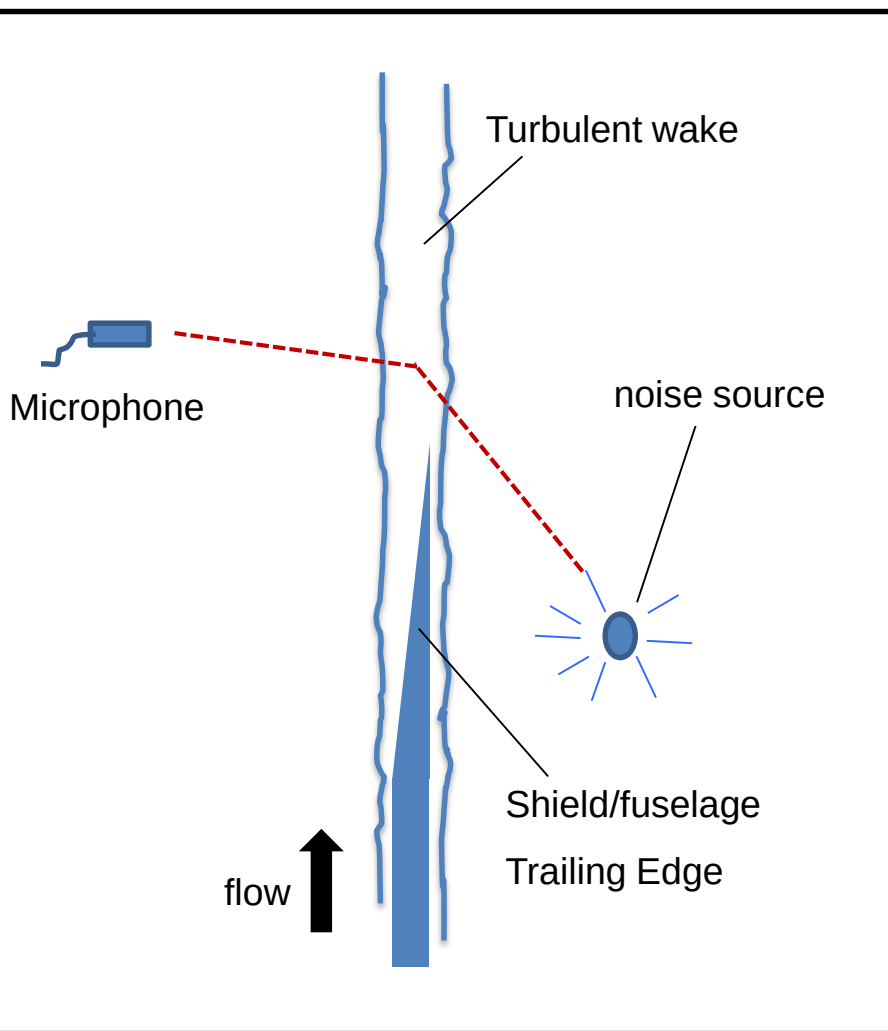
- Incorporation of higher fidelity tools
 - Improvement of assessment methods
 - Identification of remaining gaps/challenges
- } where applicable

Gaps in capabilities/understanding required to advance assessments

- Propulsion/airframe integration constraints for viable conceptual aircraft
- Engine source ranking for UHB engines
- Geared TurboFan (GTF) fan source prediction from data
- Ultra-High Bypass Ratio (UHB) fan noise method
- Acoustic liner methods
- Propulsion noise shielding (versus existing databases)



Wake Effects on Shielding/Scattering



Scattering of sound through a turbulent wake

Near-wake affects noise shielding

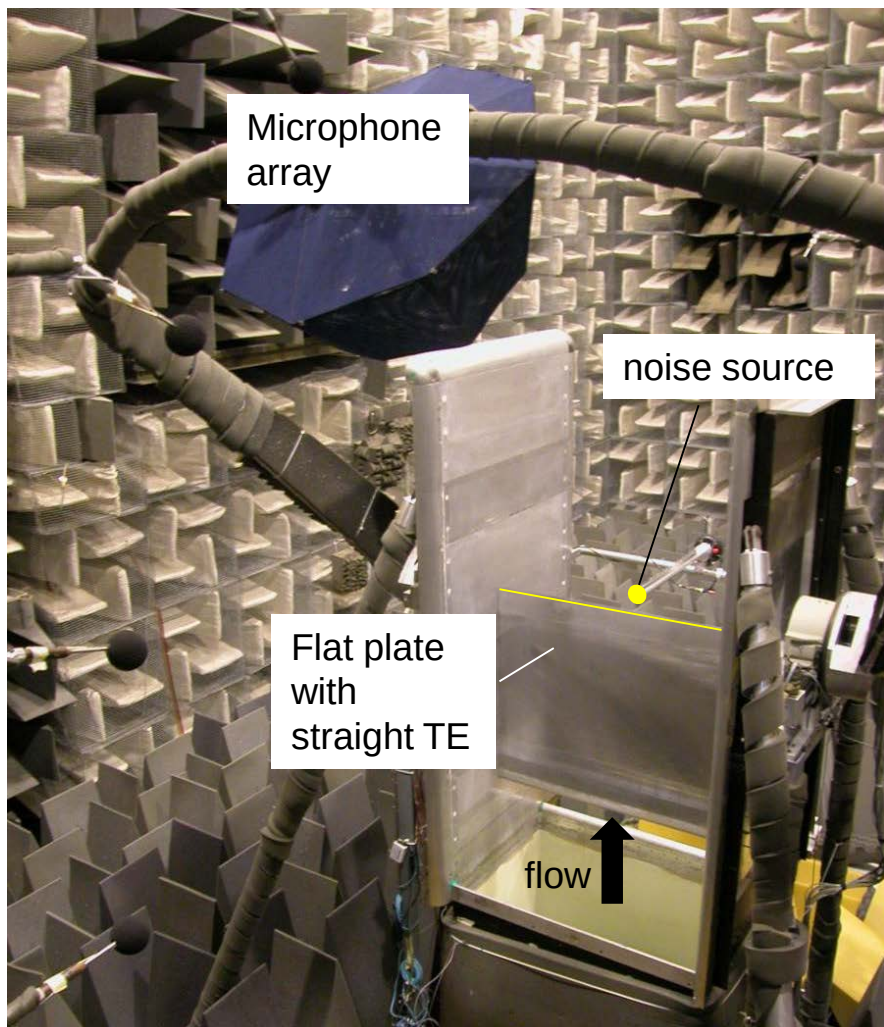
- Current prediction models do not account for the effect of the near-wake on noise scattering

Develop/validate empirical correction

- Add to ideal (no-flow or uniform flow medium) noise-shielding solutions subjected to turbulent flows in the aft near-wake



Wake Effects on Shielding/Scattering



Quiet Flow Facility (QFF) test section

Approach

- Establish effect of the near-wake on noise scattering from the analysis of the QFF shielding test data.

Status

- Empirical model was developed.
- QFF shielding test data were analyzed for plates (shields) of 3 different trailing edge thicknesses.
- Correction equation were established based on parameters of flow velocities, frequencies, and boundary layer/near-wake parameters.

Brooks, Plassman, Hutcheson, Burley



Incident Source Directivity Effects

Consider incident acoustic field from various propulsion sources

- 14x22 HWB test: Broadband Engine Simulator (BENS)
- Podded engine configuration: Turbofan source
- Open Rotor: F31A31 Historical Baseline



Van Zante *et. al.*: ISABE-2011-1310, Stephens and Envia: AIAA Paper 2011-2940, Envia: CMFF '12



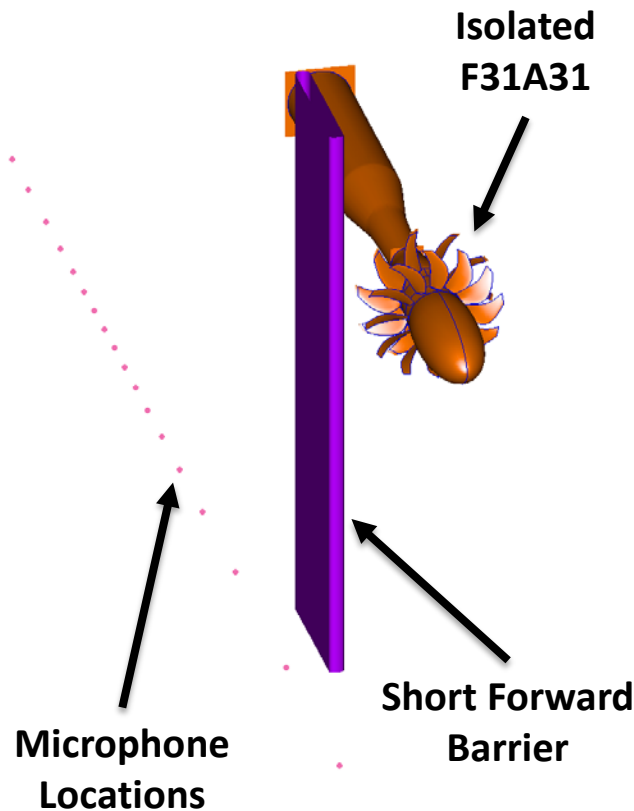
Incident Source Directivity Effects

Prediction Approach

Blade Loading: OVERFLOW (OF), FUN3D

Acoustics: ASSPIN, PSU-WOPWOP (PSW), F1A

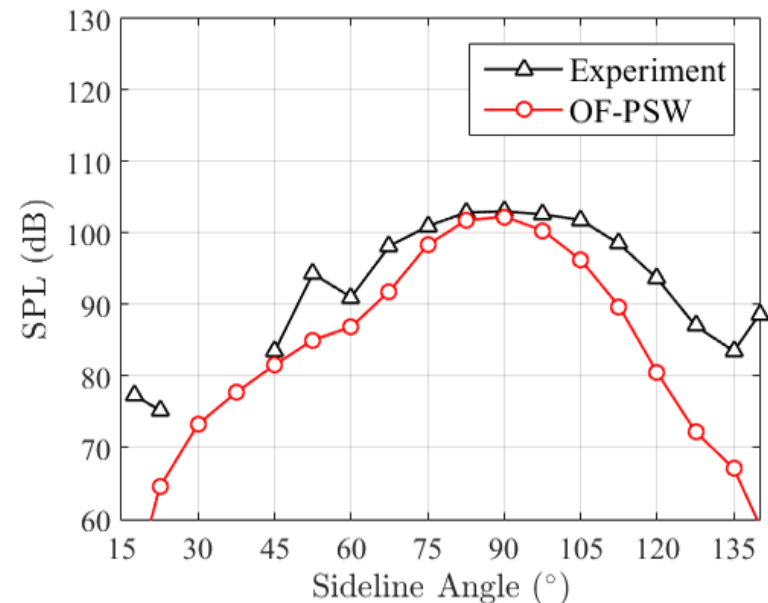
Shielding/Scattering: FSC, TD-FAST



Predicted Cp contours (Isolated)



BPF: Forward Blade Row (Isolated)





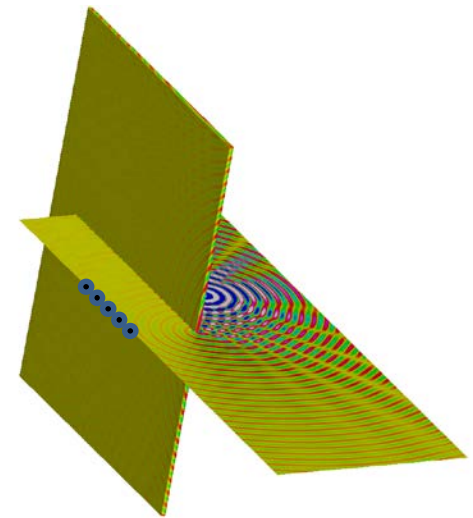
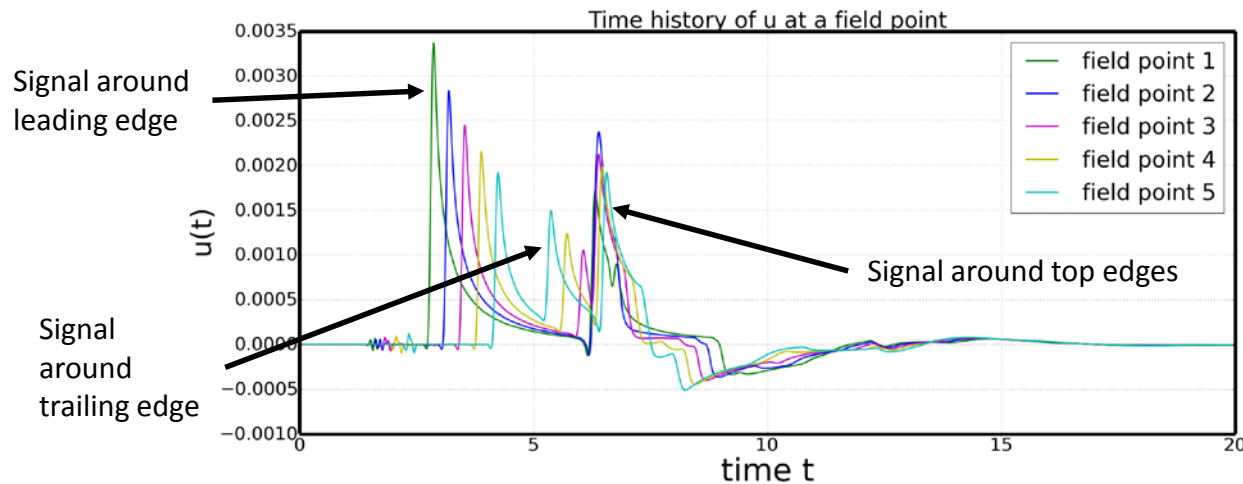
Incident Source Directivity Effects

“Fast and efficient computation of acoustic scattering and its application to aircraft noise prediction”

PI: Fang Hu, TM: Doug Nark, NNX11AI63A

Time Domain Integral Method (TD-FAST)

- Forward and aft barrier configurations run on the NASA Pleiades GPUs
- Single point source initially used to simulate the propulsion source
- Barrier length effects assessed to determine geometry requirements for comparison with Fast Scattering Code (FSC) predictions and measured data
- Formulation/implementation of the acoustic treatment boundary conditions underway



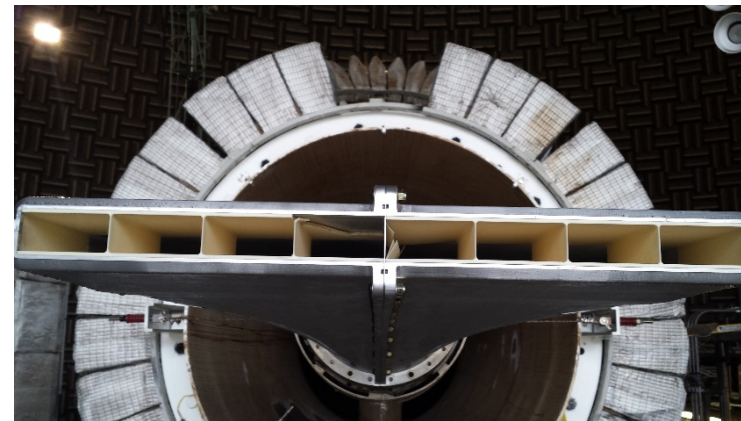
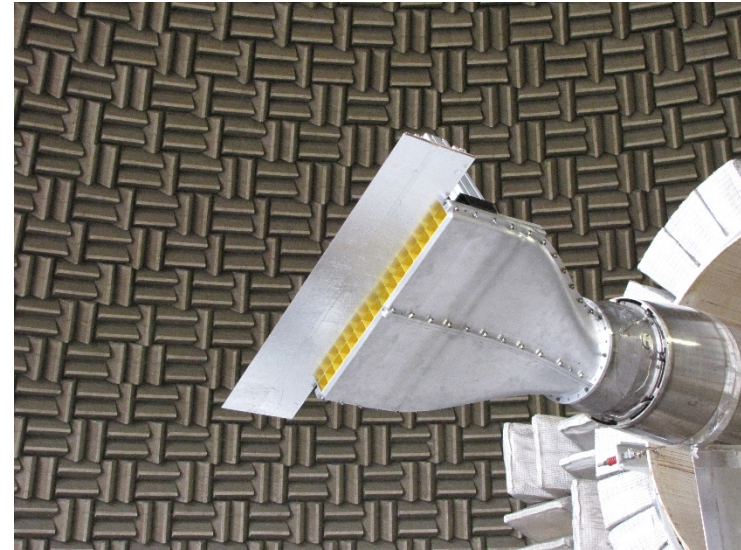


Propulsion Source Shielding/Scattering

Jet-Surface Interaction Test (JSIT)

JSIT began at AAPL facility

- Aluminum 16:1 aspect ratio nozzle with septa insert
- Far-field noise data acquired at flow Mach numbers 0.5, 0.6, 0.7, 0.8, and 0.9
- Total pressure scan acquired at nozzle exit near the edges at Mach numbers 0.5 and 0.9
- Preliminary analysis of the pressure data shows good comparisons to the CFD used to design the nozzle and round-to-rectangular transition
- Cliff Brown and Vance Dippold presentations provide further details

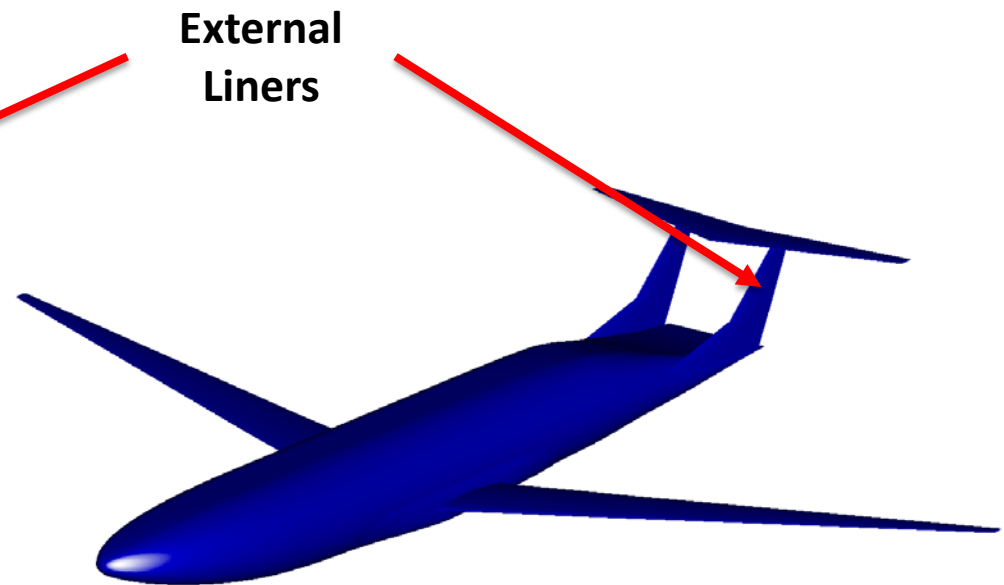
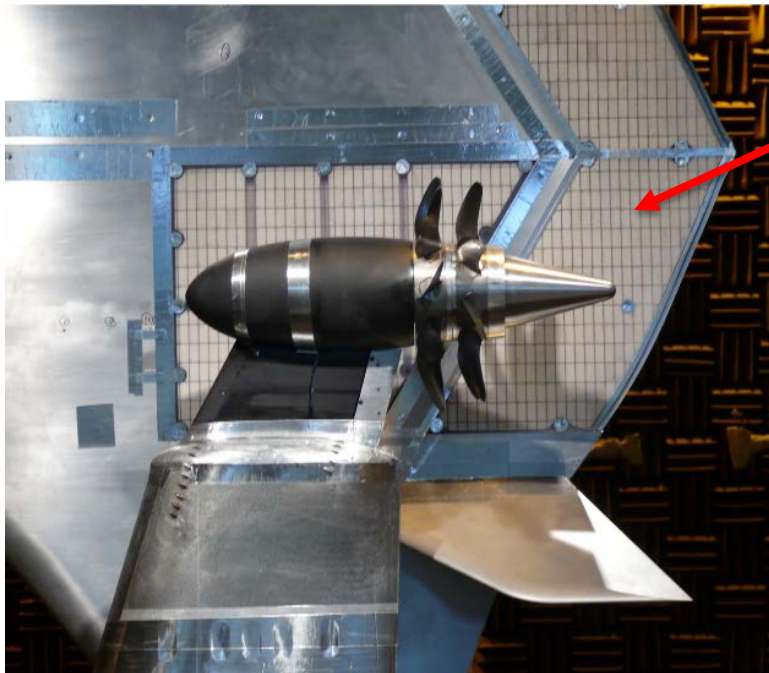




External Acoustic Liners

Couple with work on adaptive low-drag liners

- Assess system benefit with updated suppression tables (accounting for liners)
- Adaptation on impedance and/or drag metrics
- Optimize liner location based on source and liner characteristics



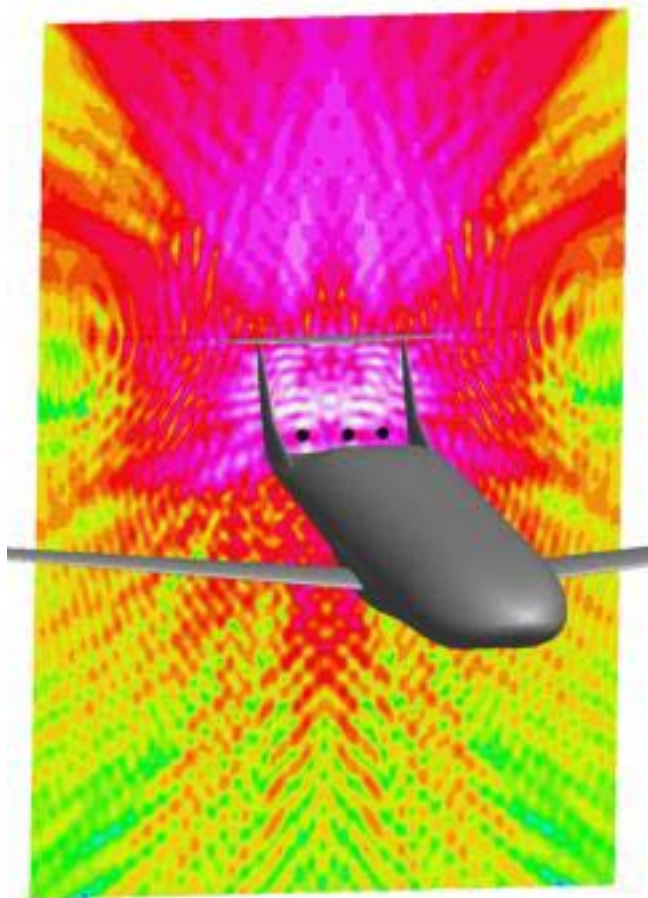
External
Liners



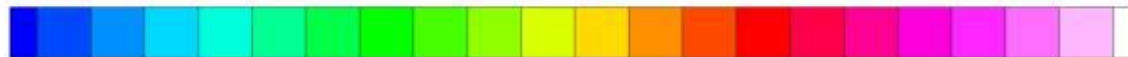
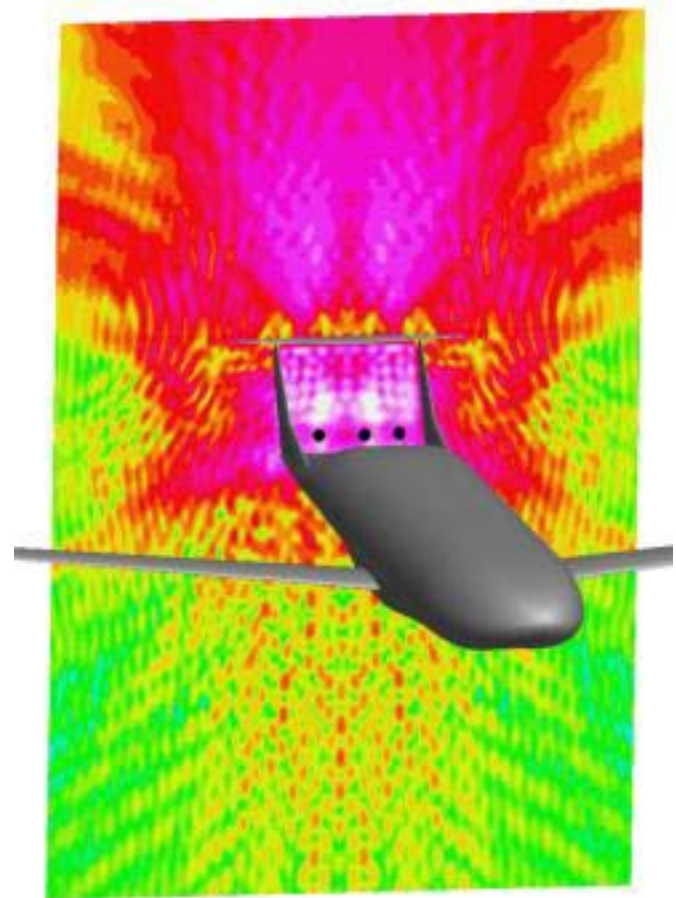
MIT D8.5 System Noise Assessment

Total Acoustic Field: $f = 500$ Hz, $M = 0.23$

Baseline



Acoustically Treated Tail



SPL: 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70



Prediction Method Validation

Shielding test in QFF with NACA0012 airfoil – FY16

Unique well-defined, non-intrusive, laser-induced, monopole source

- **non-intrusive:** Capture effects of flow on shielding without perturbing the flow
- **well-defined:** Accurately modeled by point monopole in computational codes

Noise scattering predictions of QFF configuration for comparison with experimental data

- ANOPP-WING
- Kirchhoff Integral Method (KIM)
- Fast Scattering Code (FSC)
- Time Domain Integral Method (TD-FAST)



Increasing Fidelity/Complexity



Concluding Remarks

Develop noise reduction technologies addressing vehicle integration

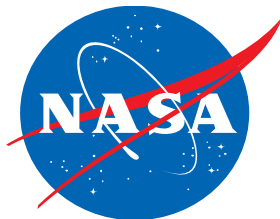
- Wake Effects on Shielding/Scattering
- Propulsion Source Shielding/Scattering
- External Acoustic Liners
- Shielding/Scattering Prediction Method Validation

Assess system noise impact of component noise reduction concepts



Acknowledgements

- Jeff Berton (NASA): ANOPP (AATT)
- Doug Boyd (NASA): Overflow (RVLT)
- Casey Burley (NASA): ANOPP (AATT)
- Fang Hu (ODU): TD-Fast (TTT NRA)
- Florence Hutcheson (NASA): QFF (AATT)
- Bill Jones (NASA): FUN3D (AATT)
- Len Lopes (NASA): ANOPP2 (RVLT, TTT)
- Russell Thomas (NASA): QFF (AATT)
- Ana Tinetti (AS&M): FSC (AATT)
- Nik Zawodny (NASA): Overflow (AATT)

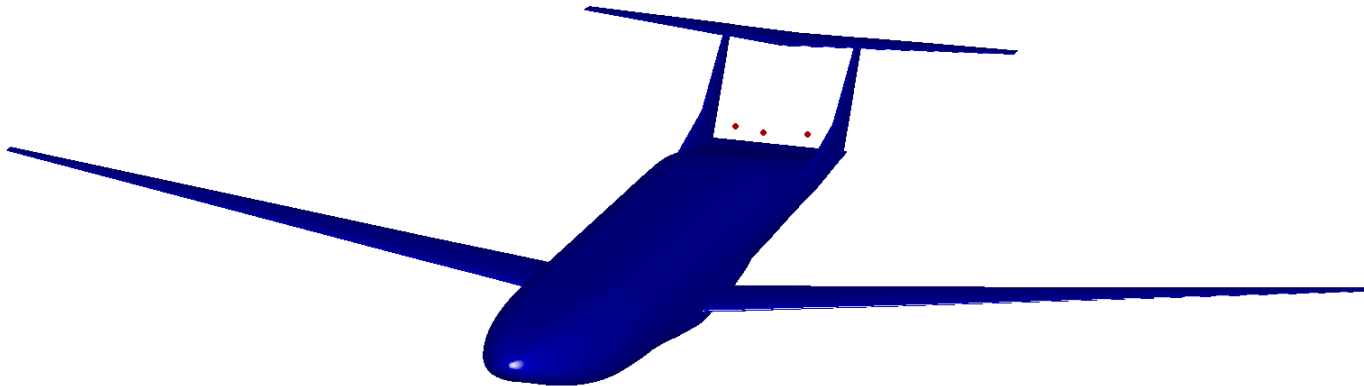




MIT D8.5 System Noise Assessment

Suppression Table Generation using FSC

- Suppression Factor, $S(f, \theta, \varphi) = 10^{\frac{\Delta dB}{10}}$
 - $\Delta dB = SPL_{\text{shielded}} - SPL_{\text{unshielded}}$
- Predictions combined for each 1/3-octave band





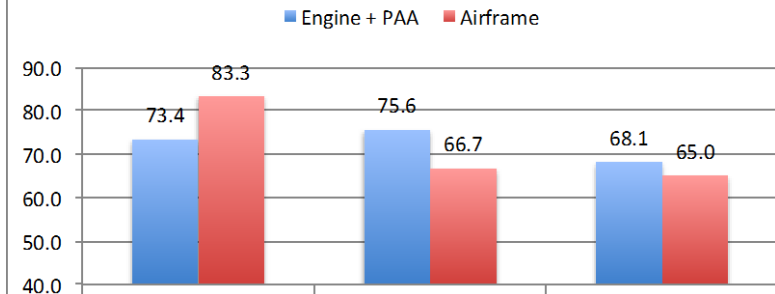
MIT D8.5 System Noise Assessment

- ANOPP-L30
- Shielding predicted by WING
 - Fan and core
- Fink for all airframe sources
- Used SAELAT on all sources

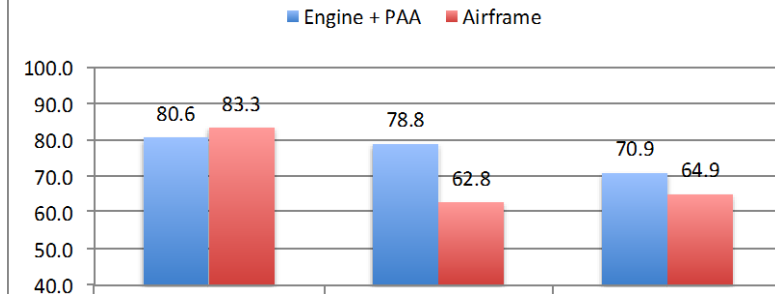
- ANOPP-L31.v1
 - Update BAF-flap (2009)
 - Update BAF-slat (2010)
- Shielding/reflection predicted by FSC and input to GENSUP
 - Fan and core
 - Jet (probably underpredicts actual installed jet noise)
- Did not use SAELAT

- ANOPP-L31.v1
 - Updated BAF-LG amplitudes
 - Updated Krejsa fan noise amplitudes
- Shielding/reflection predicted by FSC and input to GENSUP
 - Fan and core
 - Jet (probably underpredicts actual installed jet noise)
- Did not use SAELAT

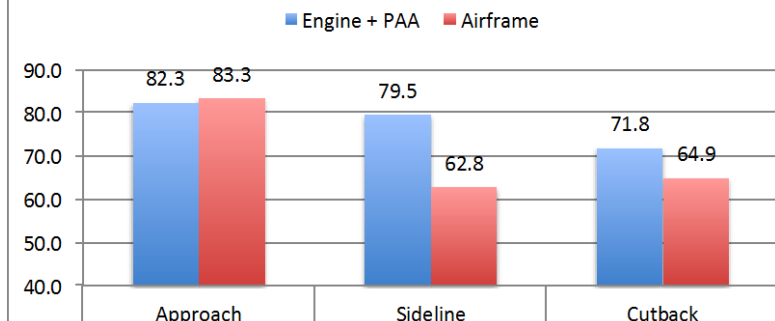
D8.5-2014-WING



D8.5-2015-FSC



2015-FSC-A+





Scattering/Shielding Methods

ANOPP: WING module

- Zorumski, W., "Aircraft Noise Prediction Program Theoretical Manual," NASA TM-83199, 1982.

DIM3 (based on MIT diffraction integral method) (ERA: PI: [Spakovszky](#), POC: [Burley](#))

- Colas, D., "A Diffraction Integral Based Turbomachinery Noise Shielding Method," PhD dissertation, Massachusetts Institute of Technology, 2011.

Fast Scattering Code (FSC) (SFW NRA (ended 2012): PI: [Dunn](#), POC: [Nark](#))

- Dunn, M., and Tinetti, A. F., "Aeroacoustic Scattering Via the Equivalent Source Method," AIAA 2004-2937.
- Tinetti, A., and Dunn, M., "The Fast Scattering Code (FSC): Validation Studies and Program Guidelines," NASA CR-2011-217158.

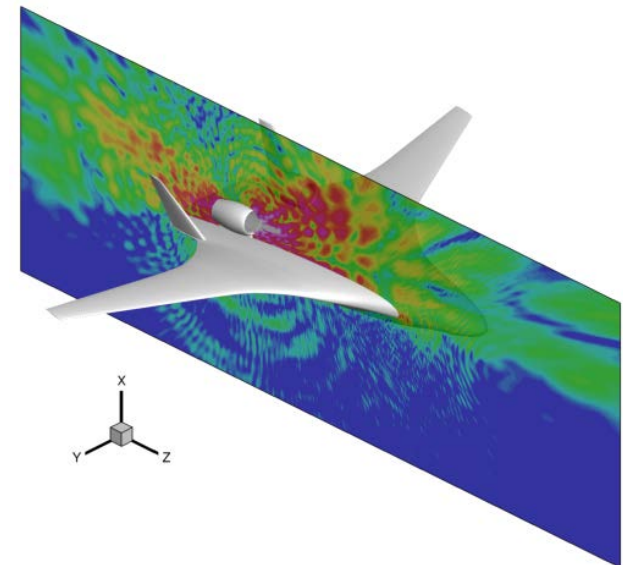
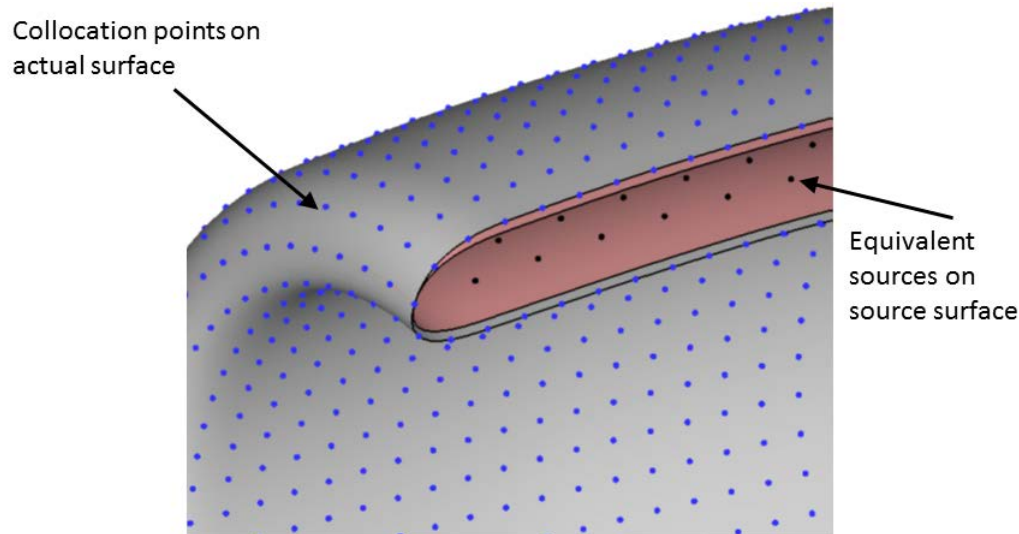
Time Domain Fast Acoustic Scattering Toolkit (TD-FAST) (AS NRA: PI: [Fang Hu](#), POC: [Nark](#))

- Hu, F., "An efficient Solution of Time Domain Boundary Integral Equations for Acoustic Scattering and its Acceleration by Graphics Processing Units," AIAA paper 2013-2018.
- Hu, F., "Further Development of a Time Domain Boundary Integral Equation Method for Aeroacoustic Scattering Solutions," AIAA paper 2014-3194.



Fast Scattering Code (FSC)

- Frequency domain solve of a 3-D Helmholtz boundary value problem via the equivalent source method (ESM)
- Scattered acoustic pressure field expanded into a series of point sources (N_s) distributed on a fictitious surface placed inside the actual scattering surface
- Scattering surface is discretized into collocation points (N_c) to produce a dense, over-determined system of linear equations of size $N_c \times N_s$.
- Source strengths are adjusted to satisfy surface boundary condition using least squares methods





Time Domain BEM (TD-FAST)

- Time domain boundary integral equation (TDBIE) reformulated for the convective wave equation
- Numerical instability in time marching stages addressed via Burton-Miller type formulation
- Computational cost of direct solution addressed via
 - High-order basis functions
 - Multi-level Fast Methods
- Utilize multi-core CPU and GPU architectures

