



Acoustic Liner Overview

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Advanced Measurement and Data Systems Branch:

Scott

Aeroacoustics Branch:

Brown

Computational Aerosciences Branch:

Watson (retired)

Structural Acoustics Branch:

Dodge, Galles, Howerton, Jones, Nark, Schiller

On-site contractor support:

Becker, Leath, Reid

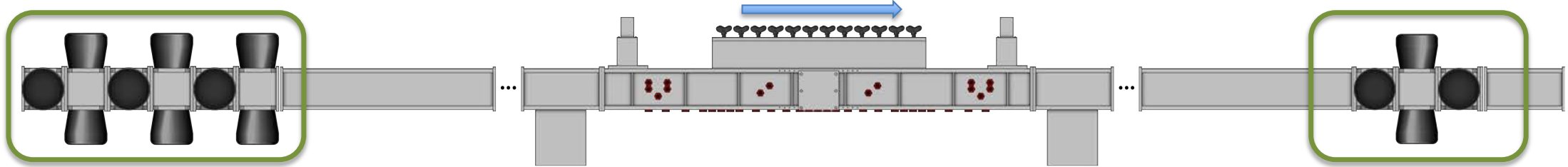


- Impedance Eduction
- Novel Liners
- Liner Technology Facility Enhancements
- External Collaborations
- References

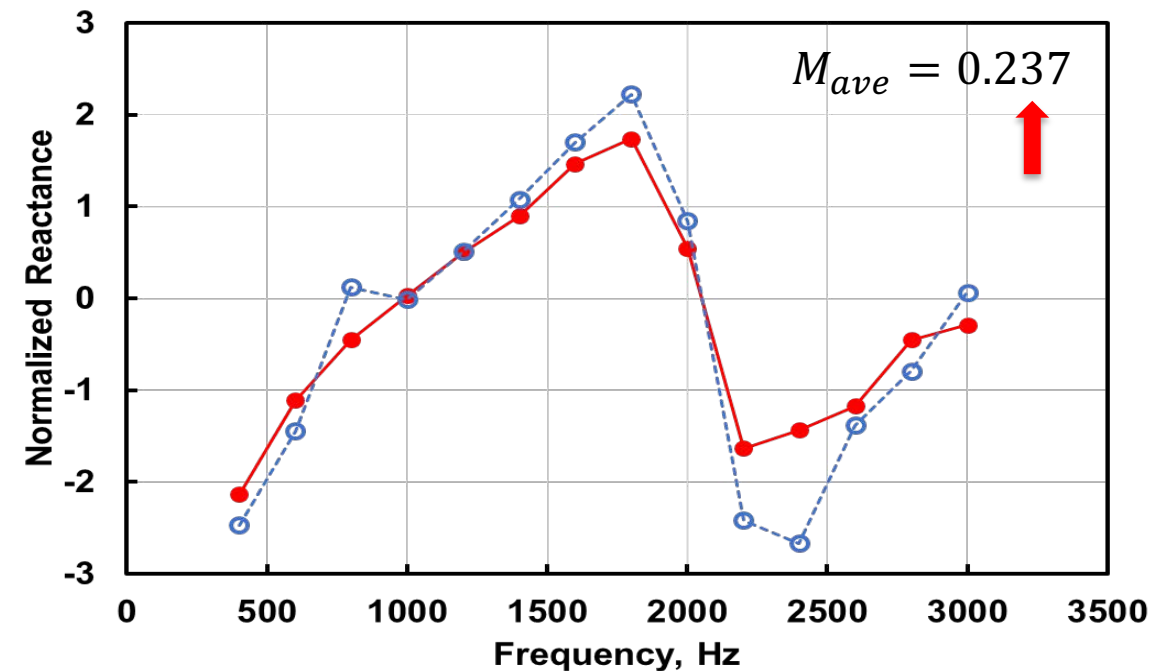
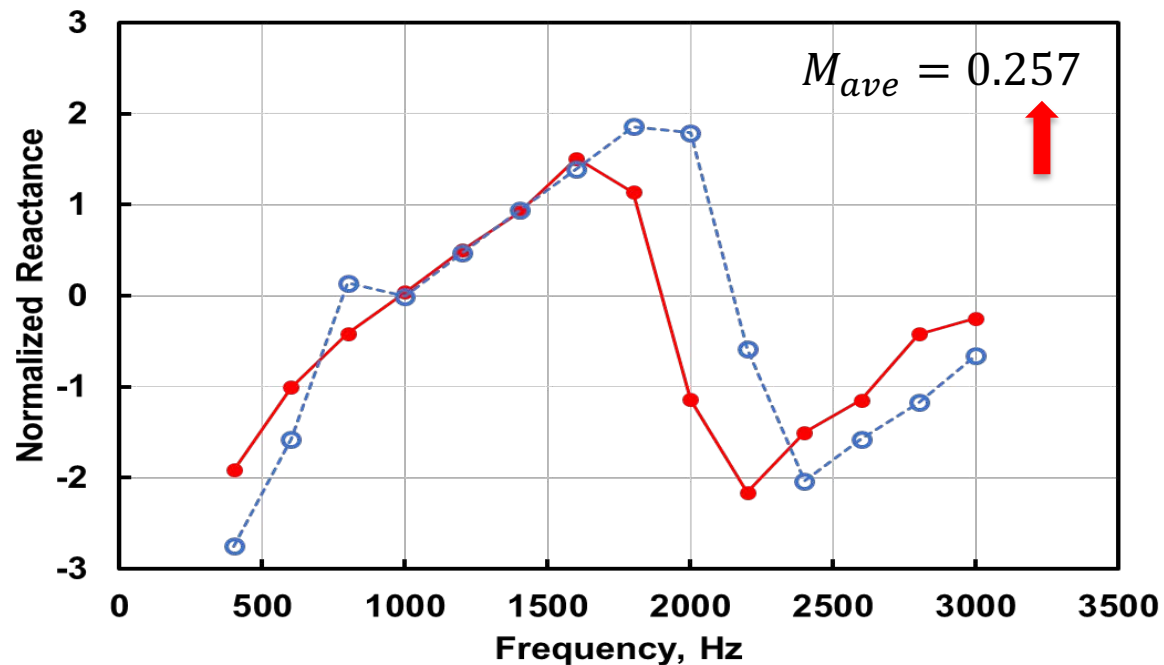
Impedance Education



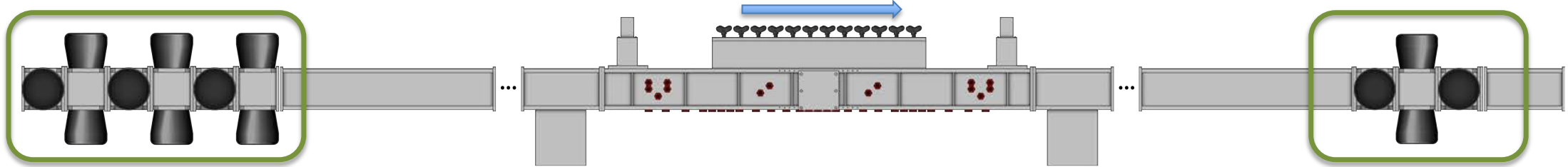
Impedance Eduction: Flow Direction Effects



- Combine inlet & aft results with calibration liner to **fine tune estimate of M_{ave}**
- Initial test conducted in 200 Hz increments

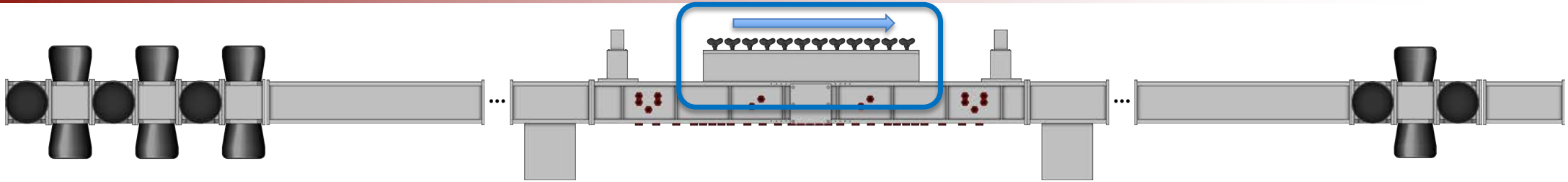


Impedance Eduction: Flow Direction Effects



- Conducted GFIT tests
 - Three liners: one linear and two nonlinear
 - Swept-sine source: 400 – 3000 Hz in **10 Hz increments**
 - Centerline Mach #: 0.1 – 0.6 in **0.1 increments**
 - Source: 140 dB, upstream (aft mode) and downstream (inlet mode)
- Used Prony method to find M_{ave} where aft and inlet results coalesce (**Nark**)
- Resultant equation: $M_{ave} = f(M_{CL})$
- **Aft mode (preferred) results are applicable to both inlet and aft conditions**

Impedance Eduction: Current Status and Investigations



Current Status

Uniform liners

- Prony (direct method – fast)
- PyCHE (indirect method – time-consuming) with gradient-based optimizer

Multizone liners

- PyCHE with global optimizer

Current Investigations

- Comparison of CHE (four predefined initial guesses) and Hybrid (PyCHE with Prony result as initial guess) (**Howerton**)
- Fine tuning of optimizers used in PyCHE (**Galles**)
- Extending application of swept-sine source (**Howerton/Vold**)

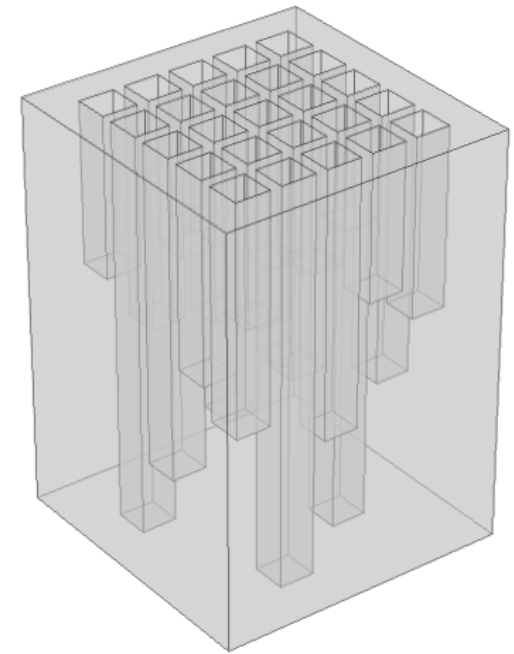
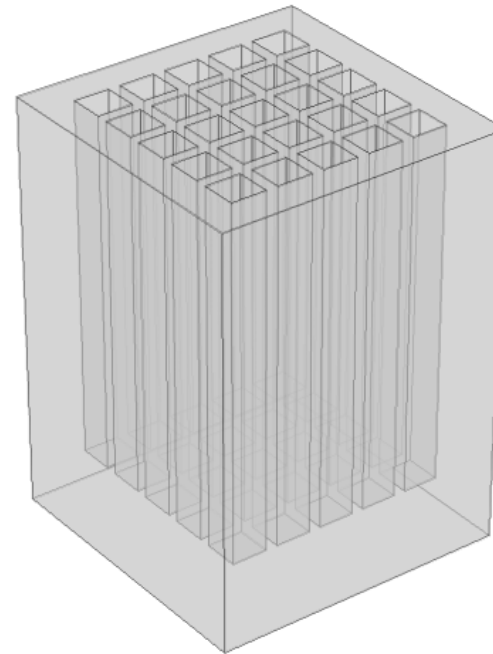
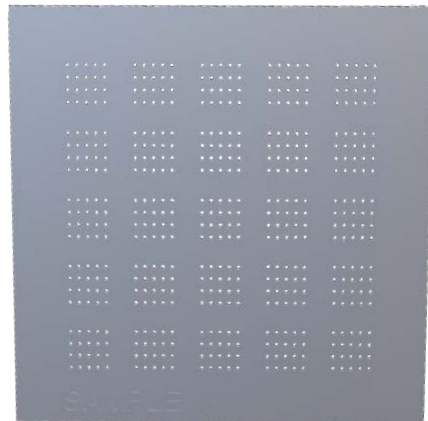
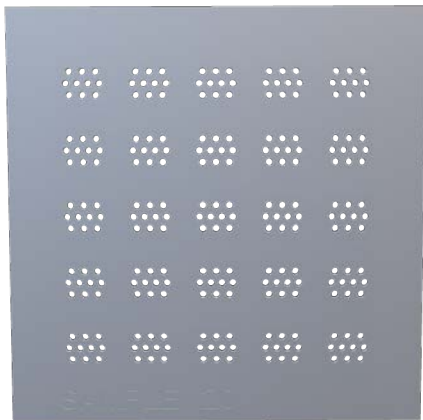
Novel Liners



Liner Design/Modeling: Perforate Facesheet Model



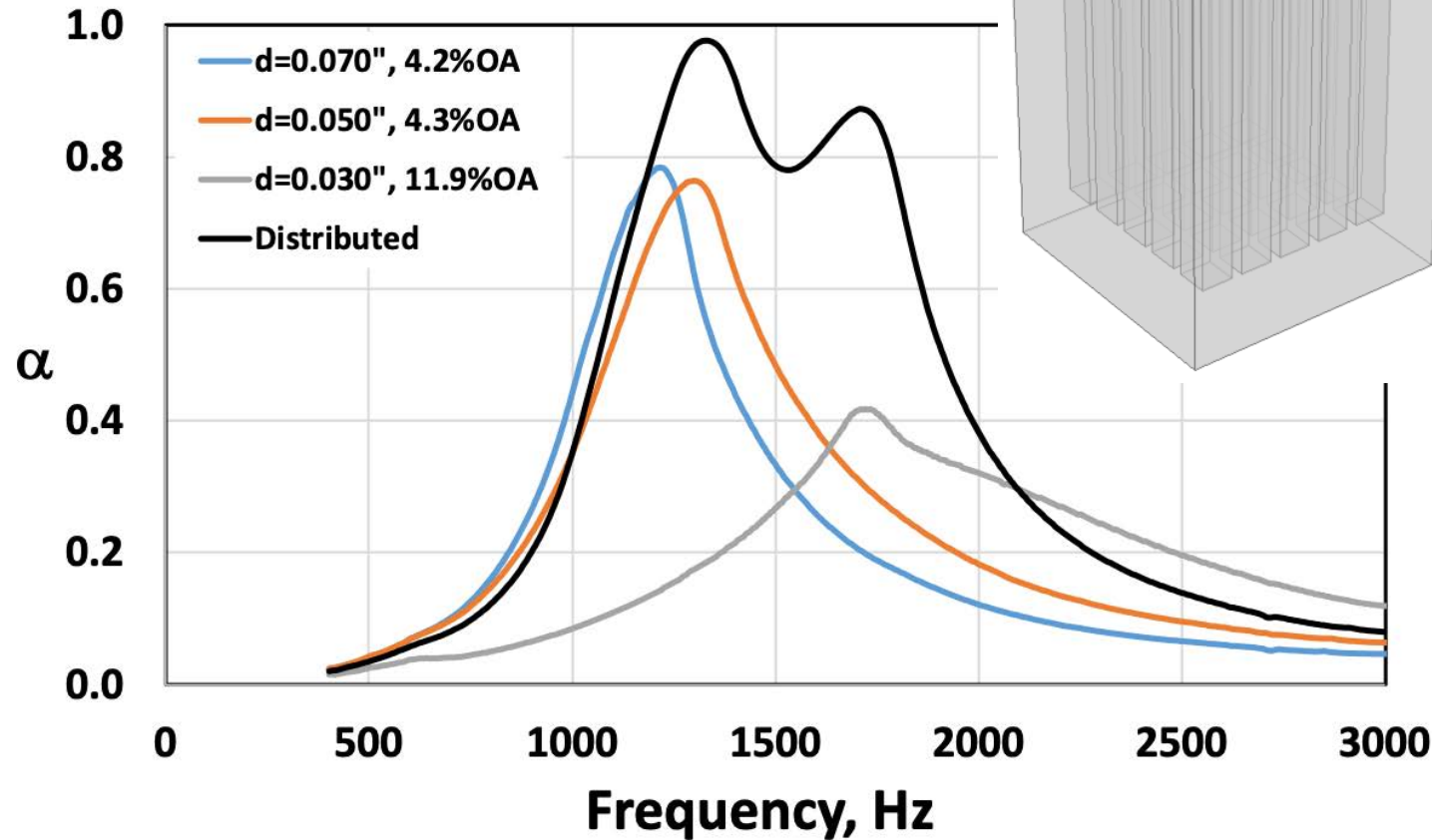
- Current facesheet model works well for conventional liners, but not as well for variable-impedance liners
- **Goal:** Find/develop a model suitable for these novel liner concepts (**Jones**)
- Completed NIT tests of numerous samples – multiple facesheets; uniform and variable-depth cores (**Galles, Reid**)



Novel Liner Concepts: Distributed Facesheet

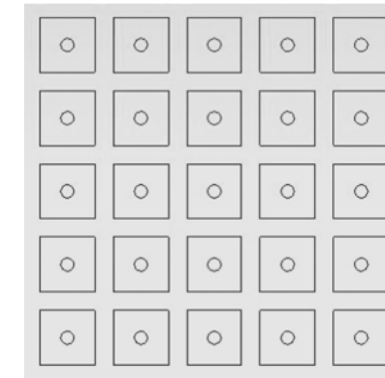


- Distributed (variable $\{d, \sigma\}$) facesheet for broadband noise reduction (Brown)
- NIT tests complete
- GFIT samples ready for testing

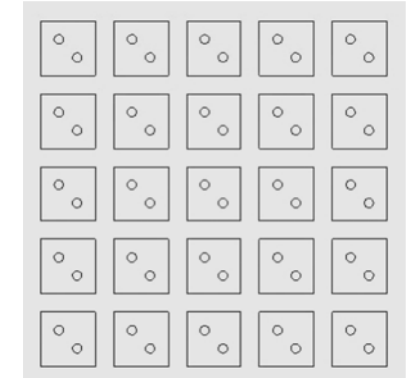


1.5" Core

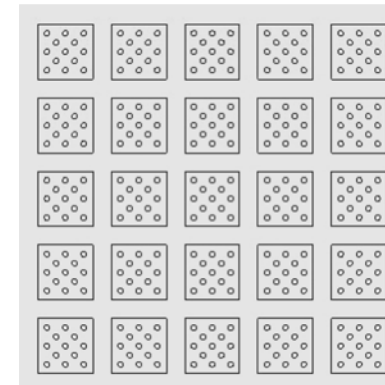
Facesheets



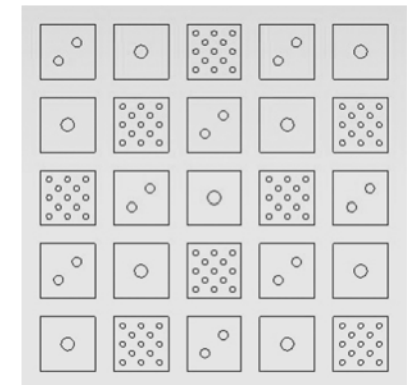
$d=0.070"$, 4.2% OA



$d=0.050"$, 4.3% OA



$d=0.030"$, 11.9% OA



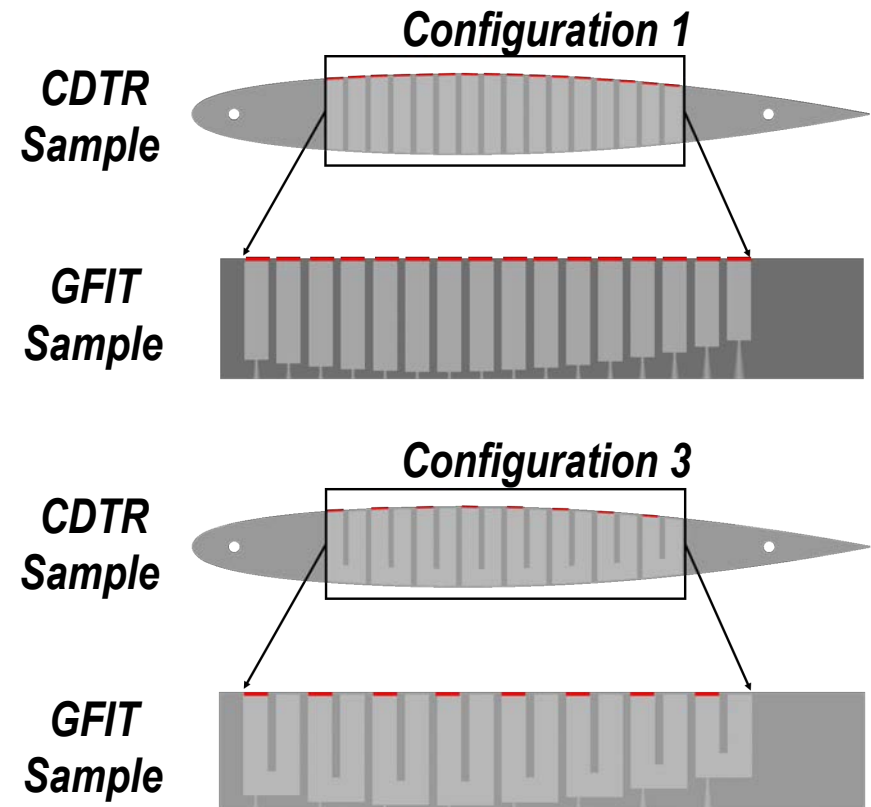
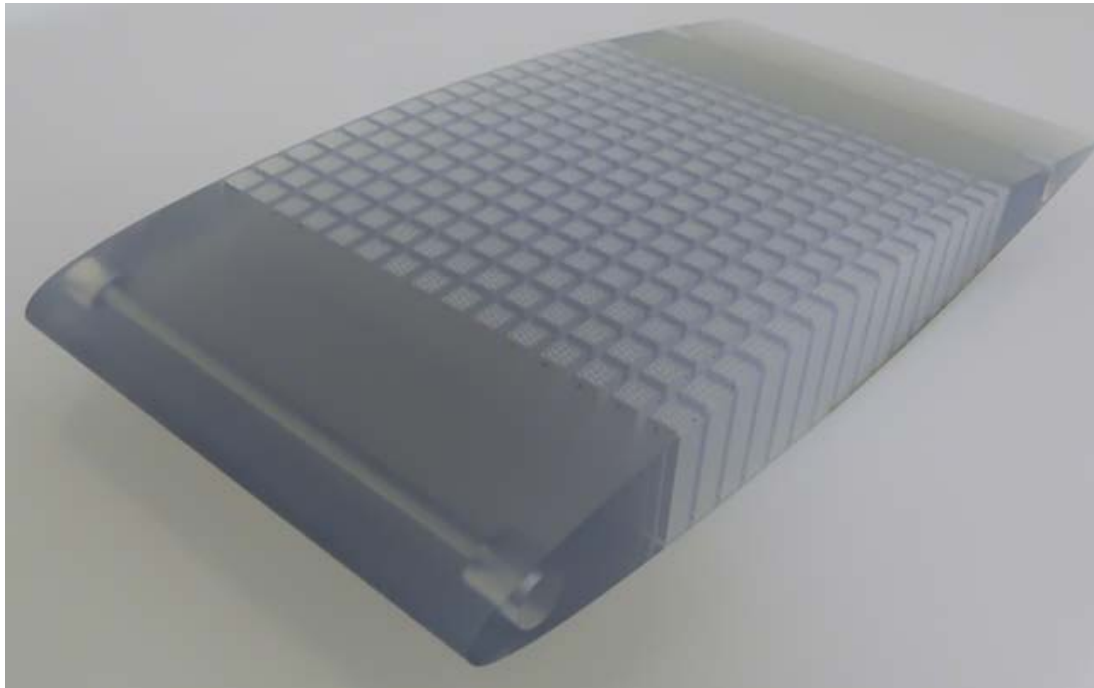
Distributed

Novel Liner Concepts: Acoustically Treated Bifurcations



- Used NIT, GFIT, and CDTR tests to verify models for simple liner designs
- **Current activity:** Design/test optimized CDTR configurations (Nark)

CDTR test samples
Profile: NACA0012-64

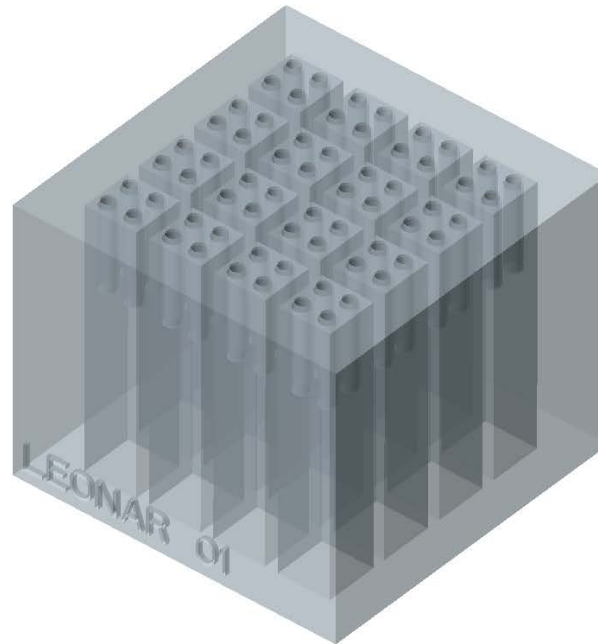


Novel Liner Concepts: LEONAR Liner (ONERA)

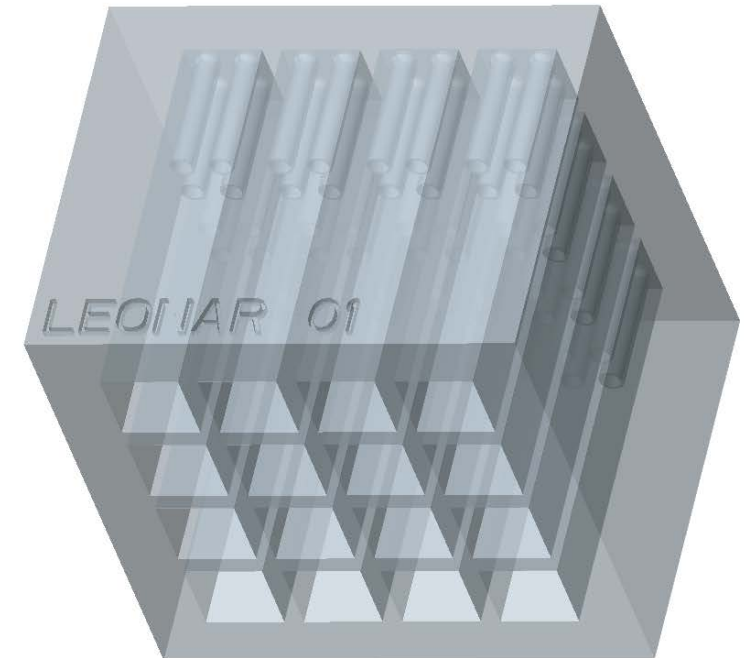


- Long Elastic Open Neck Acoustic Resonator (LEONAR)
- Low-frequency tuning with shallow liner
- Shift of peak attenuation: Conventional: 1500 Hz; LEONAR: 730 Hz;
shift from $\lambda/4$ to $\lambda/10$ resonator

4x4 array of chambers



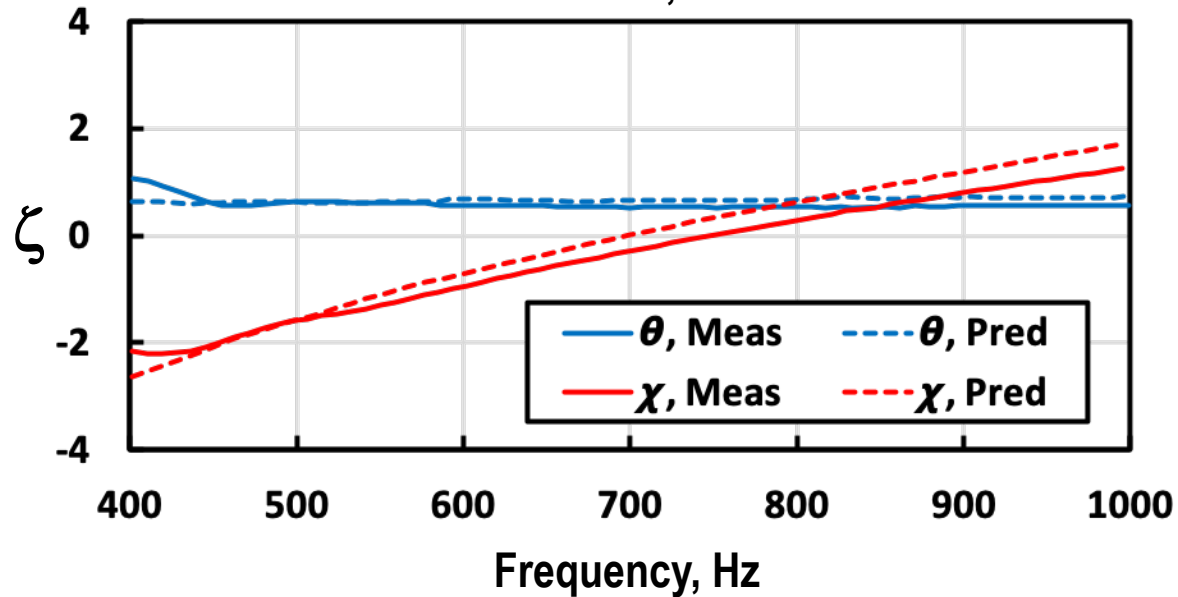
Facesheet holes replaced with tubes



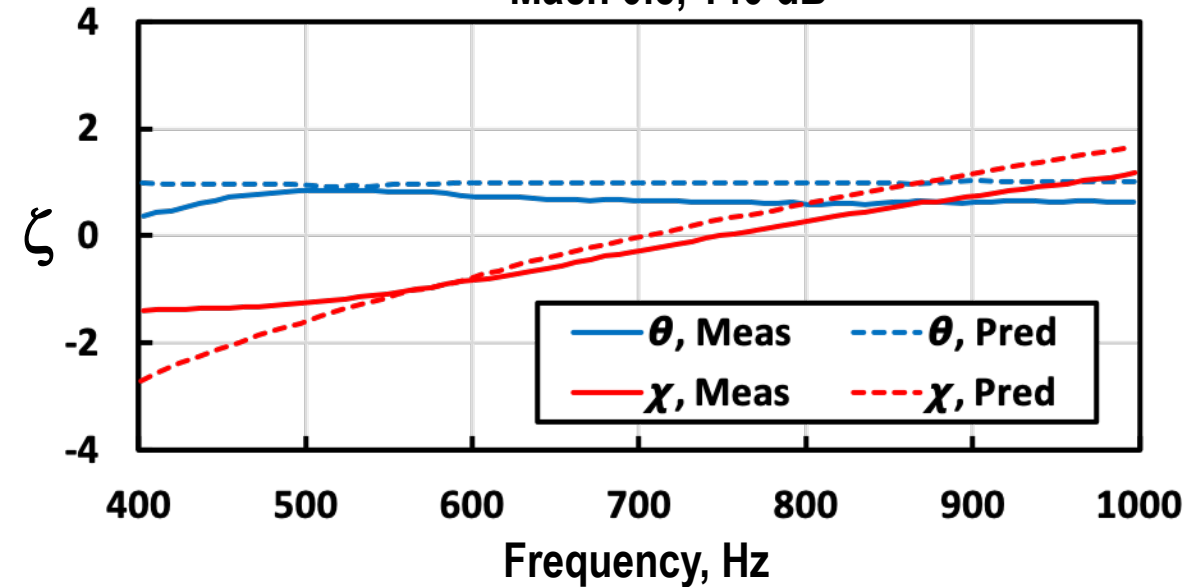
Novel Liner Concepts: LEONAR Liner (ONERA)



Mach 0.3, 140 dB



Mach 0.5, 140 dB



- Favorable comparison between simulated and measured (GFIT) impedances in presence of flow
- See Frank Simon's presentation

Novel Liner Concepts: Active Liner (NRA: Boeing/FSU)



Power Functional Check

POC: Evaluate components

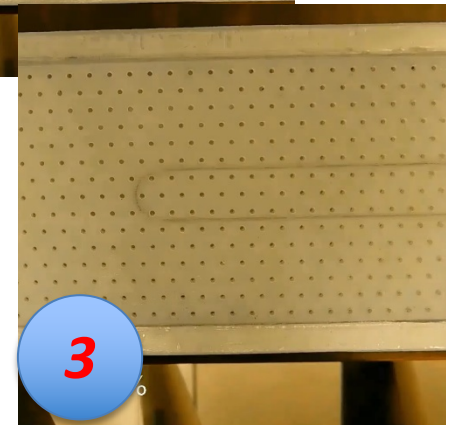
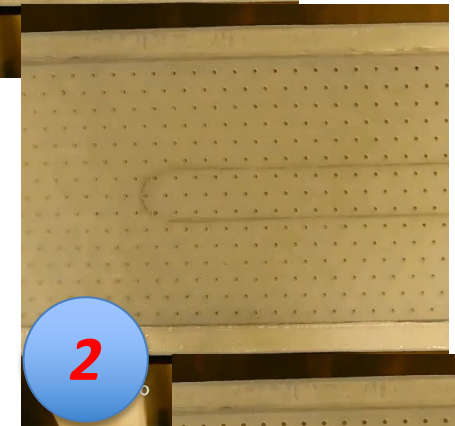
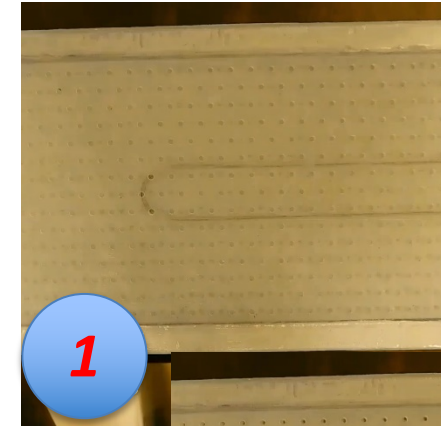
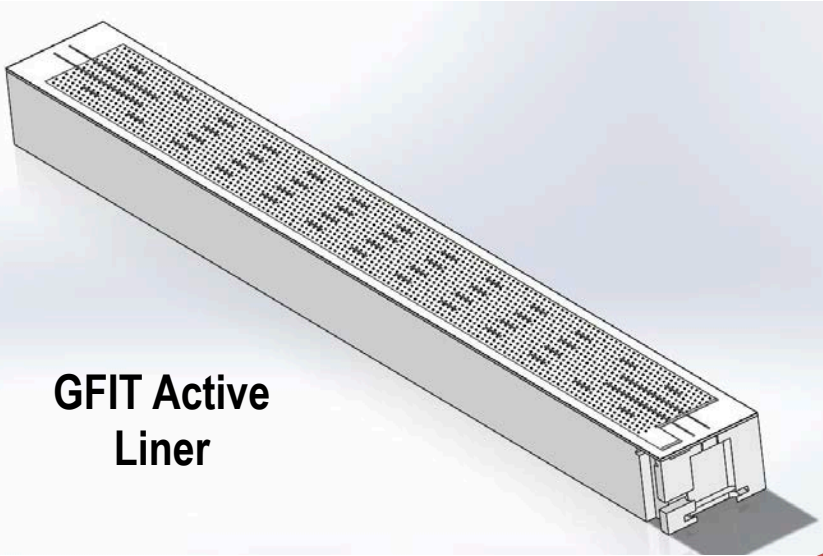
Active Demo 1: Demonstrate ability to actively modulate the hole size

Active Demo 2: Incorporate curvature representative of aircraft system

GFIT Active Liner: Acoustic test of liner with active face sheet and backplate in representative environment (Mach 0.5, 140 to 150 dB)

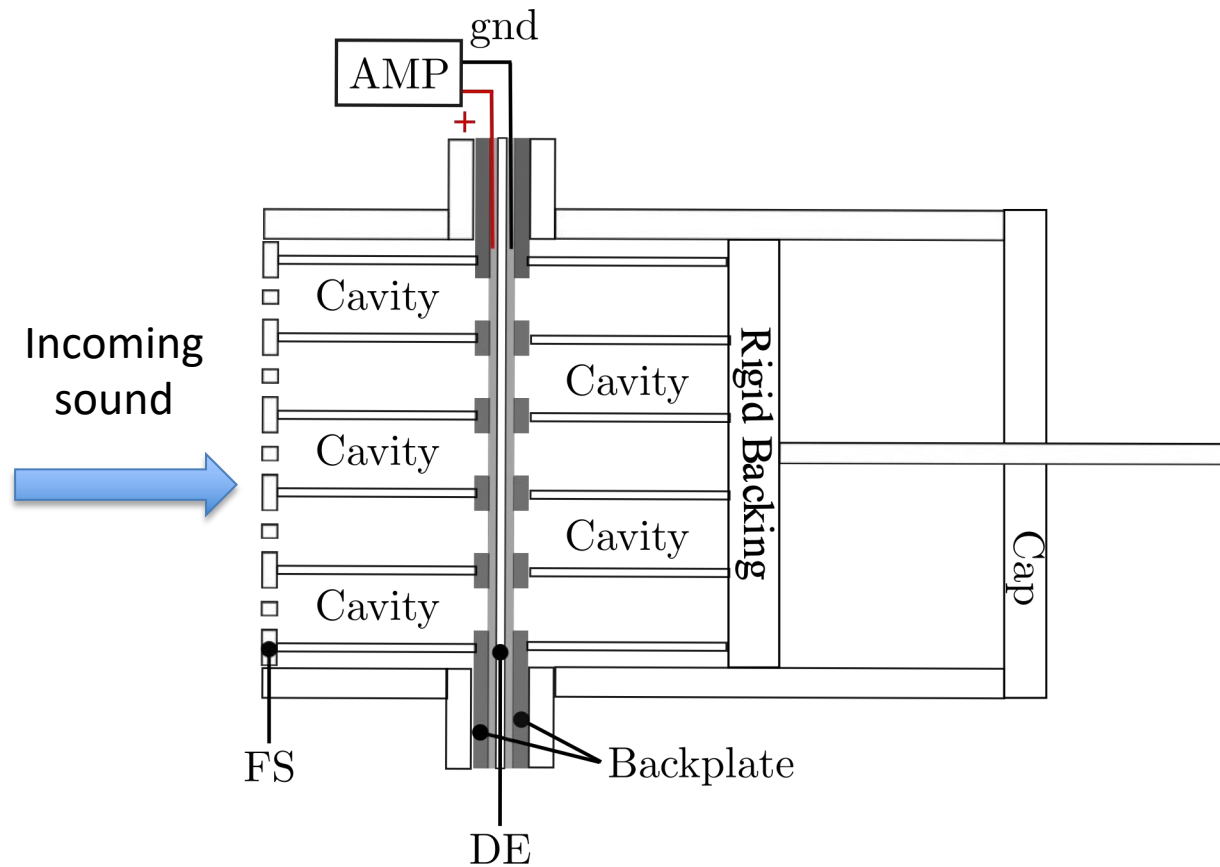
Status: Test GFIT Active Liner

GFIT Active Liner

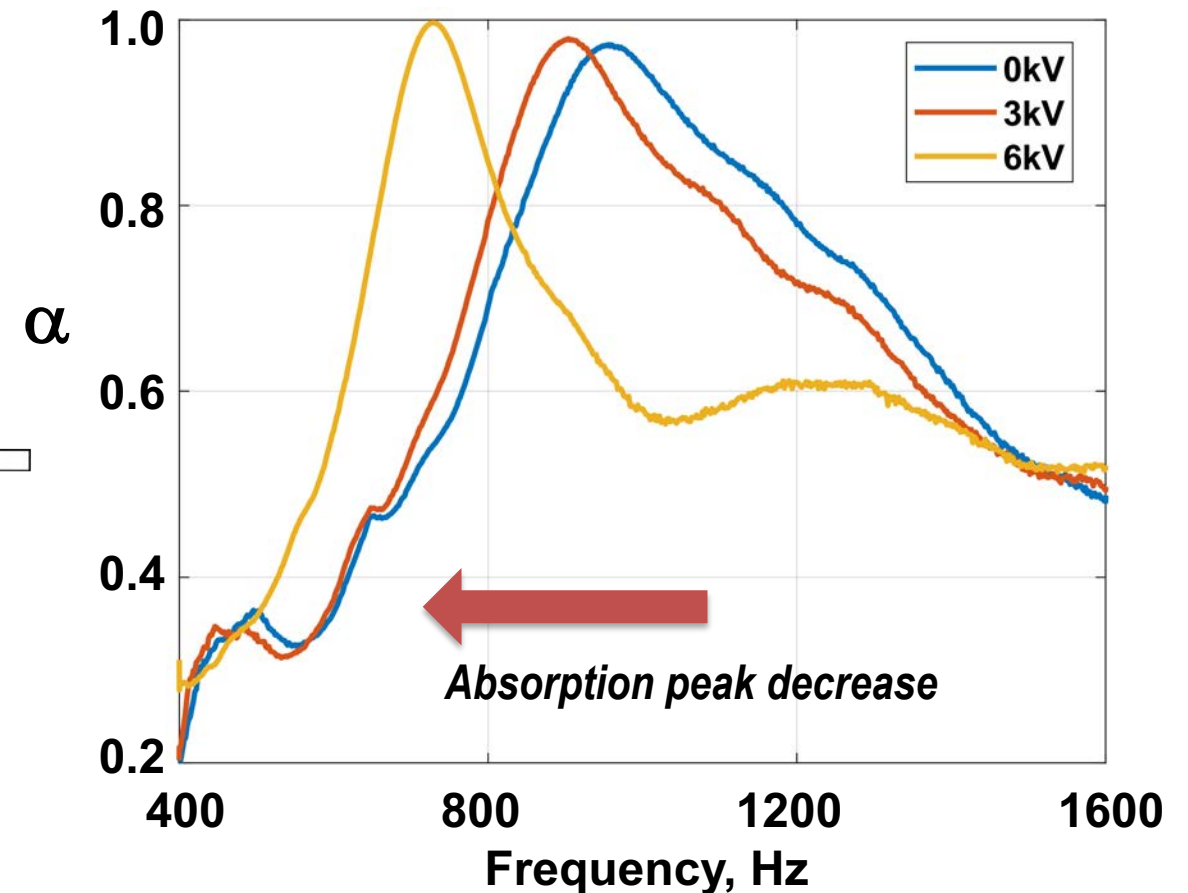


- Boeing delivered liner to NASA with active (SMA) facesheet
- NASA conducted tests to evaluate ability to control porosity (Dodge, Howerton)

Novel Liner Concepts: Active Liner (NRA: Boeing/FSU)



Schematic of a Dielectric Elastomer Acoustic Liner comprised of a facesheet (FS), honeycomb cores, and a dielectric elastomer (DE) actuator membrane



Absorption coefficient spectra for compliant septum layer

- Absorption peak tuning of 225 Hz (~24%)
- Assuming a SDOF liner, 0.9" effective depth change

Novel Liner Concepts



- Active liner (NRA: Boeing/FSU)
- Bio-Inspired liner (NASA GRC: [see Koch presentation](#))
- Distributed impedance
 - Variable depth, bent chamber
 - Distributed facesheet
- LEONAR liner (ONERA)
- Metal foam with controllable variable density (WSU)
- Multizone
- Shared port inlet
- Slotted core (Hexcel)
- Treated bifurcation

Liner Technology Facility Enhancements



Liner Technology Facility Enhancements: HIMIT



High Intensity Modal Impedance Tube (HIMIT)

- Expected to come online within next month (when we return to office)
- Will support no-flow evaluation of liners up to much higher source SPLs (up to ~170 dB) and higher frequencies (initially, up to ~6 kHz)



Liner Technology Facility Enhancements: CDTR



Curved Duct Test Rig (CDTR)

- Currently use microphones with frequency-dependent response
- Replacing with higher quality microphones with frequency-independent response
- Transition from frequency-dependent calibration (time-consuming) to *in situ* calibration (fast)





- NRA – Adaptive Liner (Boeing/FSU)
- International Agreement (ONERA) – Impedance BC investigation
- International Forum for Aviation Research (IFAR) – Measurement methods, 3D propagation code evaluation, and multizone impedance education
- ODU (NIA) – Implementing acoustic liners into scattering calculations (TD-FAST)
- Vold LLC – Improvements to swept sine source for GFIT

Space Act Agreements

- Boeing – GFIT/CDTR tests of novel liners, liner analysis collaboration
- Boeing/Purdue/ERAU – CDTR tests of acoustically treated heat exchangers
- FSU – Development of liner drag models
- GE Aviation – Conducting GFIT tests with Phase 2 samples
- General Atomics – GFIT tests of conventional liners
- Hexcel – Evaluate embedded mesh-cap and slotted-core liner concepts
- OSU – Evaluate embedded-membrane concept; journal article in review (SAA complete)
- WSU – Investigation of metallic foams



AIAA Aeroacoustics Conference to be held (???) June 2020, Reno, NV

- Howerton, Jones, Nark, “An Improved Impedance Education Process for the NASA Langley GFIT”
- Nark, Jones, Schiller, “A Fundamental Study of Bifurcation Acoustic Treatment Effects on Aft-Fan Engine Noise”
- Brown, Jones, “Evaluation of Variable Facesheet Liner Configurations for Broadband Noise Reduction”
- Jones, Nark, Howerton, Watson, “Uniform and Multizone Liner Results for the International Forum for Aviation Research”

NASA Technical Papers

- Jones, Brown, Howerton, Becker, “Over-the-Rotor Liner Investigation via the NASA Langley Normal Incidence Tube,” NASA TM 2019-220430, Nov 2019
- Marinova, Jones, Schiller, “Evaluation of Packing3D Code for Design of Variable-Depth, Bent-Chamber Acoustic Liners,” NASA TM 2020-220560, Feb 2020
- Jones, Watson, Nark, Howerton, Brown, “A Review of Acoustic Liner Experimental Characterization at NASA Langley,” NASA TP 2020-xxx, TBD (~Apr 2020)



Questions?

