Liner Physics Overview

Michael G. Jones

NASA Acoustics Technical Working Group Meeting

Cleveland, OH

October 8 – 9, 2024

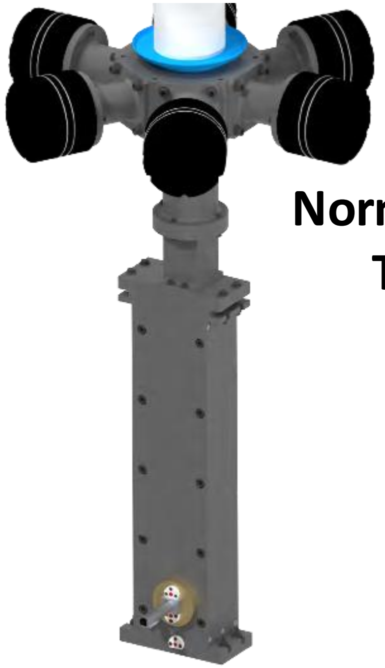
Outline

- Modeling
- Analysis/Design
- Novel Concepts
- Testing
- Background Material

- **Modeling**
- Analysis/Design
- Novel Concepts
- Testing
- Background Material

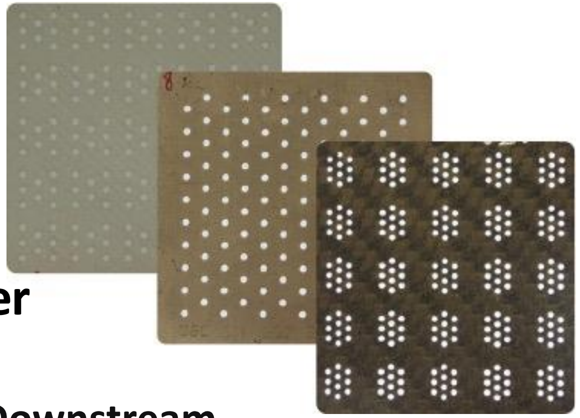
Perforate Facesheet Model

- Dataset: 5 years, 73 NIT samples, 9 GFIT samples, SPL={100, 120, 140 dB}, M={0.0, 0.3, 0.5}, 3 material types (Accura 60, aluminum, carbon fiber)
- Dataset availability: https://data.nasa.gov (search for "acoustic liner")
- Jones, Kreitzman, and Nark, "Examination of Perforate Facesheet Impedance Prediction Models," NASA TP-20240006417, August 2024

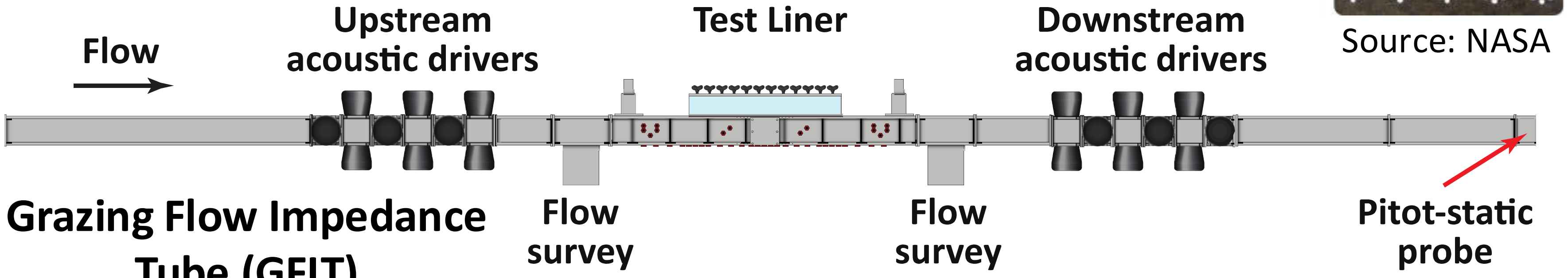


Normal Incidence Tube (NIT)

Facesheets
- Accura 60
- Aluminum
- Carbon Fiber



Source: NASA



Grazing Flow Impedance Tube (GFIT)

Perforate Facesheet Model

- Compared 8 models (7 variants of Crandall formulation plus NASA ZKTL) against 5 subsets of the data (NIT, GFIT– no flow, GFIT with flow, GFIT – all, NIT + GFIT)
- Motsinger and Kraft model had best overall performance
- Applied optimizer to determine “correction factors” for non-geometric parameters initially derived from empirical observations
- Final model (Modified Motsinger and Kraft)

$$\zeta = \frac{32\mu t}{\rho c\left(\sigma C_{D,m}\right) d^2} + \frac{0.98}{2c\left(\sigma C_{D,m}\right)^2} v_{\mathrm{rms}} + \frac{M_{\mathrm{ave}}}{\sigma\{2 + 3.32(\delta_1/d)\}} + i\left[\frac{k(t+\epsilon d)}{\sigma} - \cot(kh)\right]$$

$$\epsilon = \frac{0.65(1.0 - 0.95\sqrt{\sigma})}{1 + 305 M_{\mathrm{ave}}^3}$$

IFAR Research

- Continued efforts underway under the International Forum for Aviation Research (IFAR) {NASA, ONERA, DLR, JAXA, FOI (KTH), UFSC, Trinity}

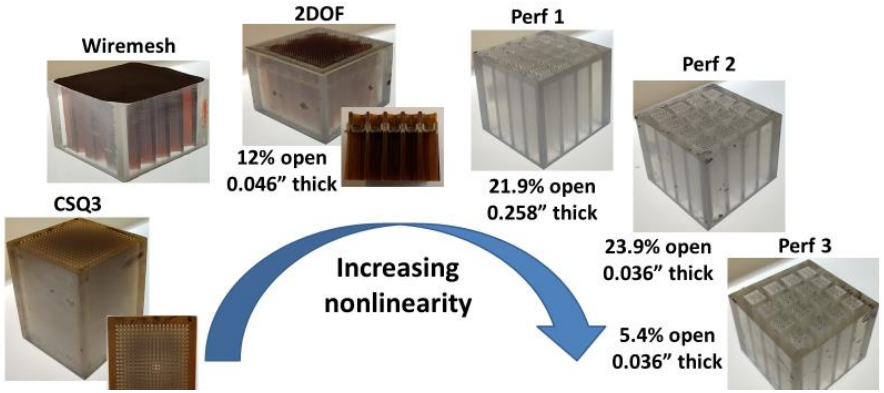
- Recently completed challenges regarding effects of source type and flow direction on impedance

- Nonlinear liner impedance with multitone source
  - Differs significantly from single-tone and broadband impedances
  - Dependent on both the amplitudes and phases of the tonal components
  - Dependent on the ratio of the particle velocity for the individual tone relative to the total particle velocity

- New models are warranted

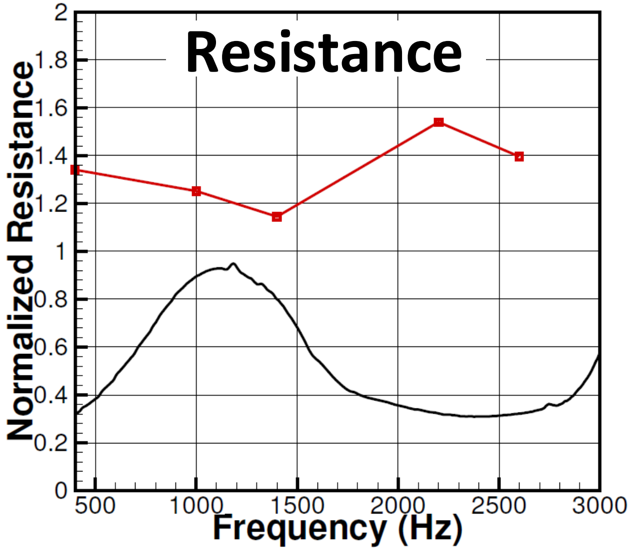
POC: Jordan Kreitzman

Samples Tested



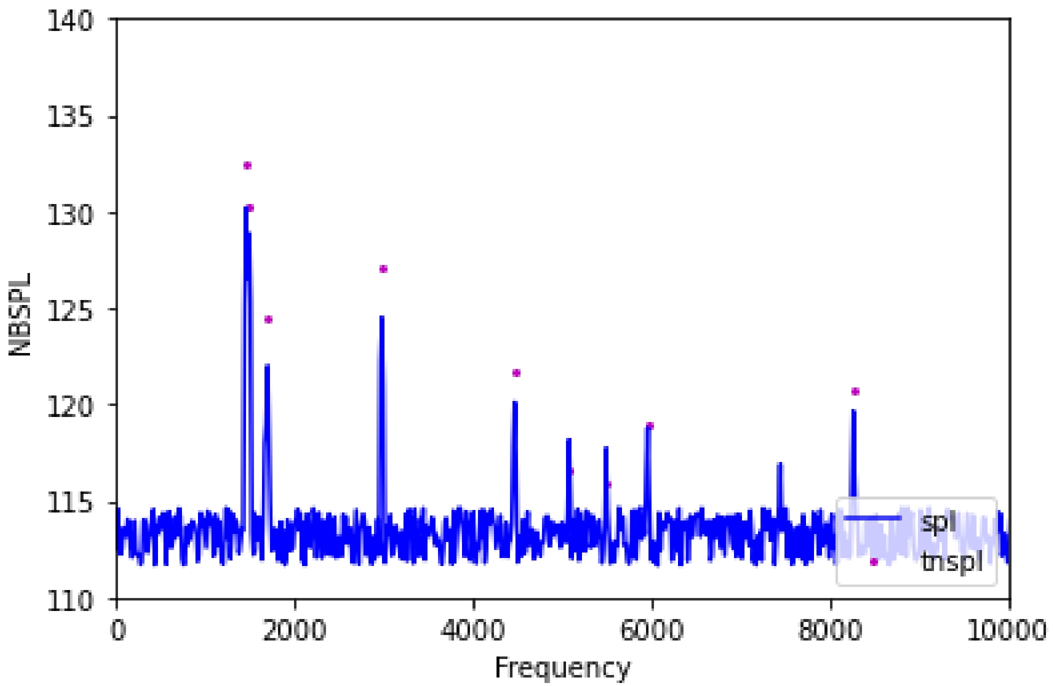
Source: NASA

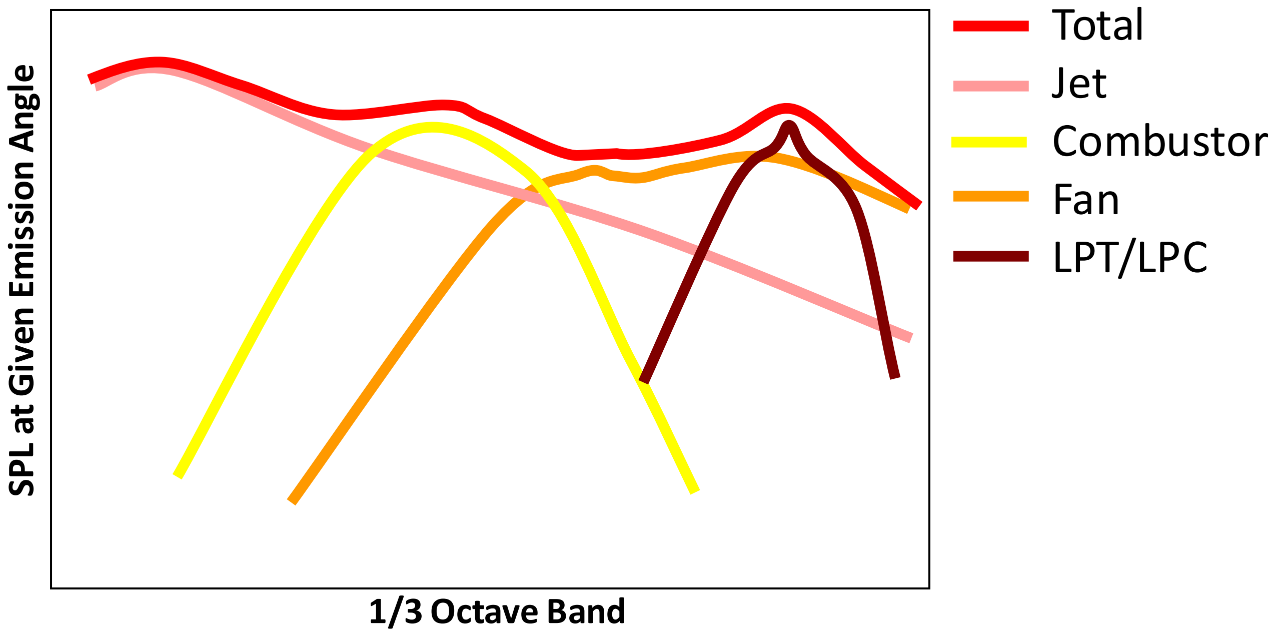
Single Tone vs. Multitone



- Modeling
- **Analysis/Design**
- Novel Concepts
- Testing
- Background Material

Component Separation Development





- Developing improved tone extraction/identification tool for static engine test data
  - Determines tone sources based on blade count
- Developing tools to extract the different broadband noise sources from spectra

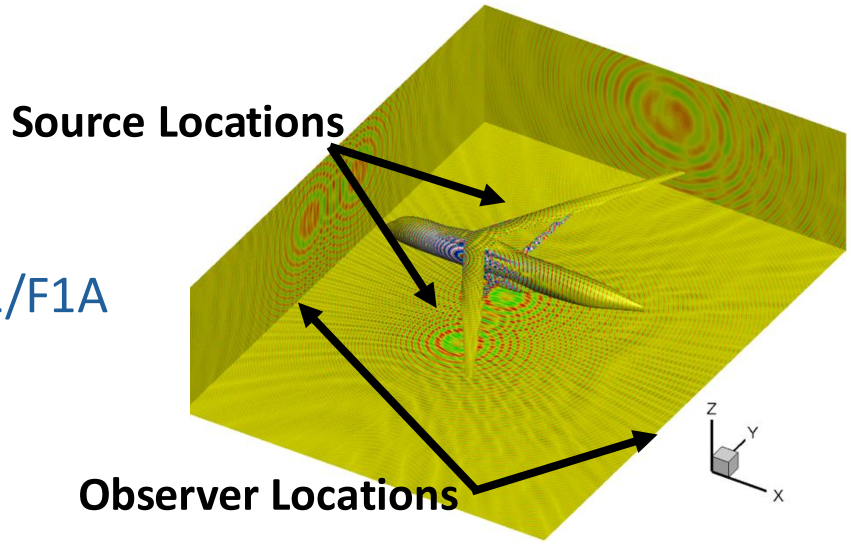
POC: Eric Nesbitt

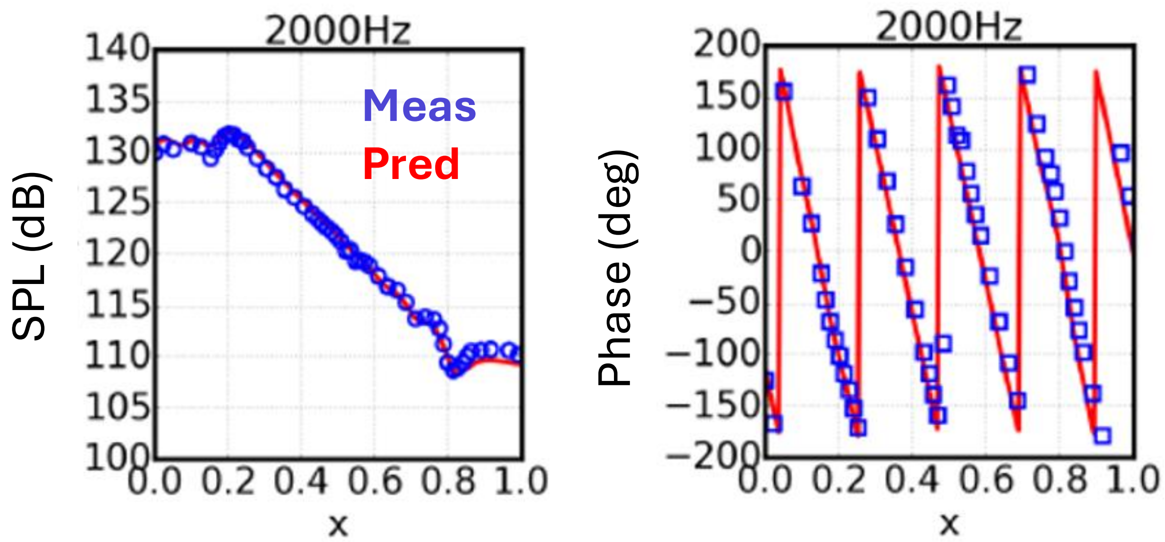
Time Domain Acoustic Scattering (TDFAST)

- Enhanced time domain capability to predict internal/external acoustic scattering including the effect of acoustic treatment
- Stable time domain impedance boundary condition
  - Validation with GFIT data (AIAA 2024-3291)
  - Planned testing in SALT facility
- TTBW predictions for approach and takeoff configurations
- Expanding external source specification, coupling with ANOPP2/F1A

POCs: Fang Hu, Doug Nark

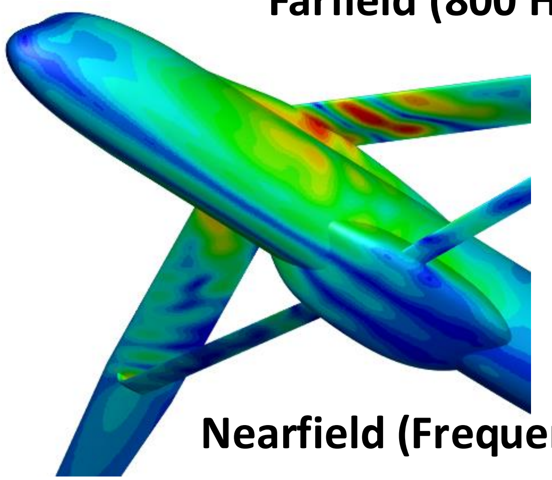
TTBW predictions (open configuration)





Comparison with Grazing Flow Impedance Tube (GFIT) Data

Farfield (800 Hz, Full Scale)

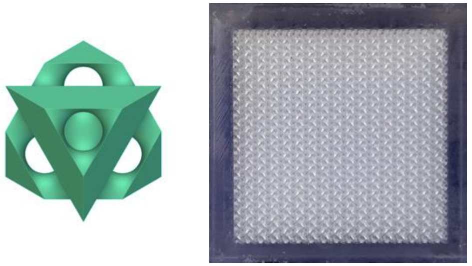


Nearfield (Frequency Domain)

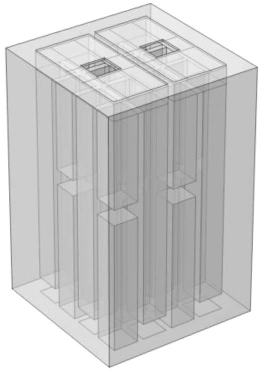
- Modeling
- Analysis/Design
- **Novel Concepts**
- Testing
- Background Material

Novel Liners (Examples)

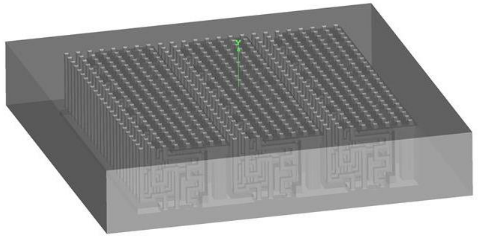
- Work is ongoing with many novel liner concepts
  - Narrow/bent-chamber liner enables broadband absorption in very shallow space
  - TPMS liner for broadband sound absorption
  - Shared inlet port enables variable depth core to share one external opening for reduced drag
  - Exploring wide/bent chambers to better understand physics of bends



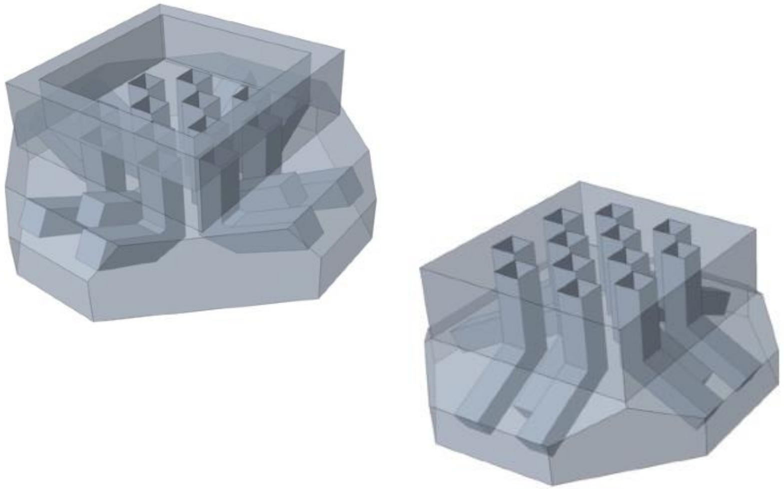
Triply Periodic Minimal Surfaces (TPMS)



Shared Inlet Port



Narrow/Bent-Chamber (worm)



Wide/Bent-Chamber

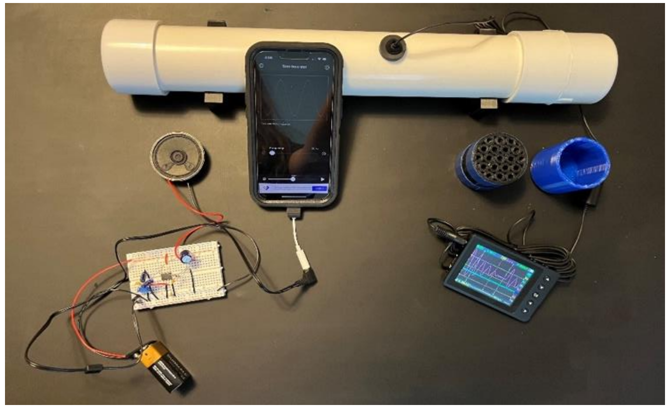
POCs: Mike Jones, Martha Brown, Matt Galles, Jordan Kreitzman

Bio-inspired Broadband Acoustic Absorber Research/Outreach Update

POC: L.Danielle.Koch/ NASA GRC L.Danielle.Koch@nasa.gov

- The first annular version of the bio-inspired acoustic absorber was designed, fabricated, and tested as part of the QUiet Electric ENgines (QUEEN) tests that occurred in the NASA GRC Acoustical Testing Laboratory in May 2024. Results will be presented at AIAA SciTech 2025.
- NASA has licensed the bioliner technology to one organization. A technical package is available to licensees. For more information about licensing NASA technology, please contact Aaron Brister in the NASA GRC Tech Transfer Office. Aaron.B.Brister@nasa.gov
- Thousands of middle school and high school students nationwide are discovering NASA's aviation noise reduction research via a hands-on Acoustic Damping Capstone Project. Four universities are participating in the MAA Acoustic Damping Project in 2023-24: Florida Atlantic University, California State University-San Marcos, University of Central Florida, and the University of Texas – El Paso. Each of these universities work with several local high schools to perform the Acoustic Damping Capstone Project. Funding for the grants to the MUREP MAA awardees is provided by NASA's Office of STEM Engagement, via the Engagement Oppportunities in NASA STEM 2022 (EONS-2022) solicitation. NASA awarded a total of $3.8 million to eight institutions operating as MUREP's Aerospace Academy.

Annular Perforate Over Bio-inspired Broadband Acoustic Absorber tested at GRC 2024.



Low-Cost Impedance Tube Fixed end configuration

Source: NASA

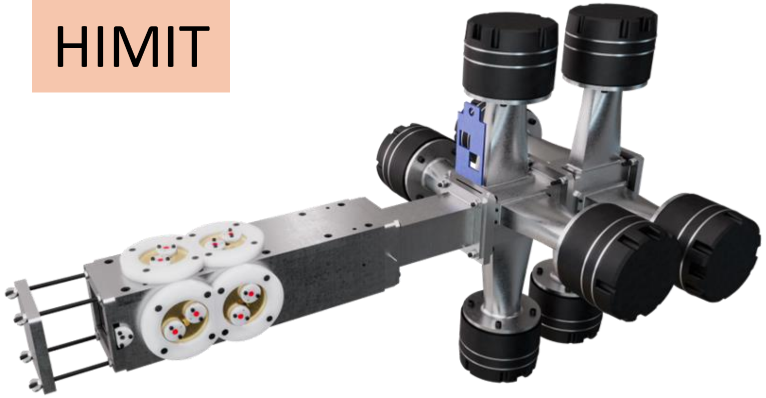
- Modeling
- Analysis/Design
- Novel Concepts
- **Testing**
- Background Material

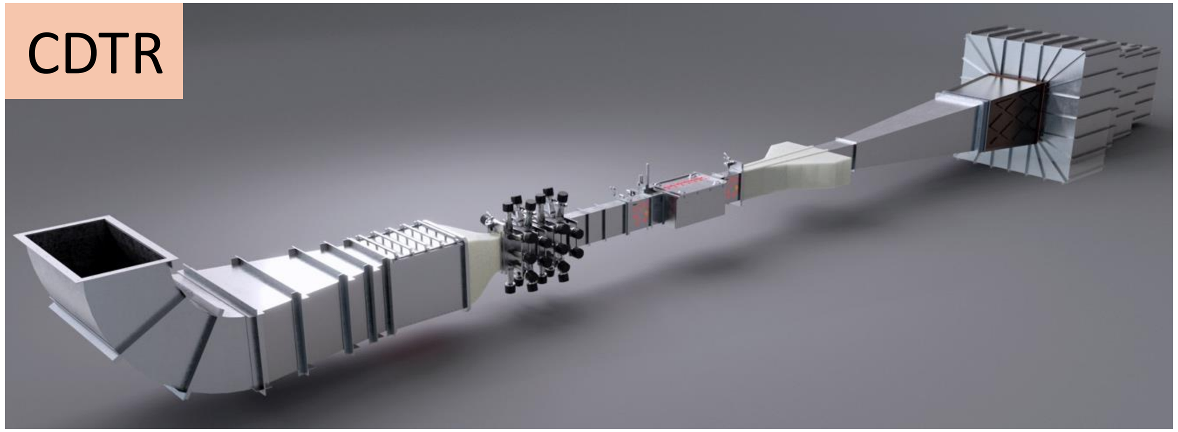
Liner Technology Facility

- High Intensity Modal Impedance Tube (HIMIT) upgrade
  - 8 acoustic drivers and/or mode plates enable mode control for frequencies up to 6 kHz
- Curved Duct Test Rig (CDTR)
  - Preparing to perform Alodine process to minimize corrosion and improve durability
  - Completed upgrade studies
    - Install a heat exchanger to improve flow environment throughout the year
    - Increase maximum flow speed to Mach 0.7

POCs: Scott Haigler, Max Reid, Alex Carr, Martha Brown, Brian Howerton

HIMIT





- Modeling
- Analysis/Design
- Novel Concepts
- Testing
- **Background Material**

External Collaborations

- AARC Grant: Preparing to submit joint journal article re comparison of impedance eduction results for test rigs with different displacement thickness
- Collins: CDTR tests of novel liner concepts
- Hexcel: Investigate novel concepts based on design of embedded septa
- Honeywell: Explore conventional and novel acoustic liner concept design and modeling
- Honeywell: Honeywell preparing for static engine test with novel liners designed by NASA
- IFAR (International Forum for Aviation Research): Investigate source and flow direction effects on acoustic impedance
- MTU: Poroelastic liner research
- ODU: Explore time domain method to study acoustic scattering with liners
- Raytheon Technologies: Compare analytical and computational impedance prediction tools
- Sierra Space: Design/evaluate bulk absorbers and local-reacting tonal liners for reduction of fan noise on the Large Integrated Flexible Environment (LIFE) habitat
- A few others are in negotiations

Publications

30th AIAA/CEAS Aeroacoustics Conference (2024) – Rome, Italy

- B.M. Howerton, “Acoustic Liner Drag: Measurement Uncertainty Reduction and Application to Novel Perforate Geometries,” AIAA 2024-3247
- J. Kreitzman, M.G. Jones, “Influence of Source Type on Acoustic Liner Impedance in No Flow,” AIAA 2024-3249
- D.M. Nark, M.G. Jones, J. Kreitzman, B. Schuster, “Bypass Duct Acoustic Liner Design with and without Bifurcation Effects,” AIAA 2024-3250
- F.Q. Hu, D.M. Nark, “An Extension of the Truncated Ingard-Myers Boundary Condition for High Mach Number Grazing Flows,” AIAA 2024-3291
- M.G.Jones, D.M. Nark, B.M. Howerton, “NASA Investigation of Flow Direction Effects on Impedance Eduction for Acoustic Liners,” AIAA 2024-3297
- B.M. Howerton, J. Kreitzman, C. Solano, “Extending Acoustic Liner Bandwidth with Simple Embedded Septa,” AIAA 2024-3302
- A.N. Carr, “Acoustic Mode Decomposition in Rectangular Ducts with Sheared Flow,” AIAA 2024-3368
- J.C. June, E. Nesbitt, D.M. Nark, M.G. Jones, “Comparison of Inlet Broadband Acoustic Liner Predictions to Quiet Technology Demonstrator 3 Flight Data,” AIAA 2024-3371

Publications

Journal Articles

- F. Hu, D. Nark, “On a stabilization of the Ingard-Myers impedance boundary condition and its time domain implementation,” International Journal of Aeroacoustics, Vol. 23, Issue 3-4, 2024, https://doi.org/10.1177/1475472X241230649
- A.N. Carr, J.B. Lonzaga, S.A.E. Miller, “Split-step simulations to assess the effects of atmospheric boundary layer turbulence on the dose variability of N-waves and shaped booms,” Journal of Sound and Vibration, https://doi.org/10.1016/j.jsv.2023.118118

Other Publications

- A.N. Carr and B.M. Howerton, “Background turbulence characterization of the curved duct test rig,” NASA/TM-20230018450, February 2024
- M. Brown, A. Ciletti, J. Godakawela, B. Sharma, “The two-cavity method for characterizing acoustical materials — an interlaboratory study,” NOISE-CON 2024, June 13-17, New Orleans
- M.G. Jones, J.R. Kreitzman, and D.M. Nark, “Examination of Perforate Facesheet Impedance Prediction Models,” NASA/TP-20240006417, August 2024

Presentations

- A. Ciletti, M. Brown, J. Godakawela, B. Sharma, “Sound Absorption Properties of Additively Manufactured Porous Materials With Minimal Surface Pore Geometries,” Acoustical Society of America, May 13-17, Ottawa, Canada.

This work was conducted in support of the Advanced Air Transport Technology and Revolutionary Vertical Lift Technology Projects of the NASA Advanced Air Vehicles Program.

Questions?