Project 79

Novel Noise Liner Development Enabled by Advanced Manufacturing

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PM: Arthur Orton

Cost Share Partner: Raytheon Technologies Research Center

Co-PI: Jeffrey Mendoza

NASA Langley Research Center (un-funded)

POCs: Mike Jones and Doug Nark

Co-PIs: Allison Beese, Eric Greenwood, Jay Martin

Objective:

Develop and demonstrate a methodology for rapid design, analysis, fabrication, and testing of novel structures that can enhance noise attenuation in aircraft engines

Project Benefits:

Novel acoustic liner designs and materials will provide a new approach for aircraft engine manufacturers to realize simultaneous noise, emissions, and fuel burn reductions

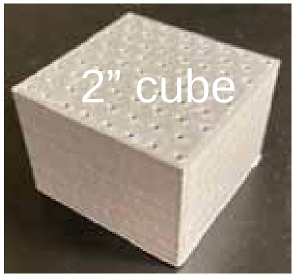
Research Approach:

1. Establish a set of acoustic requirements for future aircraft engine designs
2. Design and analyze lattice-based acoustic liners using advanced software tools
3. Rapid, iterative prototyping and testing to identify promising designs and materials
4. Detailed assessment of manufacturability
5. Acoustic and structural evaluation of novel liners in collaboration with NASA Langley
6. Document results and archive data for FAA

Major Accomplishments (to date):

- New project awarded in October 2021
- Compiled team's testing capabilities
- Identified baseline design geometry
- Prototyping design-build-test workflow across partners

3DP SDOF liner



Future Work / Schedule:

Jan 2022: Demo/test design methodology

Mar 2022: Fab/test 5-6 lattice design samples

May 2022: Structural integrity testing

Aug 2022: Experimental acoustic evaluation

Sept 2022: Document/archive data for Year 1

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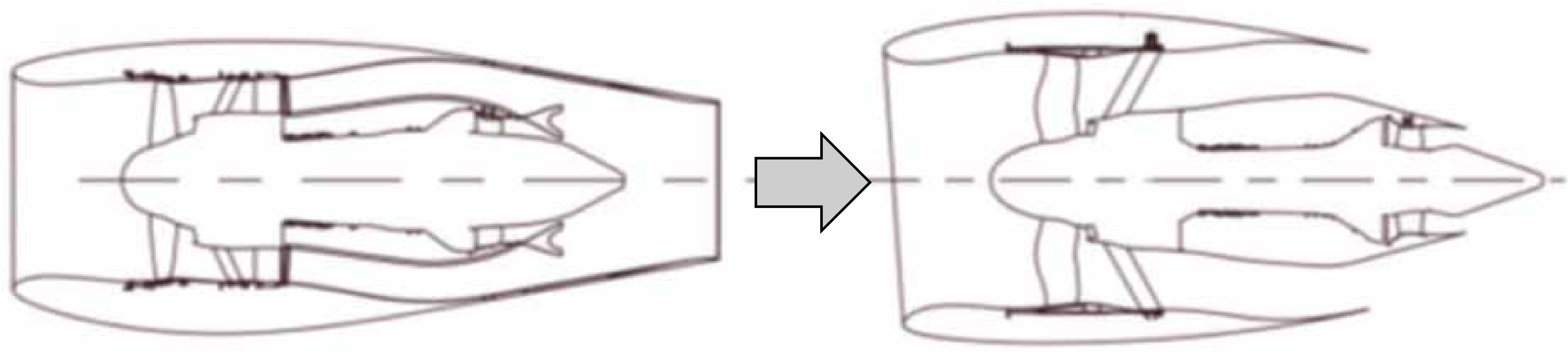
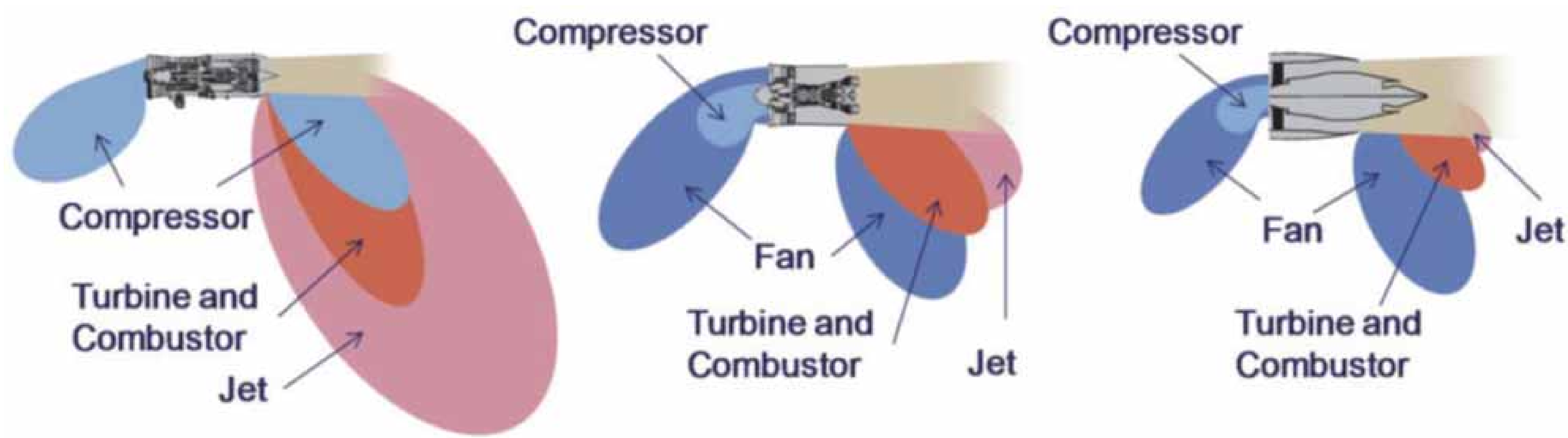
Trends toward ultra-high bypass ratio aircraft engines dramatically changes acoustic liner requirements

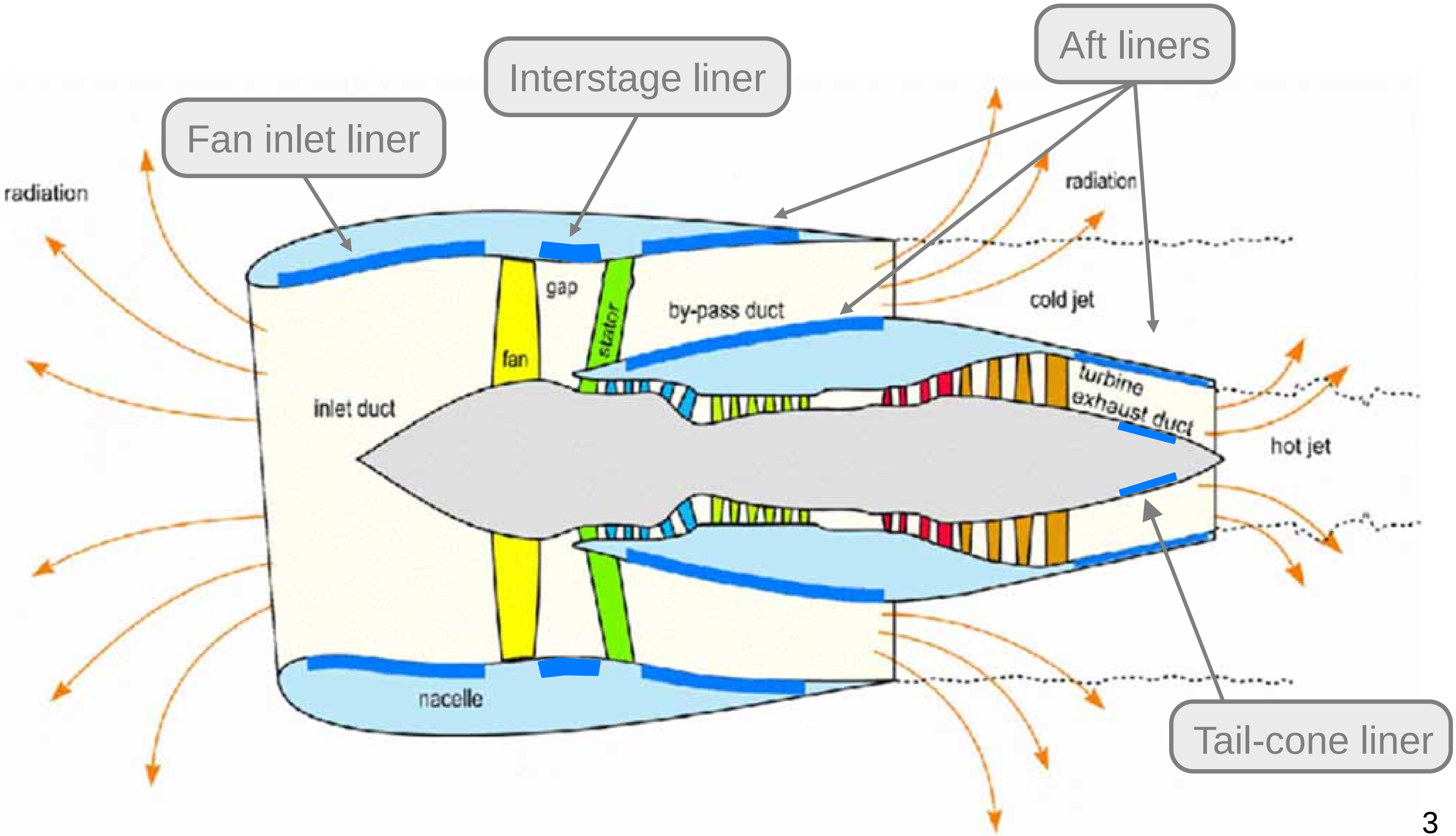


Growth in turbofan engine bypass (above) leads to wide variation in noise requirements, frequencies, and amplitudes (below)

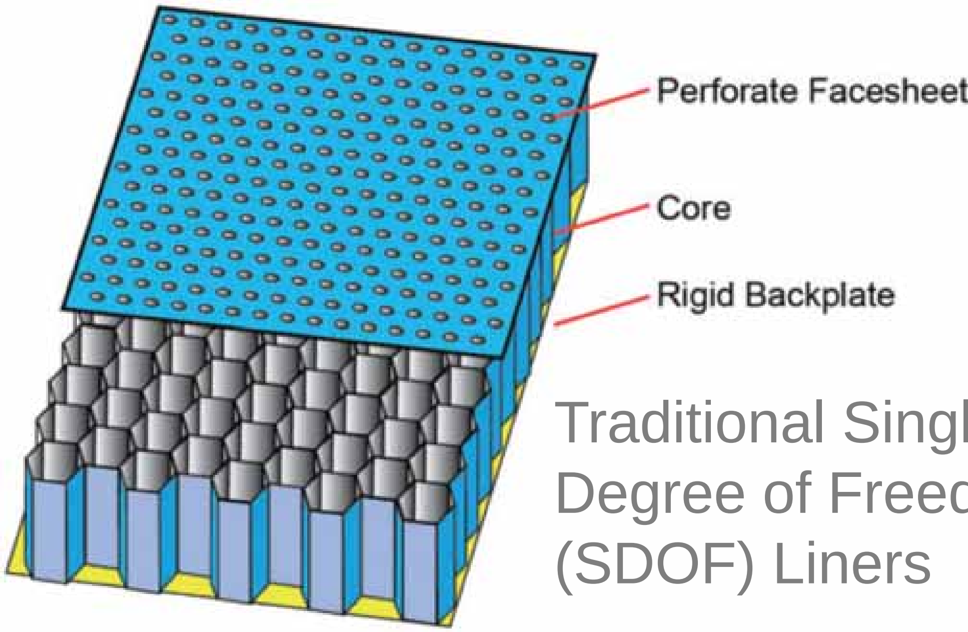


Changes to nacelle designs combined with drive to reduce weight necessitate new acoustic liner designs and placement

Traditional locations of acoustic liners

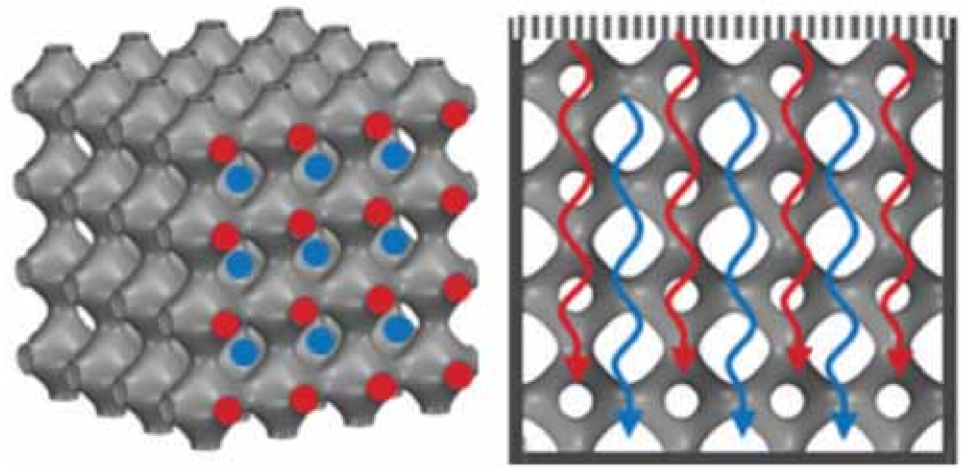


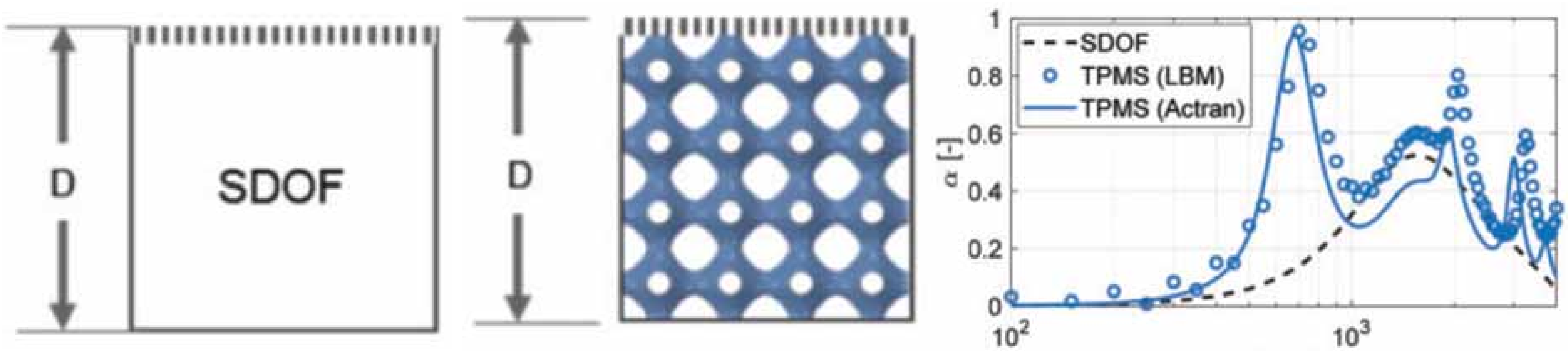
Additive manufacturing (AM) enables new acoustic liner designs that can enhance noise attenuation and save weight



Traditional Single Degree of Freedom (SDOF) Liners

Acoustic liner based on Schwarz P TPMS* design



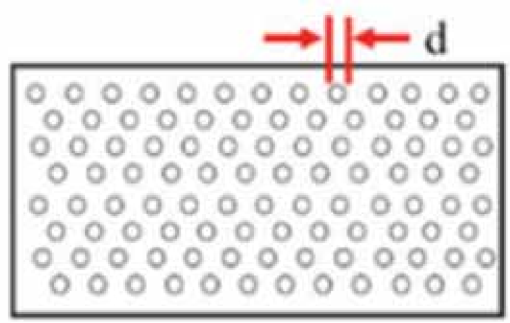


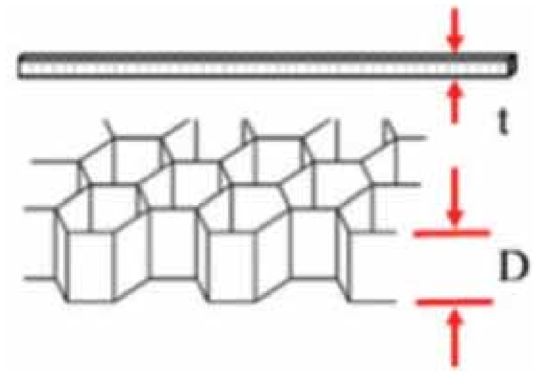
Enhanced attenuation with less material

*Triply Periodic Minimal Surfaces

Design space has significantly expanded due to range of geometries, materials, and AM technologies now available

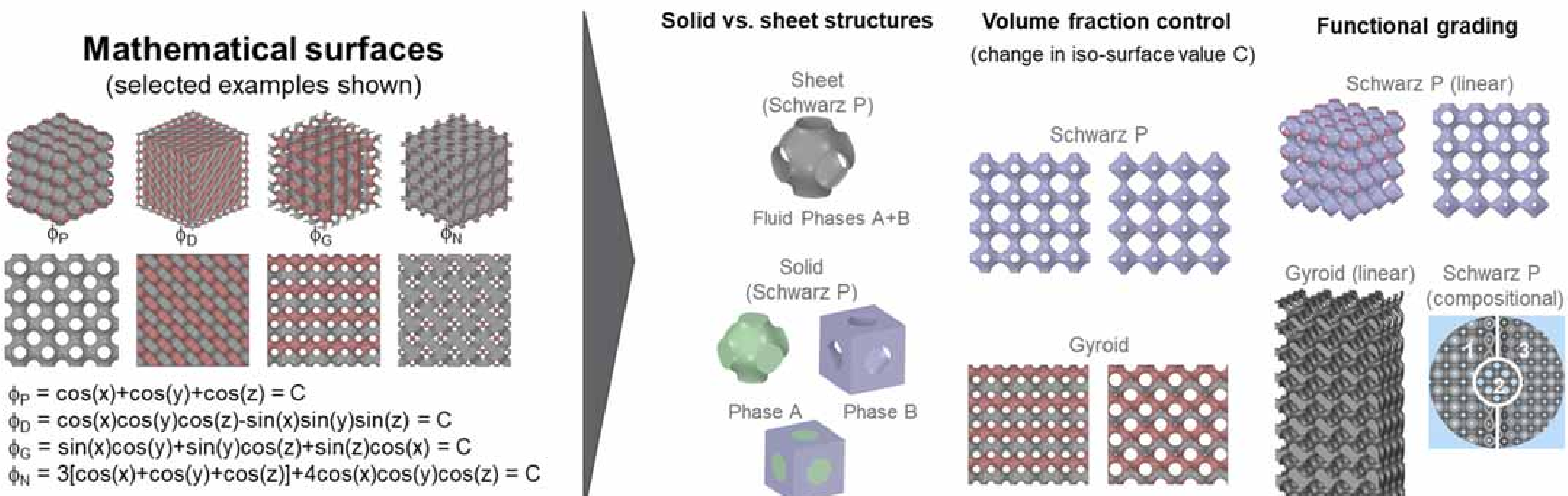
Design parameters for traditional SDOF liners



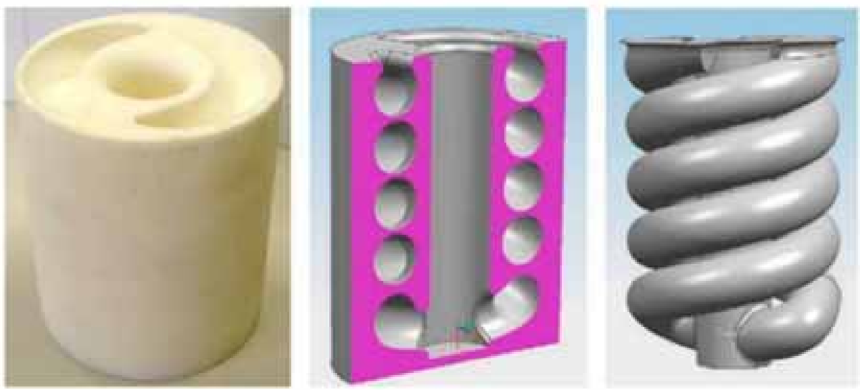


Vs.

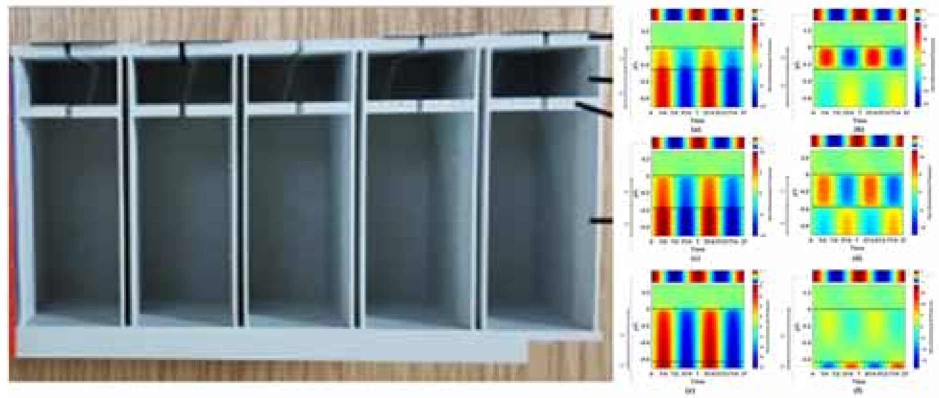
Infinite geometries with countless parametric variations



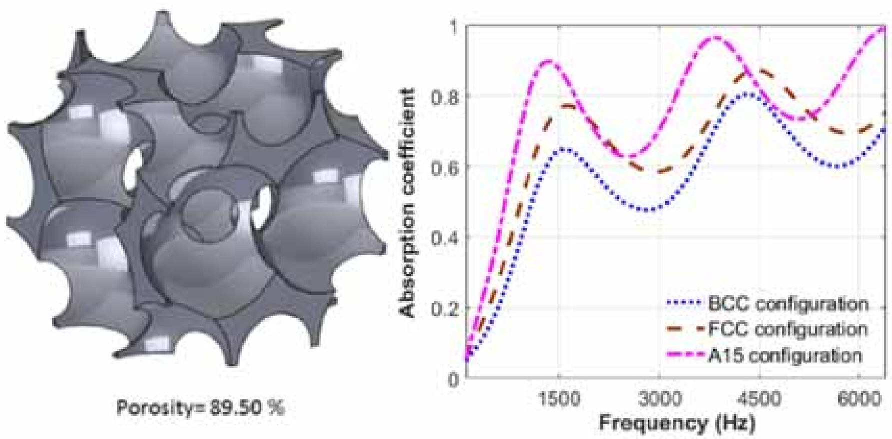
Design and testing of AM acoustic liners is still in its infancy



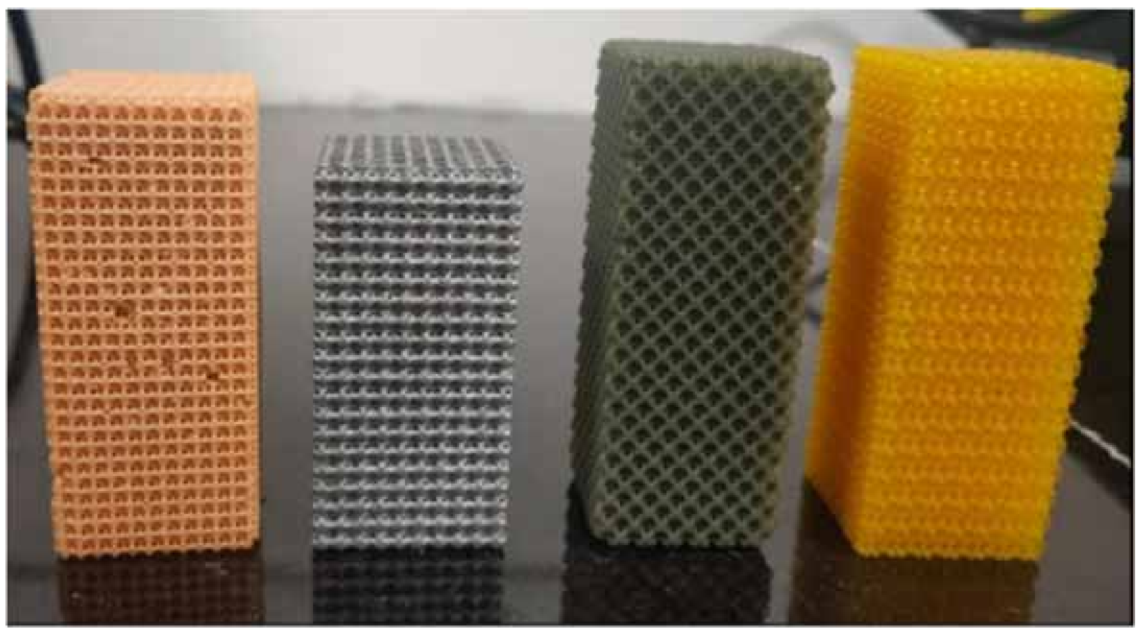
Space-coiling resonator[A]



Double DOF Helmholtz resonators[B]



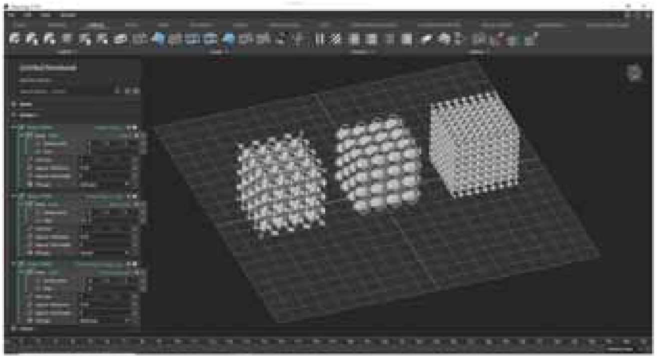
Period foam structures[B]



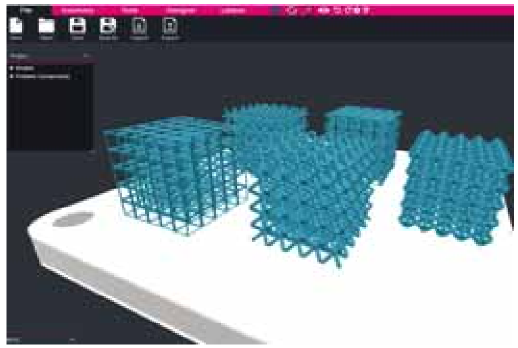
Examples of AM structures for acoustic liners[C]

[A] Source: https://doi.org/10.1016/j.sna.2019.01.022
[B] Source: https://arxiv.org/abs/2010.05665
[C] Source: https://doi.org/10.1007/s00170-020-05853-2

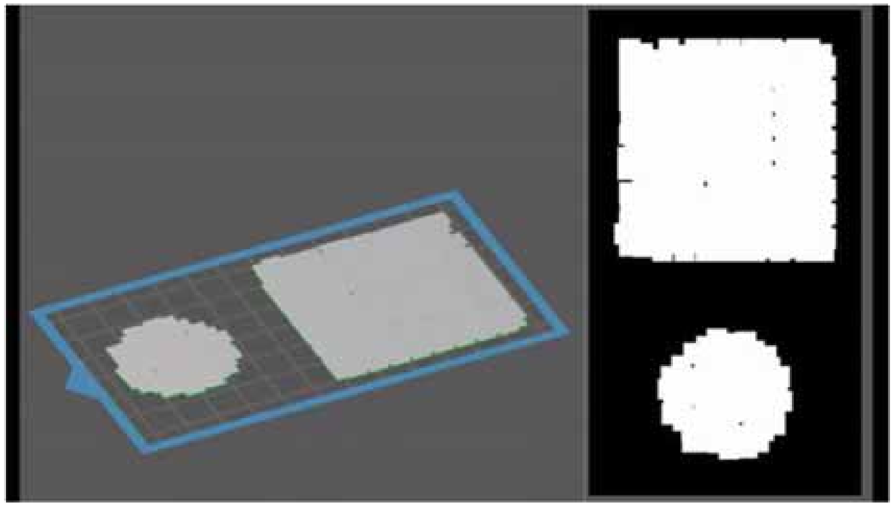
We will develop and demonstrate a new methodology to enable rapid design-build-test cycles for novel AM acoustic liners



New digital design tools

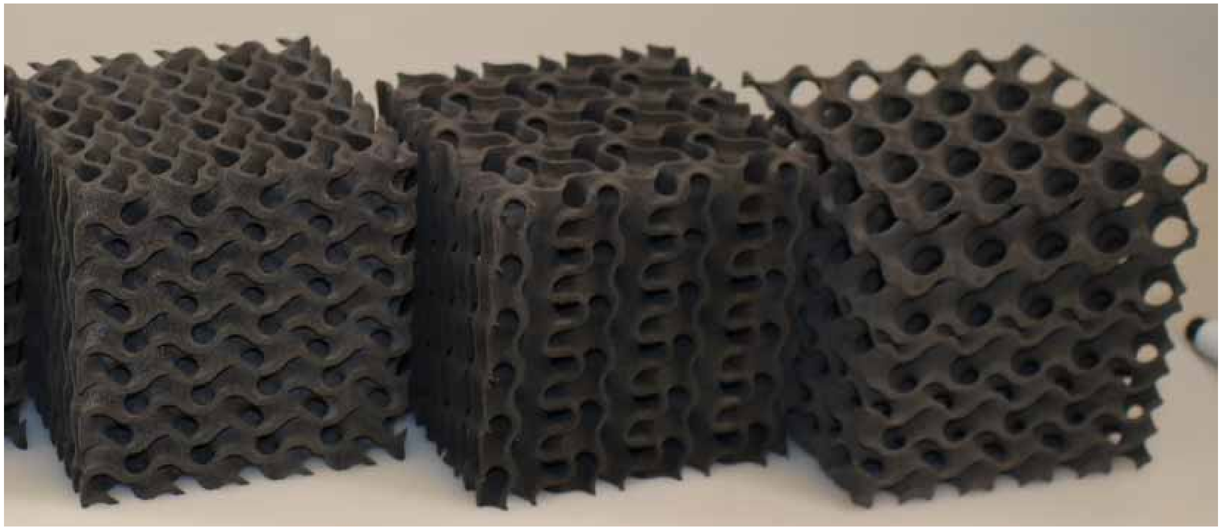


Print layout



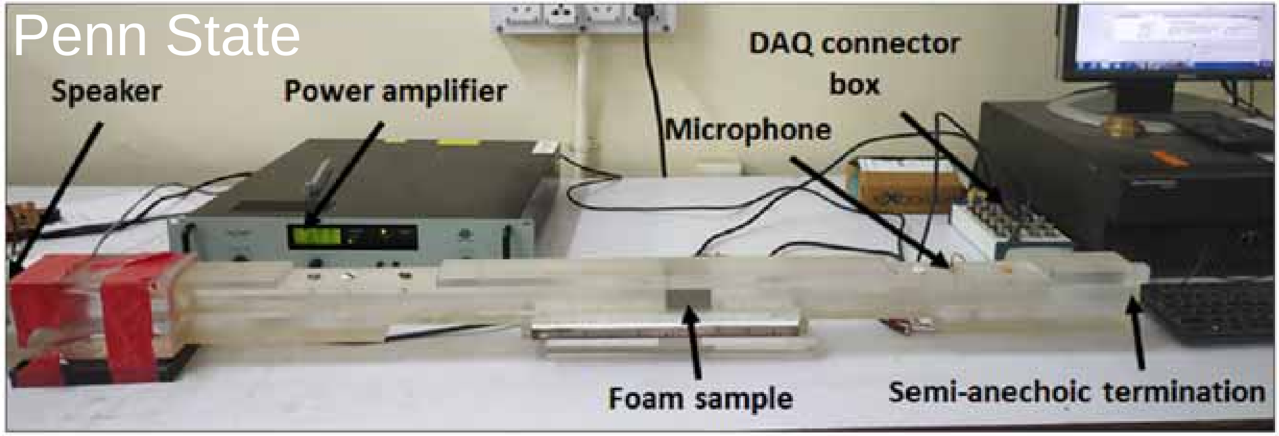
Print verification

Polymer and metal AM processes and materials



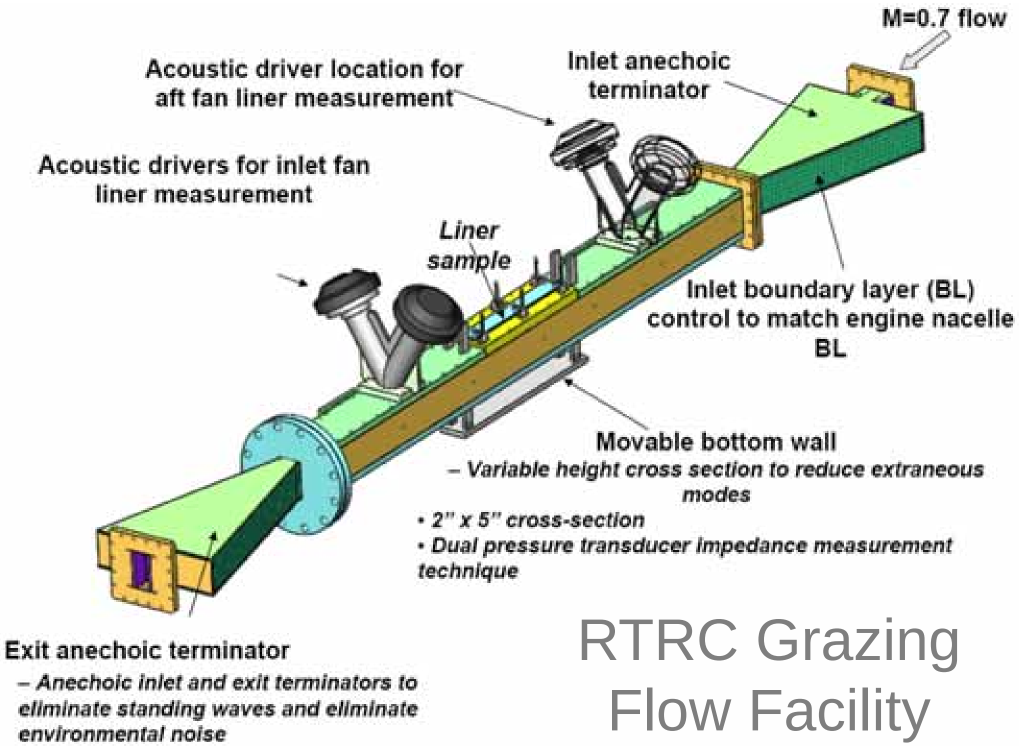
Parallel prototyping for rapid design iteration

Combined team has a variety of normal impendence flow testing capabilities for experimental validation



NASA Langley

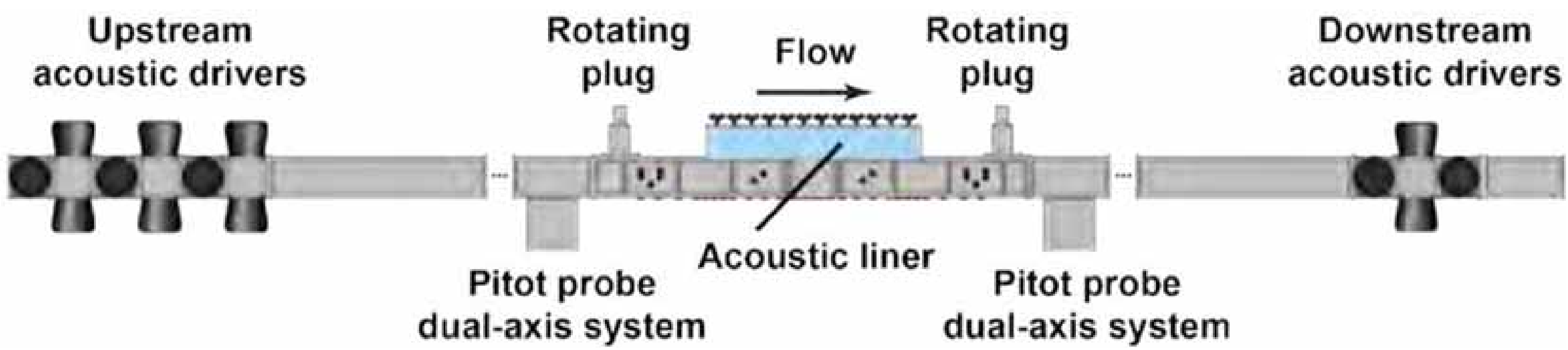
Grazing flow and advanced curved flow testing capabilities are also available



RTRC Grazing Flow Facility

NASA Langley Curved Duct Testing Rig

NASA Langley Grazing Flow Impedance Tube



Experimental testing will be used to modeling and analysis capabilities for complex acoustic liner designs

Team's starting point: Raytheon's rapid design screening approach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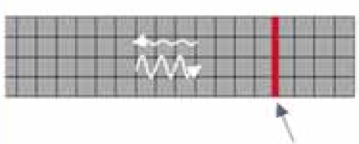
High fidelity modeling tools for engine liner design and screening of advanced concepts

Julian Winkler[1], Jeffrey M Mendoza[1], C Aaron Reimann[1], Kenji Homma[1] and Jose S Alonso[2]

Rapid design screening

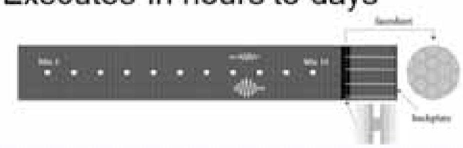
- FEM-based, linear
- Geometry approximated
- Integrated sub-models for losses
- Executes in seconds



Example: SDOF liner facesheet as interface (transfer matrix)

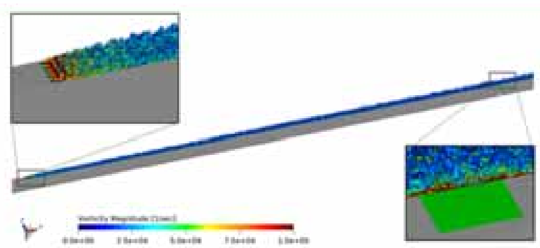
Normal-incidence impedance tube

- LBM-based, linear and non-linear
- No flow
- Actual geometry
- Executes in hours to days



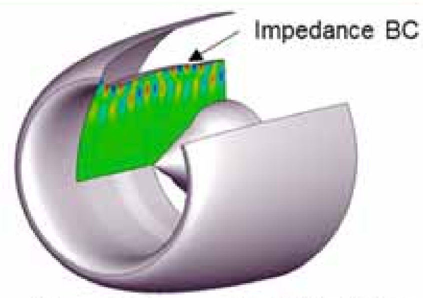
Grazing flow impedance tube

- LBM-based, linear and non-linear
- Grazing and bias flow
- Actual geometry
- Heterogeneous liners
- Executes in hours to days



System study

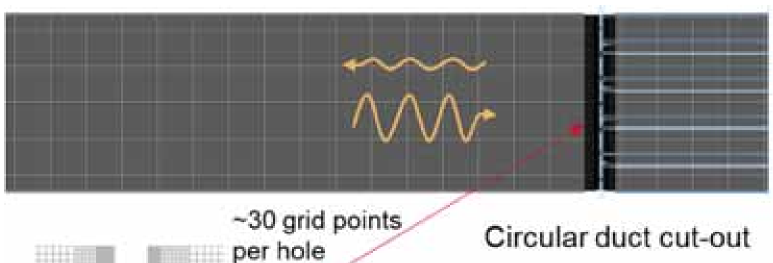
- FEM-based, linear
- Represent liner effect by Impedance BC
- Executes in minutes

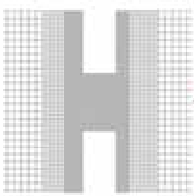


Picture from: https://technology.nasa.gov/patent/LAR-TOPS-185

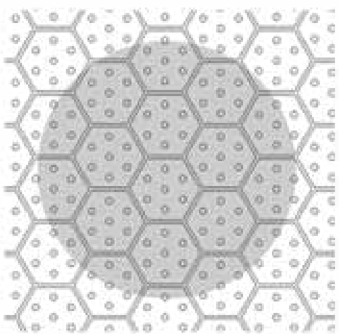
Technical challenges and risks associated with high computational costs, test facility calibration, and AM resolution accuracy

High fidelity = high computational cost

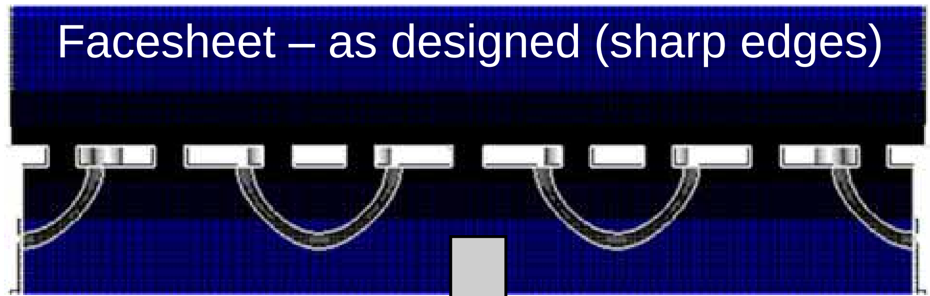


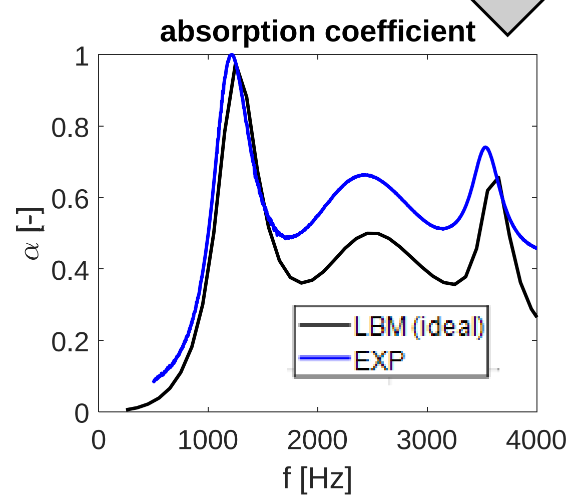


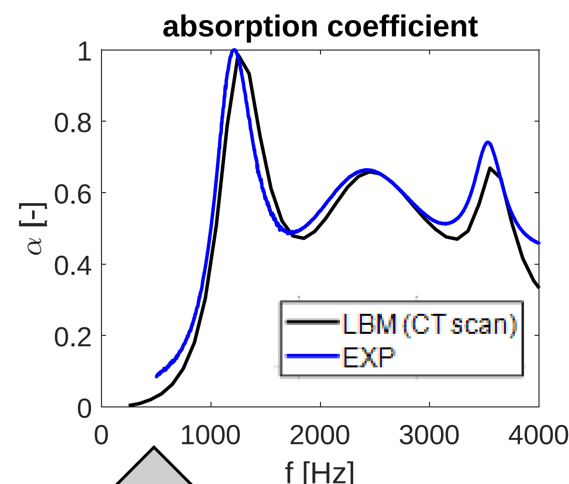
Circular duct cut-out

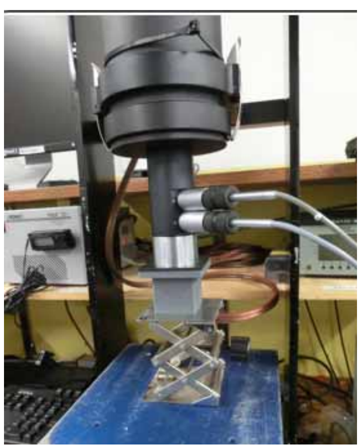


- ~74 Mvoxels total
- ~5 kCPUh runtime

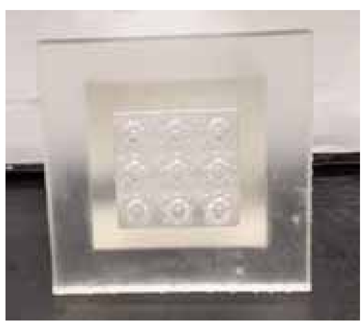


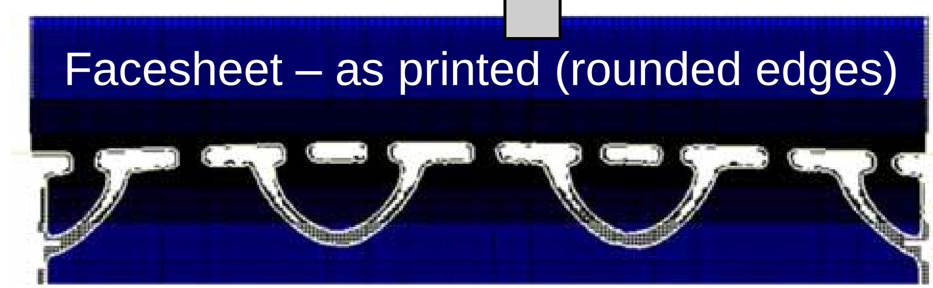






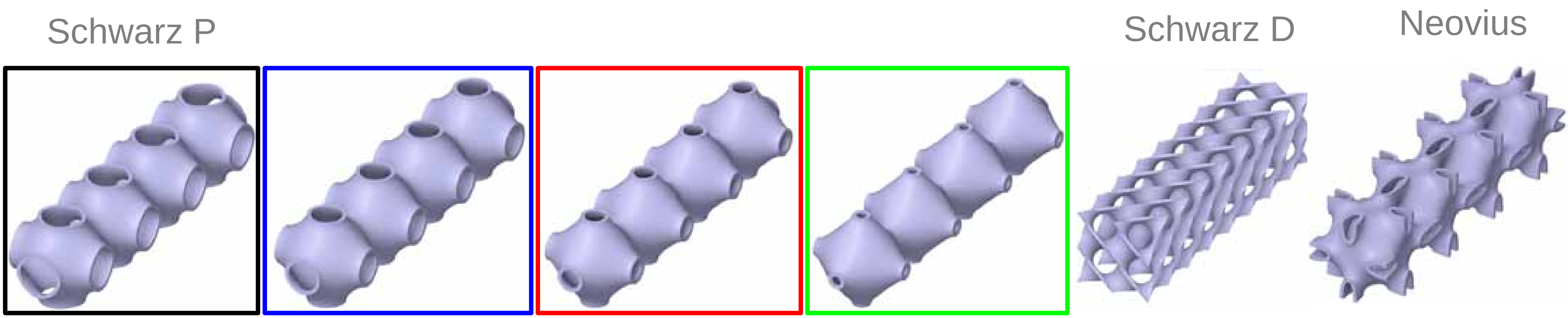
Baseline testing

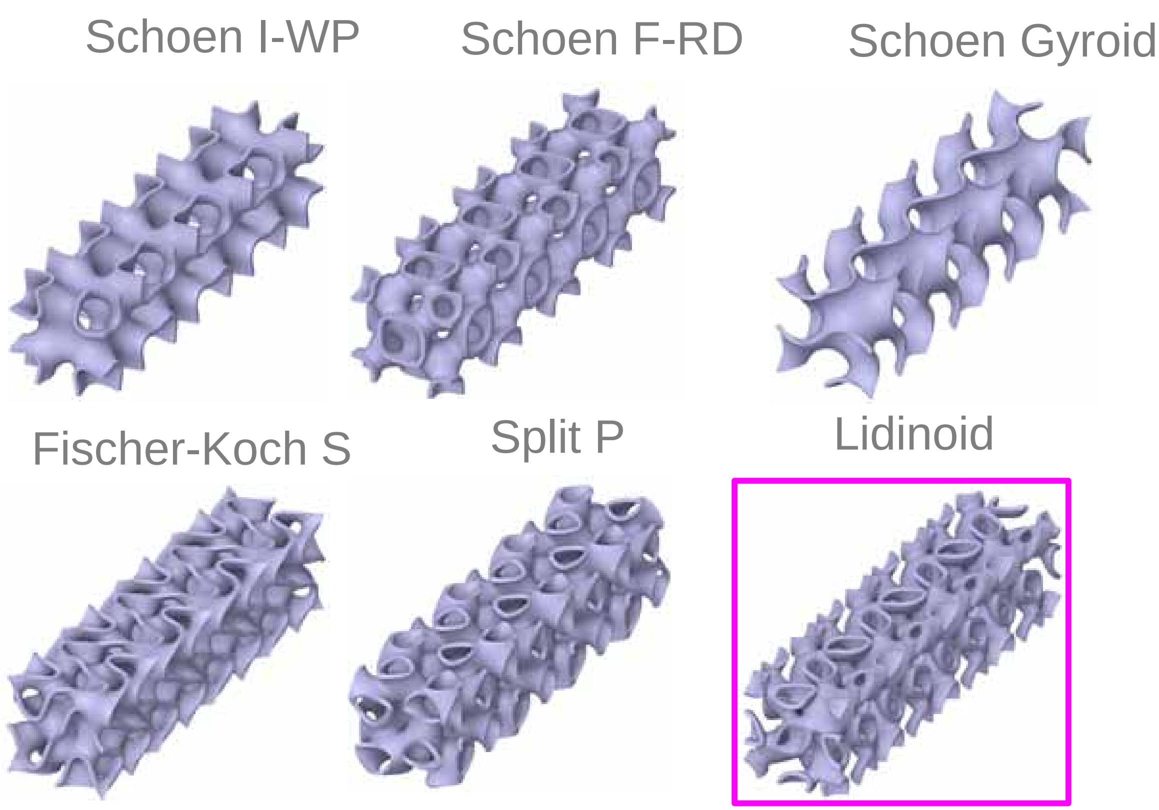


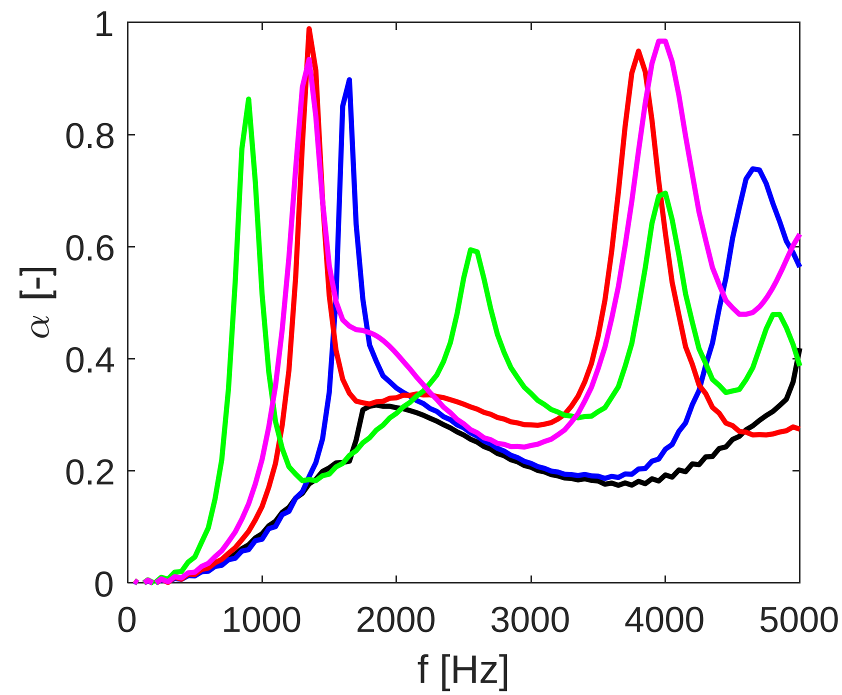


Model geometry can be "corrected" by x-ray CT scan

Plan to advance 5-6 designs in Y1 and scale to larger testing in Y2-Y3 as we learn how to tailor local resonance and tune frequency







Multidisciplinary team of experts from industry, academia, and government (NASA) will ensure project success

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