Acoustic Scattering Predictions for Complex Sources and Aircraft Configurations

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Outline

• Background
• MIT D8.5 scattering/shielding
  – FSC Suppression Tables
  – Next Steps
• Incident Source Directivity Effects
  – F31A31 9x15 test predictions
  – Initial TD-Fast predictions
  – Additional geometric complexity
• Concluding Remarks
Incorporate higher-fidelity acoustic scattering/shielding predictions into system noise assessment of integrated configurations
• Shielding can constitute a large portion of Stage 4 margin
• Work from initial D8.5 (tri-jet) assessment by Berton
  • ANOPP/WING module initially employed
  • Create ANOPP suppression table using FSC
  • Quantify effect on system noise benefit
FSC Modeling:

- Incorporates geometric effects
- Propulsion sources considered separate point sources
Suppression Table Generation using FSC

• Suppression Factor, $S = 10^{\frac{\Delta dB}{10}}$

  • $\Delta dB = SPL_{\text{shielded}} - SPL_{\text{unshielded}}$

  • $S < 1$ indicates suppression
  • $S > 1$ indicates amplification

• Predictions combined for each 1/3-octave band
MIT D8.5 System Noise Assessment

FSC Suppression Tables

$f = 500$ Hz

$Amplification$

$f = 2000$ Hz
MIT D8.5 System Noise Assessment

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

Reflection from Tail Surfaces

SPL: 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
D8.5 Assessment: Next Steps

- System noise assessment using FSC suppression tables
  - Improved estimate of shielding effectiveness
- 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
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

F31A31 9x15 Test

Blade Loading
- OVERFLOW, FUN3D
- RPM: 6436
- Time Resolution: 1-degree

Acoustics
- ASSPIN, PSU-WOPWOP, F1A
F31A31 9x15 Test

TD-Fast (Initial Set-Up): Short Barrier, Point Source

\[ f = 800 \text{ Hz} \]

\[ f = 1600 \text{ Hz} \]
TD-Fast (initial Set-Up): Long Barrier, Point Source
($f = 1600$ Hz)
F31A31 9x15 Test

Additional Complexity
Full Test Section

- Incorporate full tunnel geometry in scattering predictions
Concluding Remarks

- Apply higher-fidelity scattering methods to quantify effects on system noise assessments
- Investigate benefits of properly placed low-drag external liners on system noise
  - Broadband attenuation capabilities increase possible liner locations
- Incorporate tunnel geometry in scattering predictions

Incorporate higher-fidelity acoustic scattering/shielding predictions into system noise assessment of integrated configurations
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Backup Slides
Background

Conventional Tube and Wing

Suppression Table Creation

HWB N2A-exTE

Installation Effects
Scattering/Shielding Methods

ANOPP: WING module

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

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

Diffraction Integral Method (DIM3)

- Based on Kirchoff diffraction theory expressing diffracted field as superposition of waves emitted through an aperture
- Determine outline of shielding object based on source location and numerically solve the contour integral
  - Babinet’s Principle with wedge potential for edge modeling
  - Beam tracing for reflections
  - Allowance for directional sources
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 (Ns) distributed on a fictitious surface placed inside the actual scattering surface
- Scattering surface is discretized into collocation points (Nc) to produce a dense, over-determined system of linear equations of size Nc x Ns.
- Source strengths are adjusted to satisfy surface boundary condition using least squares methods
• 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
• **Source projects geometrically similar shadow zone**

• **Spheroids (centered at origin)**
  • Sphere: $r = a = b = 5.0$ m
  • OS1: $a = 5.77$ m, $b = 1.147$ m
  • OS2: $a = 5.77$ m, $b = 0.38$ m

• **Sound Source**
  • Monopole of unit strength
  • Frequencies: $1 < ka < 400$

• **Observer fields**
  • Bisecting plane, plane at $z = -30$ m
  • Line at $z = -30$ m
  • Ring, $r = 7.5$ m, centered at origin
Validation Studies

Sphere/Spheroid Predictions

Pope, Burley

Tinetti (NRA: NNL09AA17C)

Hu (NRA: NNX11AI63A)
Validation Studies

- Configuration geometry/data from NASA TP 1004
- Cylinder (centered at origin)
  - Diameter: \( d = 0.48 \) m
  - Length: \( L = 3.05 \) m
- Flat plate
  - Square edges
  - \( W = 0.5 \) m, \( L = 1.6 \) m, \( t = 0.07 \) m
- Sound Source
  - Monopole of unit strength
  - Location: \((0.0, 0.0, 0.9936)\) m
  - Excitation frequencies: \( 9 < kd < 69 \)
- Observer fields
  - Bisecting plane
  - Line at \( z = -5.04 \) m
  - Sphere: \( r = 2.5 \) m, centered at origin
Validation Studies

Fast Scattering Code
(f = 8kHz)

Cylinder Alone

Cylinder – Plate

Tinetti (NRA: NNL09AA17C)
Validation Studies

Time Domain BEM: TD-Fast
(Plate Alone: f = 8kHz)

Hu (NRA: NNX11AI63A)
Isolated OR Noise Prediction

![Graph showing acoustic pressure over reception time](image)
Isolated OR Noise Prediction

![Graph showing shaft order vs. thickness in decibels with different markers for PSW (10 Rev), ASP (F31), ASP (A31), and LINPROP.](image-url)
Isolated OR Noise Prediction

![Graph showing noise prediction over shaft order with markers for different conditions: PSW (10 Rev), ASP (F31), ASP (A31), LINPROP.](image)
Isolated OR Noise Prediction