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
MIT D8.5 System Noise Assessment

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

\( f = 500 \text{ Hz} \)

\( f = 2000 \text{ Hz} \)

Amplification

<table>
<thead>
<tr>
<th>S:</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>1.25</th>
<th>1.5</th>
<th>1.75</th>
<th>2</th>
<th>2.25</th>
<th>2.5</th>
<th>2.75</th>
<th>3</th>
</tr>
</thead>
</table>

MIT D8.5 System Noise Assessment

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

Reflection from Tail Surfaces
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

External Liners
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

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F31A31 9x15 Test

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

$f = 800 \text{ Hz}$

$f = 1600 \text{ Hz}$
F31A31 9x15 Test

TD-Fast (initial Set-Up): Long Barrier, Point Source
($f = 1600$ Hz)
F31A31 9x15 Test

Additional Complexity
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
Acknowledgements

- Jeff Berton (NASA): ANOPP (AATT)
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- Bill Jones: FUN3D (AATT)
- Len Lopes (NASA): ANOPP2 (RVLT, TTT)
- Ana Tinetti (AS&M): FSC (AATT)
- Nik Zawodny (NASA): Overflow (AATT)
Backup Slides
Background

Conventional Tube and Wing

Suppression Table Creation

Installation Effects

HWB N2A-exTE
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)

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 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
• **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

DIM

FSC

TD-Fast

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 time with two lines, one labeled PSW and the other F1A. The x-axis represents reception time in seconds, ranging from 0 to 0.008, and the y-axis represents acoustic pressure in Pa, ranging from -100 to 100.](image-url)
Isolated OR Noise Prediction

![Graph showing noise prediction for different shaft orders with markers for PSW (10 Rev), ASP (F31), ASP (A31), and LINPROP.]
Isolated OR Noise Prediction

![Graph showing noise prediction data with various markers and lines representing different data sets such as PSW (10 Rev), ASP (F31), ASP (A31), and LINPROP. The x-axis represents Shaft Order, and the y-axis represents Loading in dB.]
Isolated OR Noise Prediction