Project 79
Novel Noise Liner Development Enabled by Advanced Manufacturing

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NASA Langley Research Center (un-funded)
POCs: Mike Jones and Doug Nark

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:

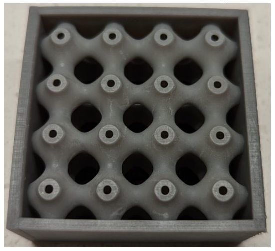
Novel acoustic liner designs and materials will provide a new approach for aircraft engine manufacturers to realize simultaneous noise, emissions, and fuel burn reductions

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):

- Compiled team's AM and testing capabilities
- Identified and compared baseline design geometry
- Performed multi-fidelity acoustic analysis of variety of novel liner geometries
- Prototyping final liners for testing at RTRC and NASA to wrap Year 1

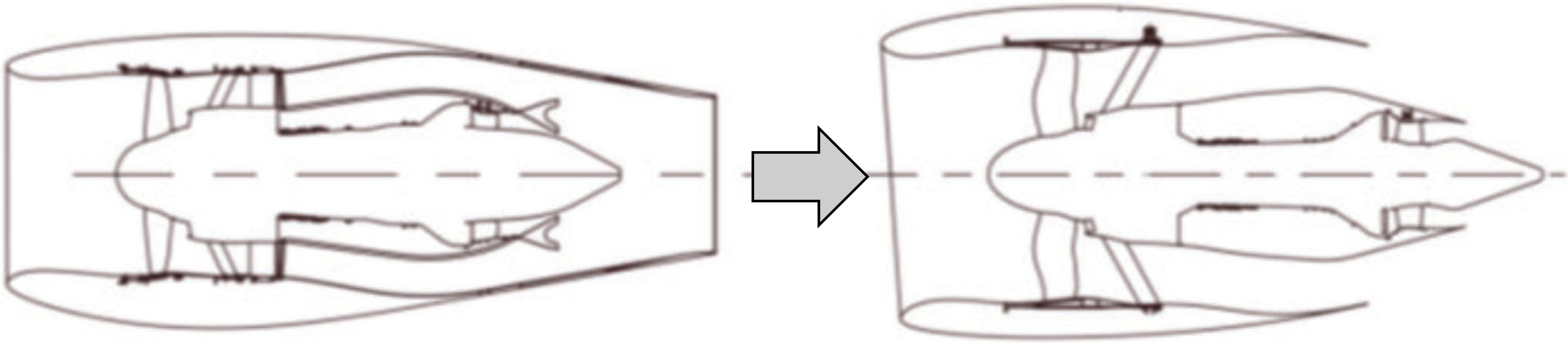


Future Work / Year 2 Schedule:

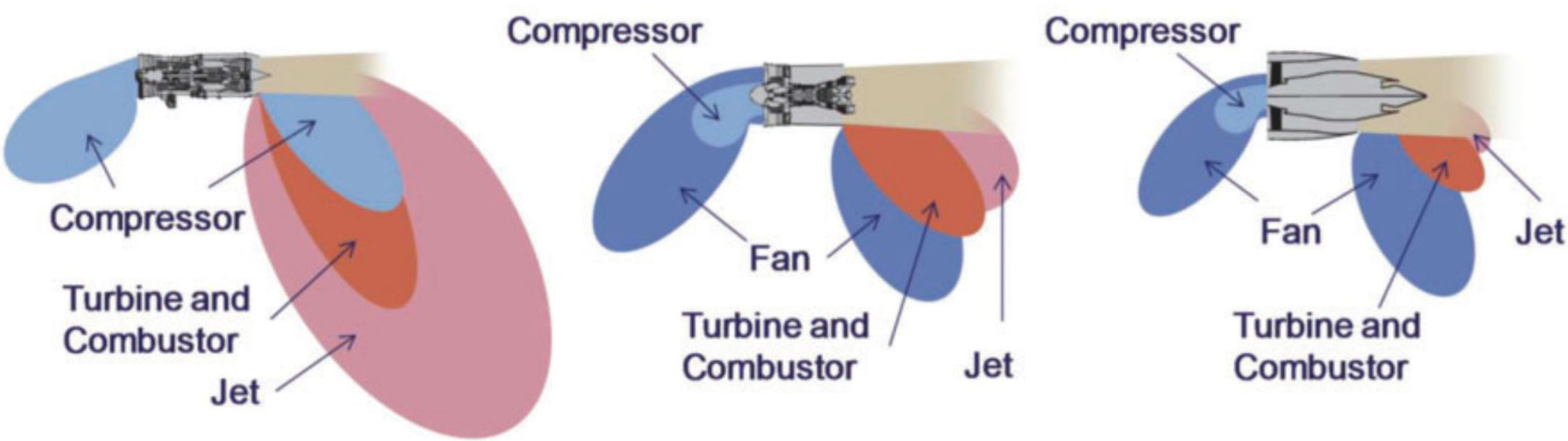
Jan 2023: Optimize 2-3 lattice topologies
Mar 2023: Build/test optimized lattice samples
May 2023: Experimental acoustic evaluation
Aug 2023: Structural integrity testing
Sept 2023: Document/archive data for Year 2

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 79 through FAA Award Number 13-C-AJFE-PSU Amendment 079 under the supervision of Arthur Orton. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

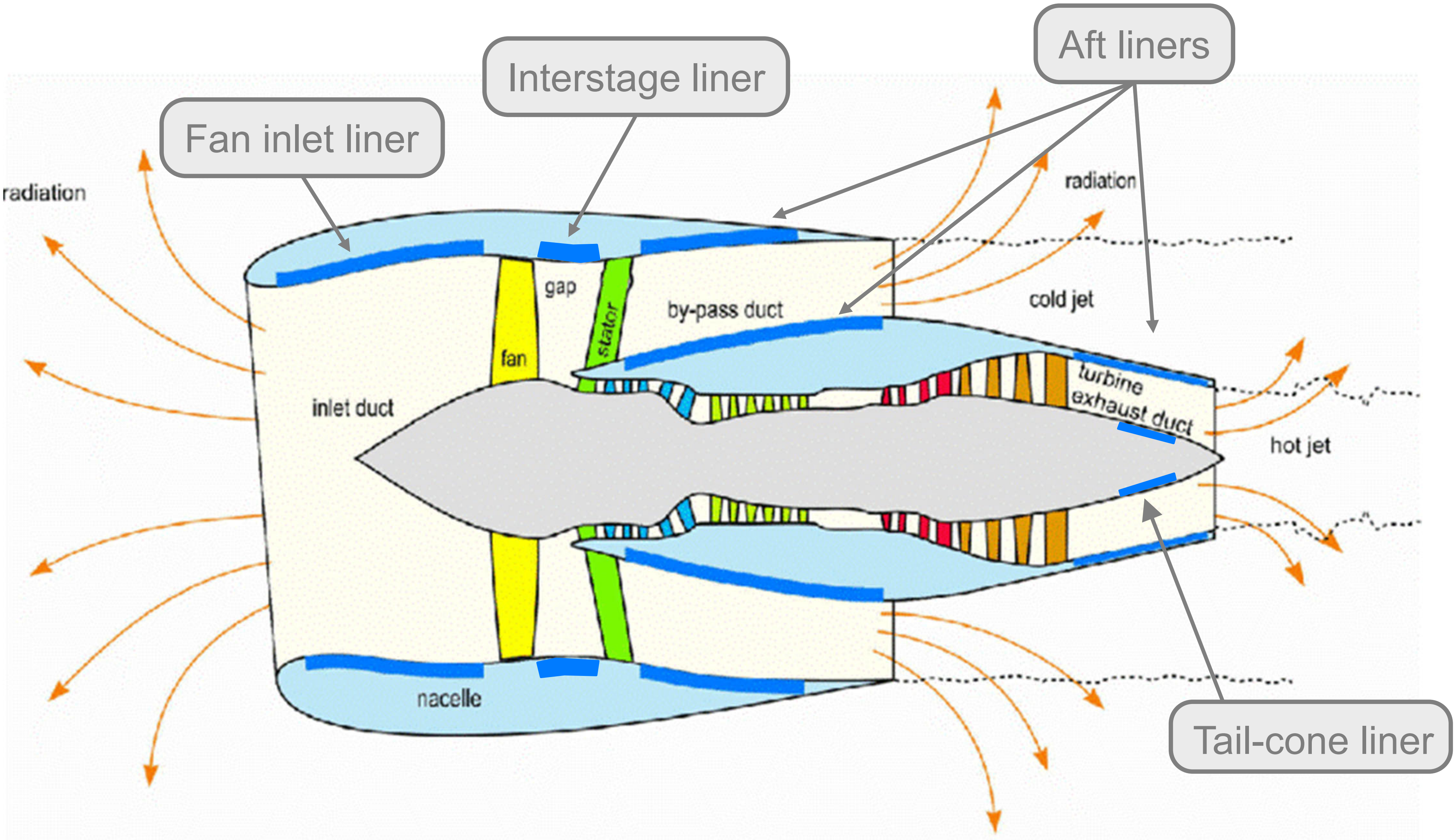
Trends toward ultra-high bypass ratio aircraft engines dramatically changes acoustic liner requirements



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

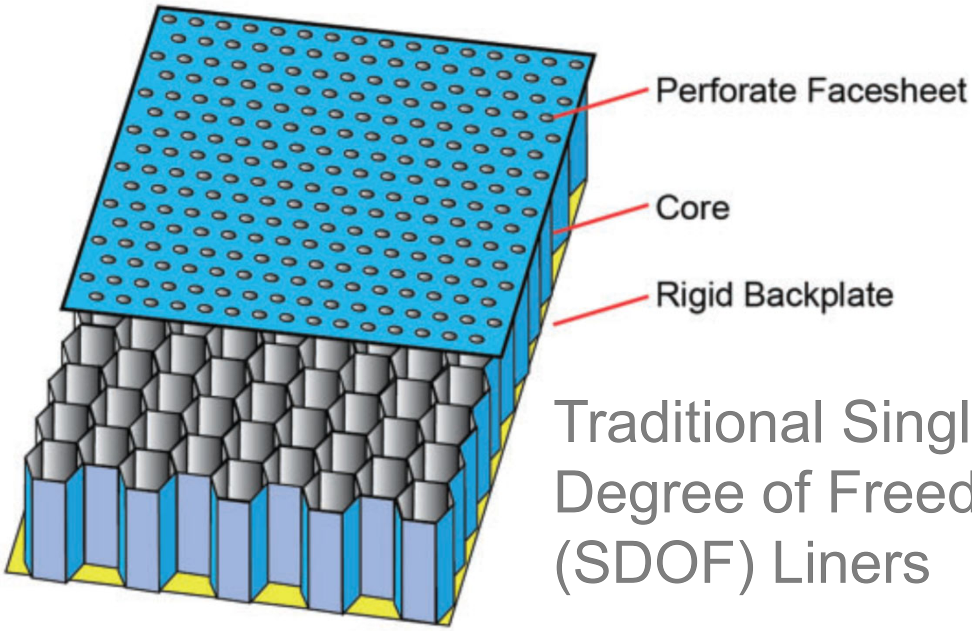


Changes to nacelle designs combined with drive to reduce weight necessitate new acoustic liner designs and placement



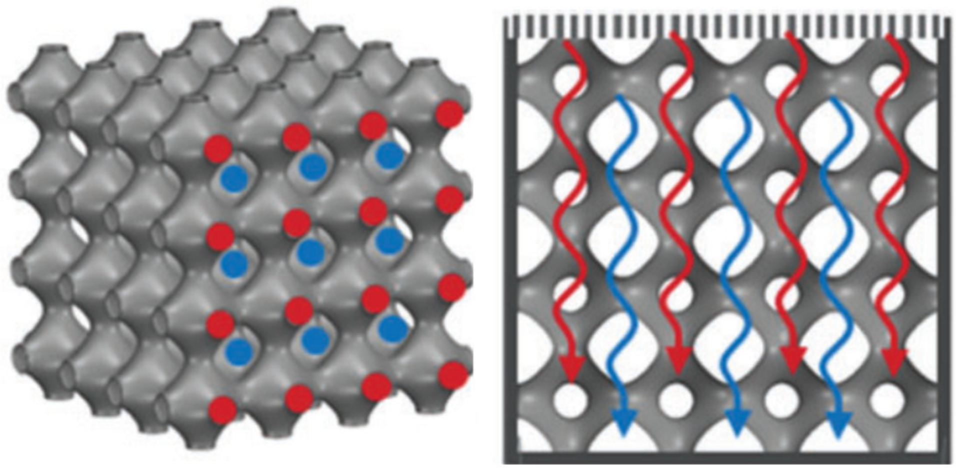
Traditional locations of acoustic liners (highlighted in blue)

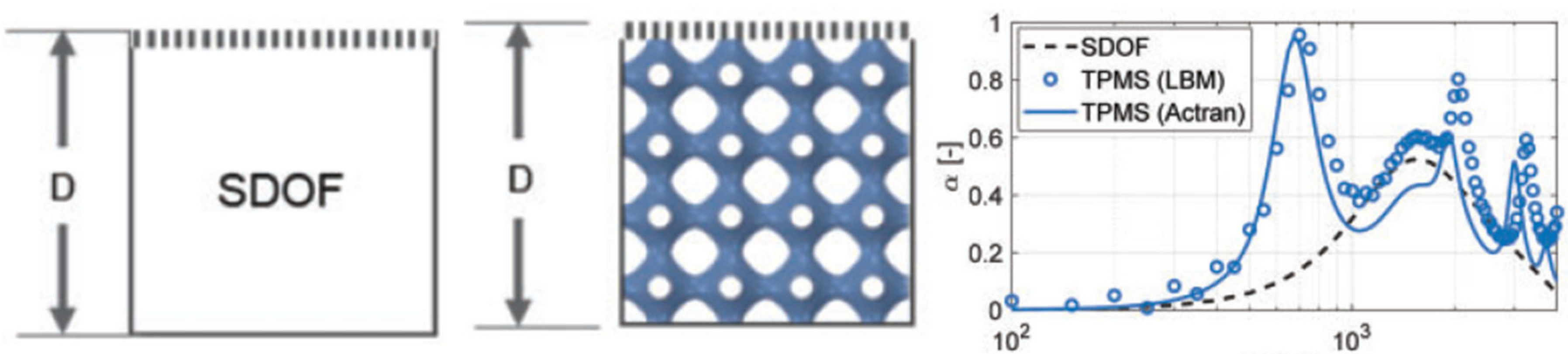
Additive manufacturing (AM) enables new acoustic liner designs that can enhance noise attenuation and save weight



Traditional Single Degree of Freedom (SDOF) Liners

Acoustic liner based on Schwarz P TPMS* design

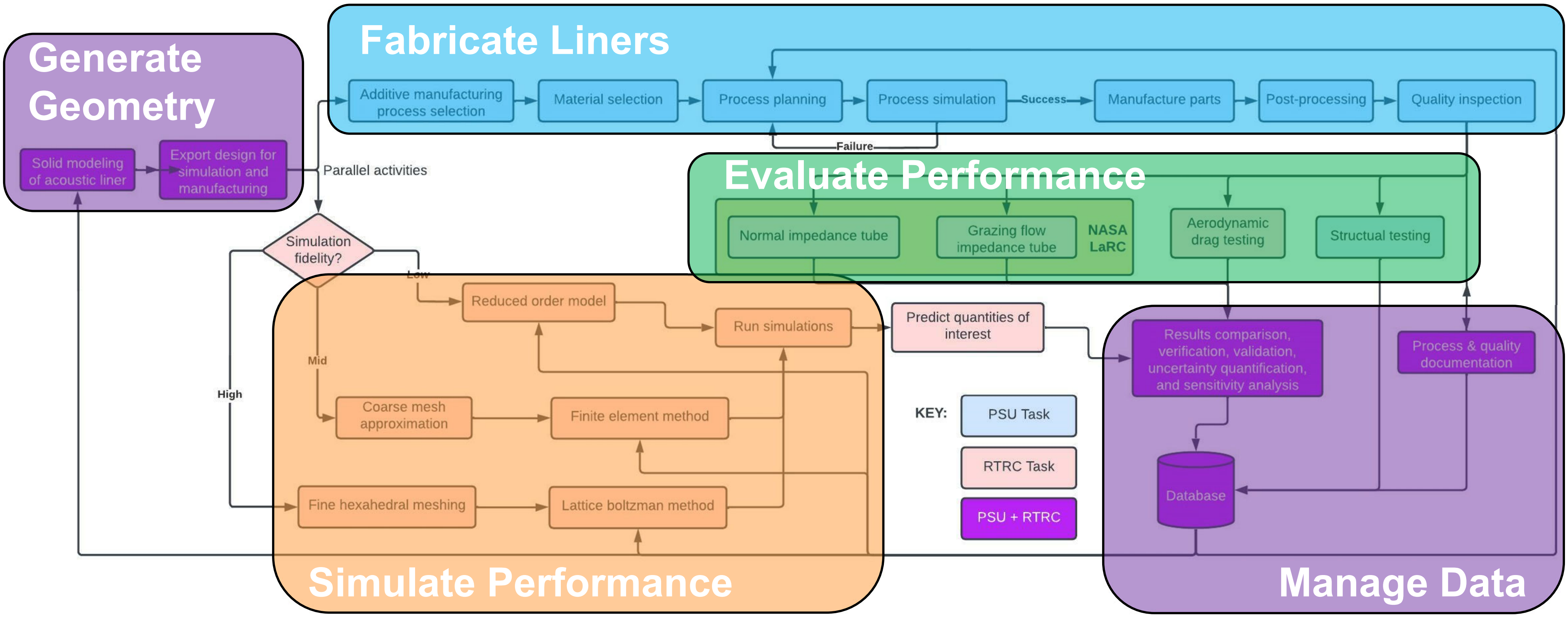




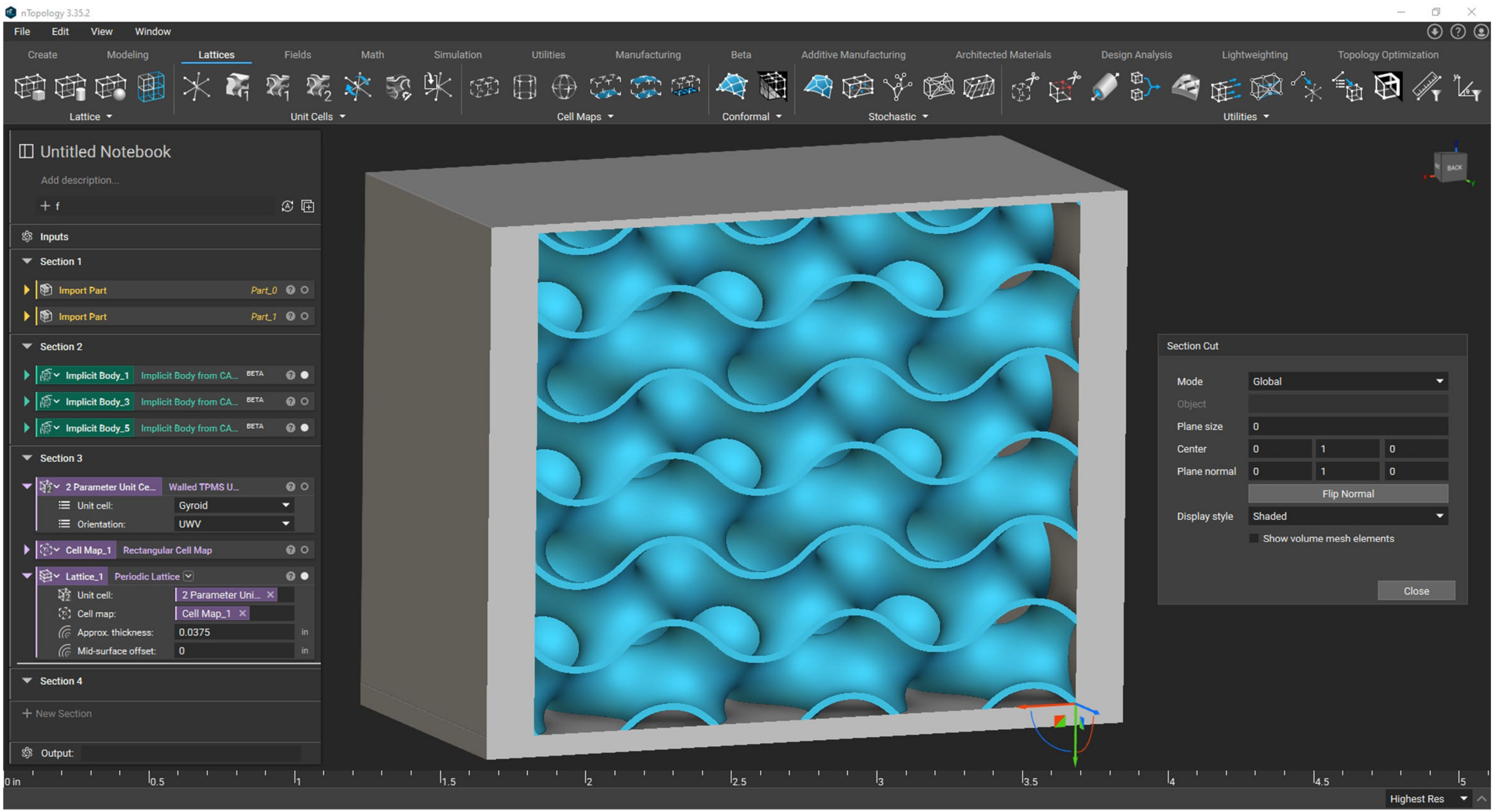
Enhanced attenuation with less material

*Triply Periodic Minimal Surfaces

Design-build-test framework established with optimization planned for Year 2



Developed workflow to rapidly generate parameterized acoustic liner geometries



Lattice Generation using Implicit Solid Modeling in nTopology

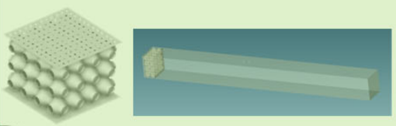
ASCENT AVIATION SUSTAINABILITY CENTER

Multi-fidelity modeling and analysis capabilities are used for complex acoustic liner designs

Primary design path

Rapid design screening (mid-fidelity)

- Numerical impedance tube
- FEM-based, linear
- Geometry approximated
- Integrated sub-models for losses
- Executes in seconds/minutes



Iterate designs

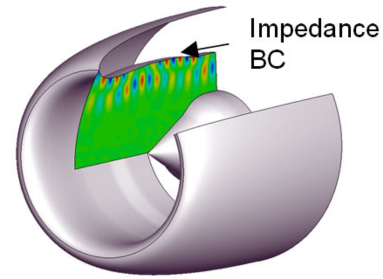
Acoustic impedance

Normal-incidence impedance tube (high-fidelity)

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

System study (mid-fidelity)

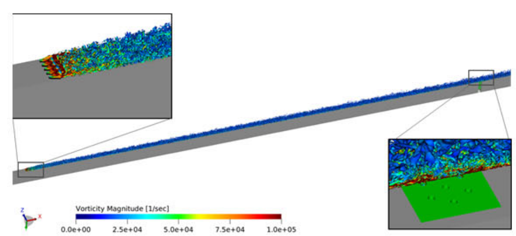
- FEM-based, linear
- Represent liner effect by Impedance BC
- Executes in minutes



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

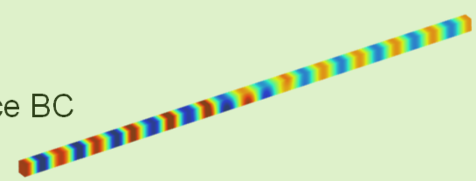
Grazing flow impedance tube (high-fidelity)

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



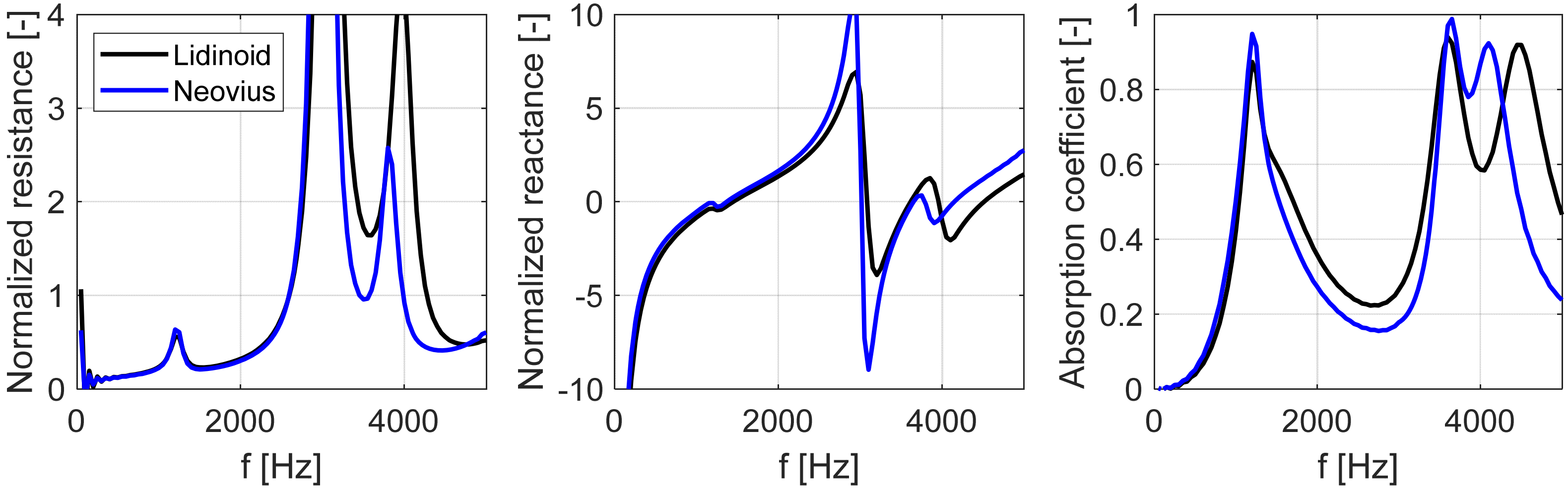
Grazing flow impedance tube (mid-fidelity)

- FEM-based, linear
- Grazing flow
- Represent liner effect by Impedance BC
- Executes in seconds/minutes

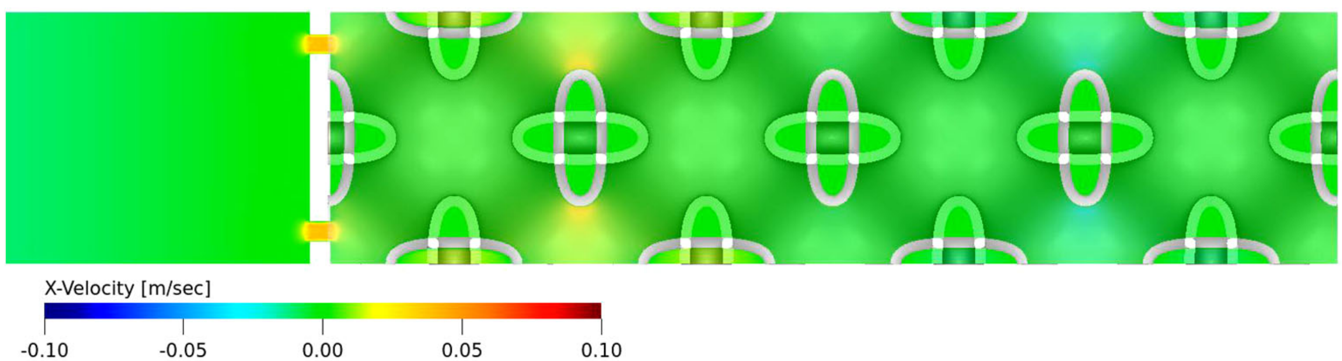


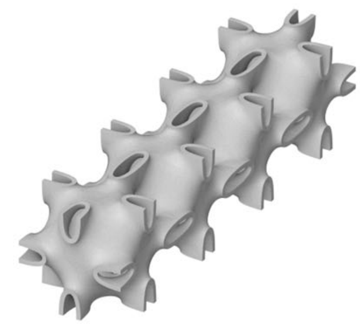
Insertion Loss [dB]

High-fidelity simulations are used to assess acoustic performance of complex liner backings for physical insight

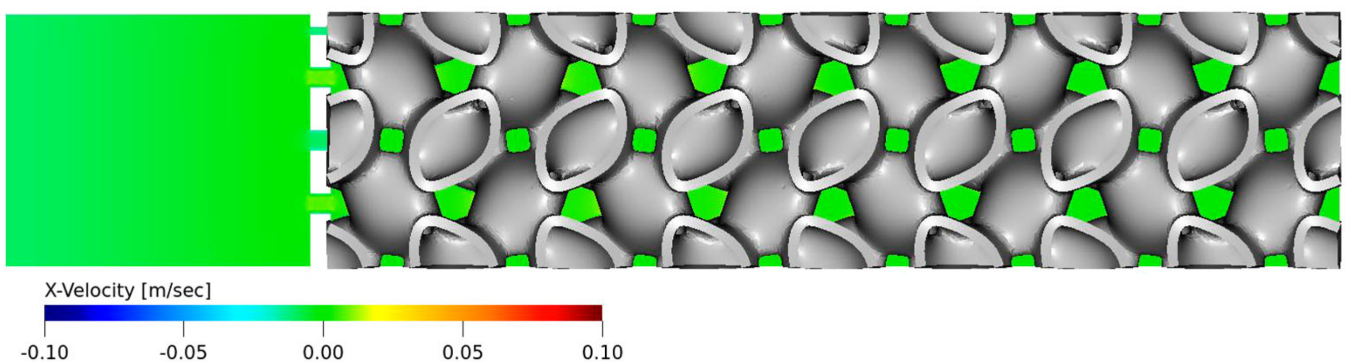


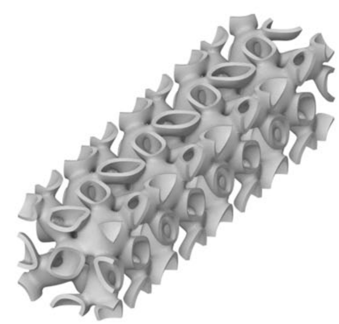
Neovius





Lidinoid

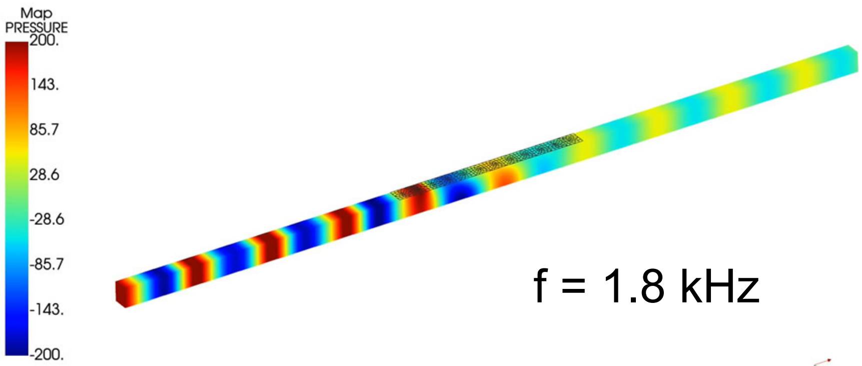


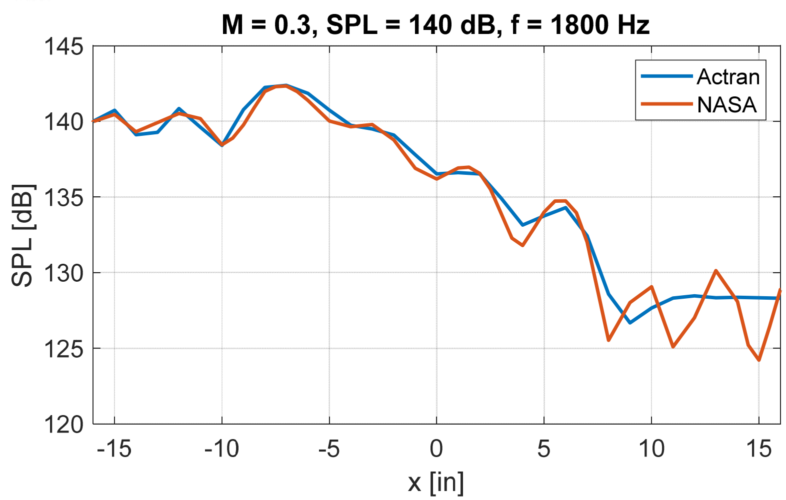


Mid-fidelity simulations are used for design purposes, informed by high-fidelity tool learnings

Virtual version of NASA grazing flow facility used for design assessment and concept down-selection

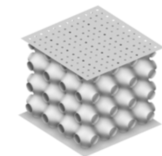
Model validation against test data

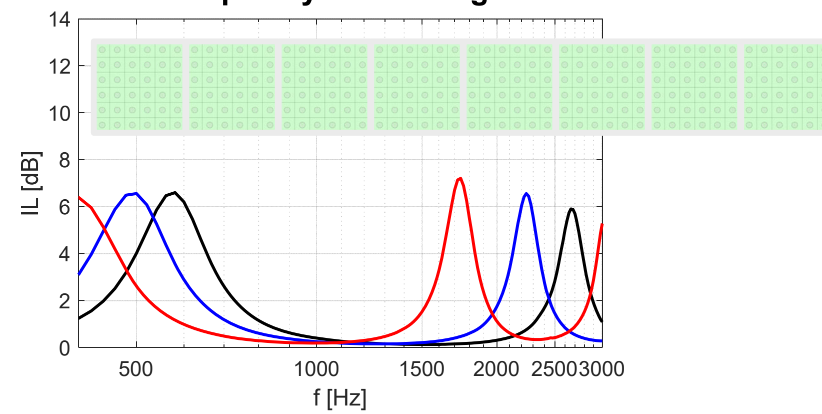


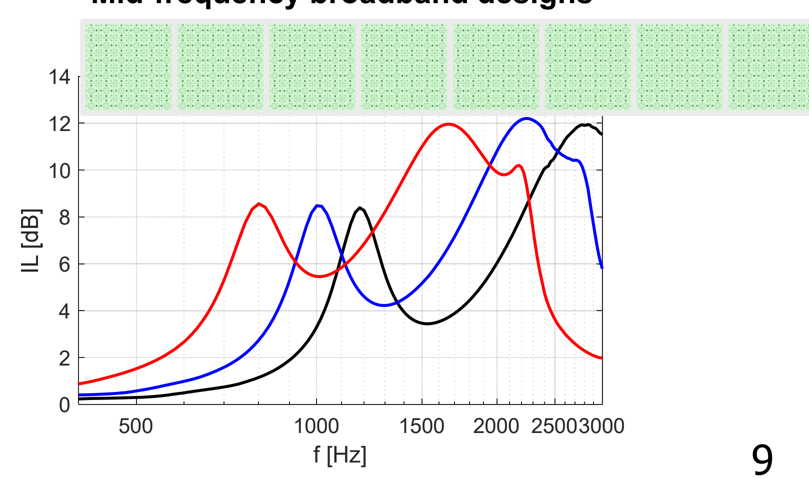


(NASA data from Howerton, B. M., Jones, M.G.. "A Conventional Liner Acoustic/Drag Interaction Benchmark Database". AIAA 2017-4190.)

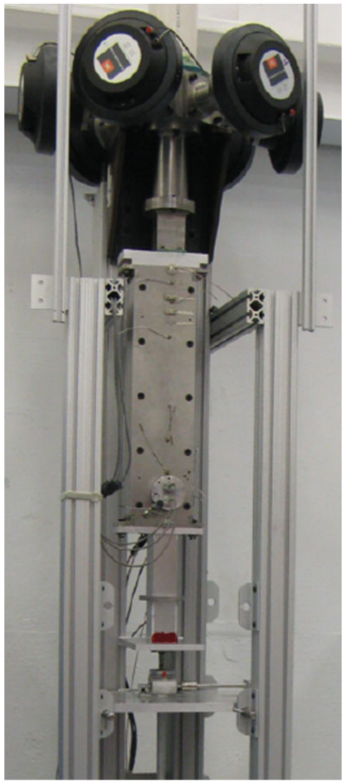
Design concept screening (16" liner samples)







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

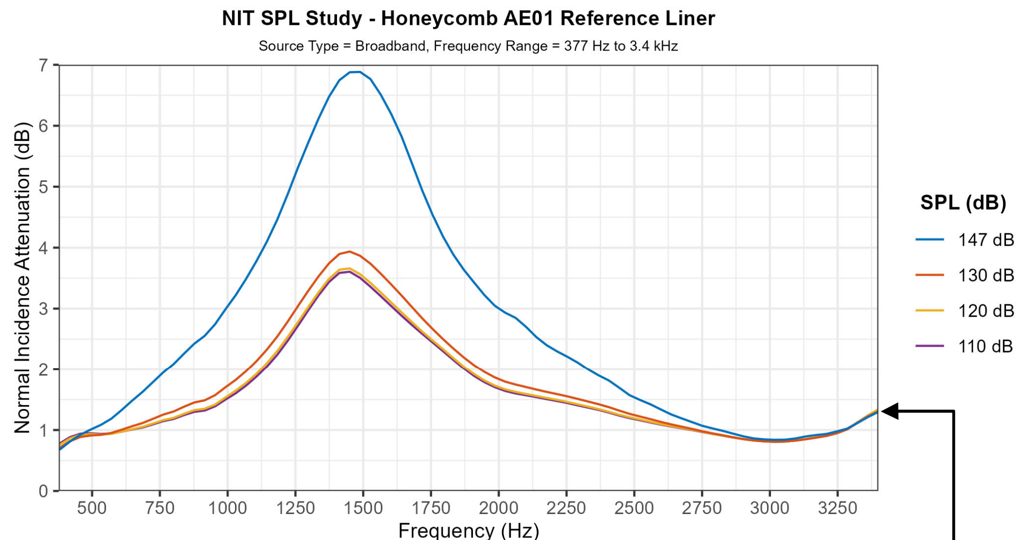


NASA Langley

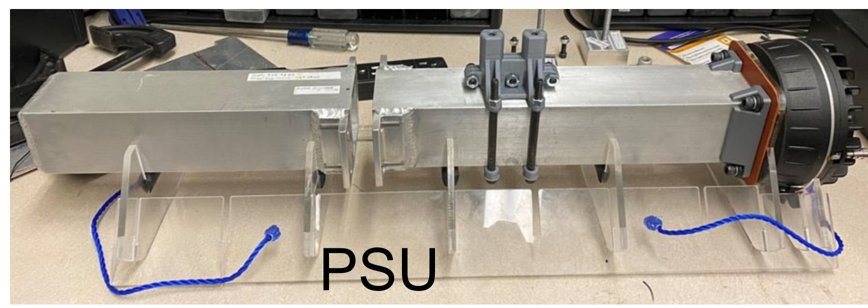
RTRC

Large Sample Config.

Small Sample Config.



Capture Nonlinear Effects at Higher SPLs

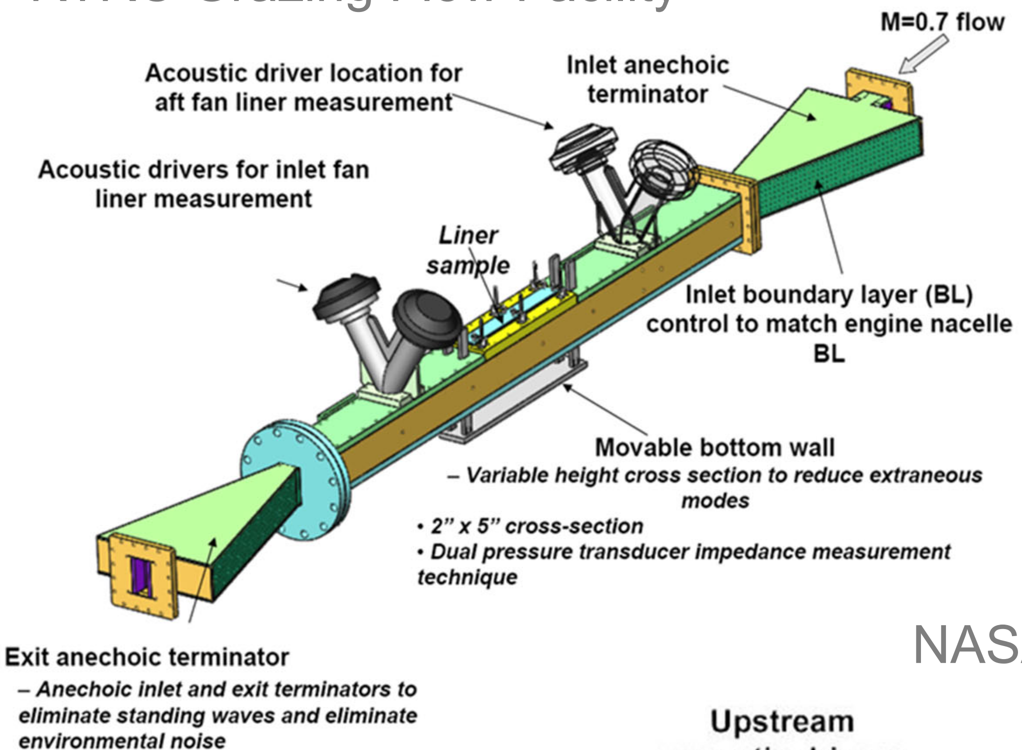


FAA Ascent Project 79 Acoustic Testing Capabilities Summary		Location	Sample Dimensions	Source Type	Frequency Range	Maximum Acoustic Pressure	Centerline Mach Number	Testing Standard
NIT	Brüel & Kjær Impedance Tube Kit Type 4206 (Large Sample Config)	RTRC	Diameter = 100 mm Height ≤ 400 mm	Broadband	500 Hz to 6.4 kHz	140 dB	0.0	ISO 10534–2 ASTM E1050–12
	Brüel & Kjær Impedance Tube Kit Type 4206 (Small Sample Config)		Diameter = 29 mm Height ≤ 200 mm		50 Hz to 1.6 kHz			
	In-House Developed NASA Langley Specification Impedance Tube	PSU	Length = 2 in Width = 2in Height ≤ 8.5 in	Stepped Sine Swept Sine Broadband	377 Hz to 3.4 kHz	146 dB (Broadband)	0.0	
	6 Driver High Intensity Impedance Tube	NASA Langley	Length = 2 in Width = 2in Height ≤ 24 in	Stepped Sine Swept Sine Broadband	400 Hz to 3.0 kHz	155 dB (Stepped Sine) 145 dB (Swept Sine) 140 dB (Broadband)	0.0	

Ascent project 79 NIT Testing Capabilities

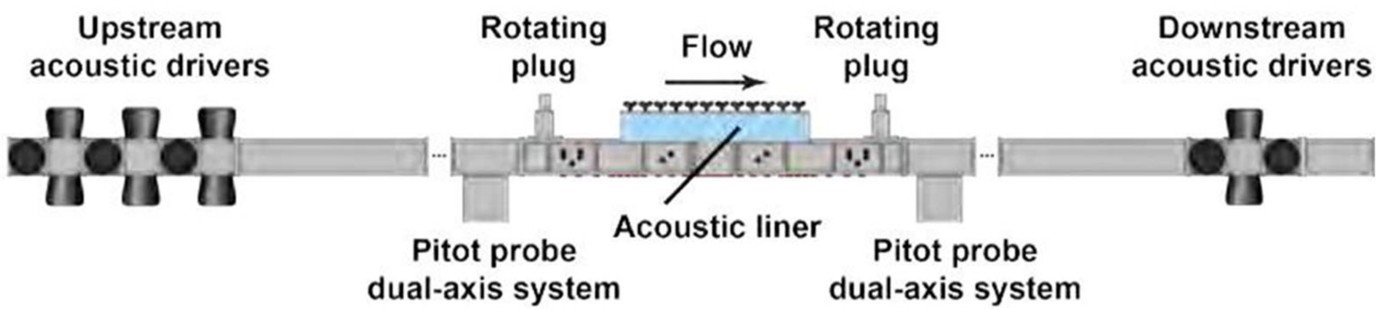
Grazing flow and advanced curved flow testing capabilities will also be utilized

RTRC Grazing Flow Facility



NASA Langley Curved Duct Testing Rig

NASA Langley Grazing Flow Impedance Tube



FAA Ascent Project 79 Acoustic Testing Capabilities Summary		Location	Sample Dimensions	Source Type	Frequency Range	Maximum Acoustic Pressure	Centerline Mach Number	Testing Standard
GFIT	In-House Developed Grazing Flow Impedance Tube	RTRC	Length = 2 in Width = 16.375 in Height ≤ 5 in	Stepped Sine Broadband	500 Hz to 6.5 kHz	160 dB	0.0 to 0.65	N/A
	In-House Developed Grazing Flow Impedance Tube	NASA Langley	Length = 2 in Width = 2 in to 24 in Height ≤ 3 in	Stepped Sine Broadband	400 Hz to 3.0 kHz	155 dB (Stepped Sine) 145 dB (Swept Sine)	0.0 to 0.6	N/A

Ascent project 79 GFIT & CDTR testing facilities

Utilizing and evaluating a variety of AM technologies to gain insight into acoustic performance and limitations

Material Jetting (Polymer Multi-Material)

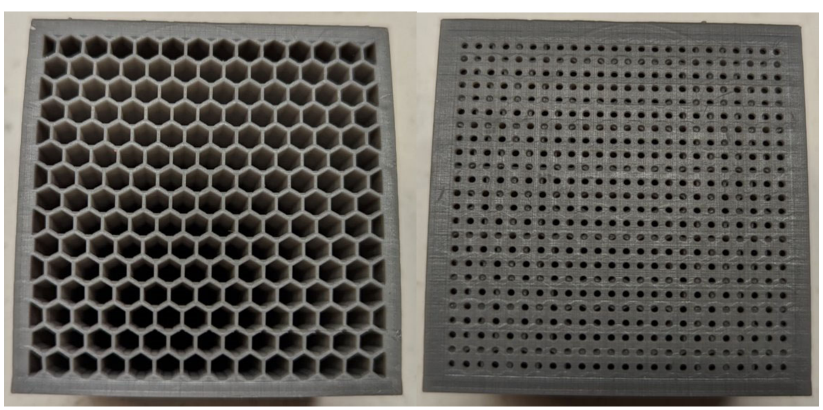
- Stratasys Object350 Connex

Vat Photopolymerization (Polymer)

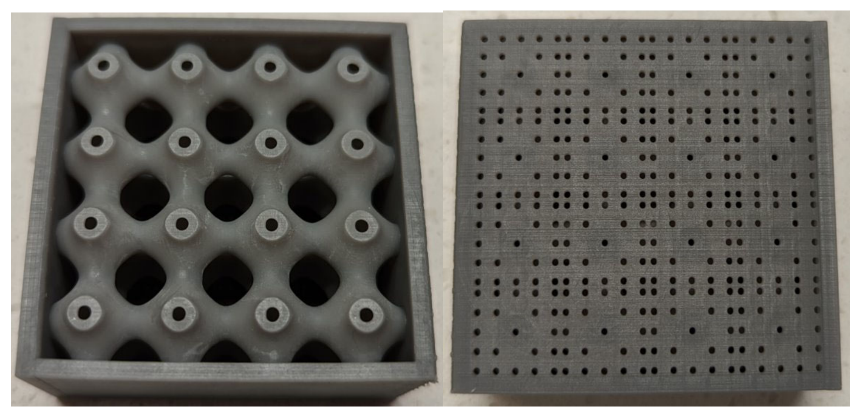
- Formlabs Form 3L
- 3D Systems Figure 4

Laser Powder Bed Fusion (Metallic)

- EOS M 280

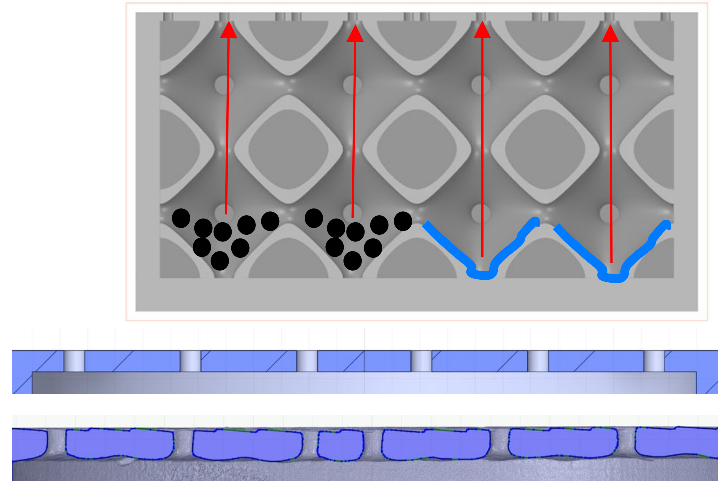


Honeycomb AE01 Reference Liner



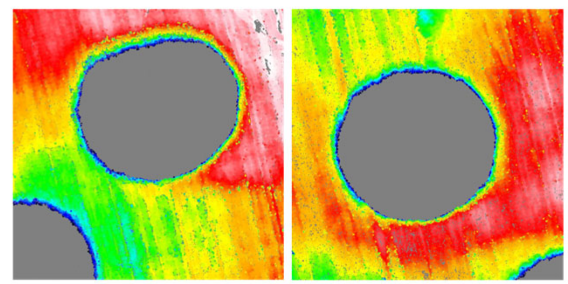
Schwarz P NIT Liner Sample

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



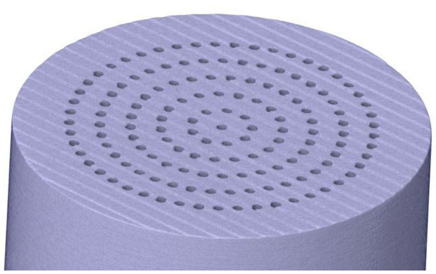
Identified component inspection capabilities

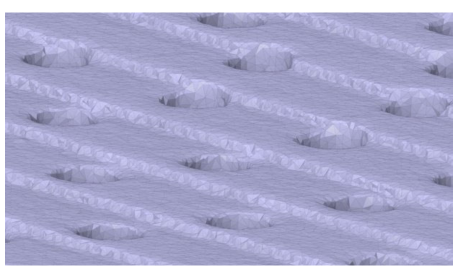
- Computed tomography
- Coordinate-measuring machine
- 3D scanning
- Optical profilometry
- Various structural load frames
- Material hardness

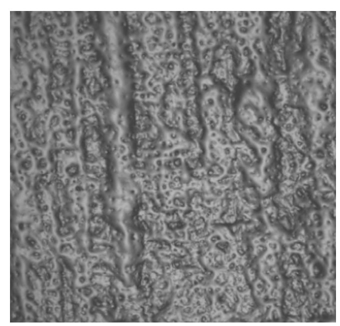


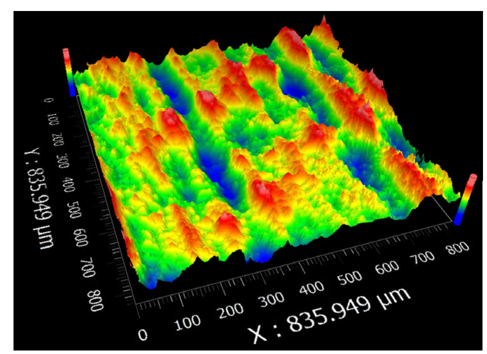
Mitigating significant manufacturing challenges

- Excess material removal
- Facesheet curvature
- Facesheet hole sharpness, shape, and dimensions
- Stair-stepping and surface roughness



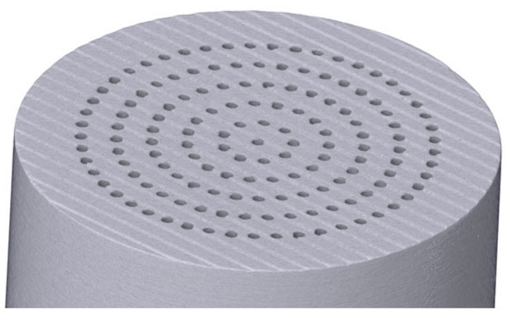




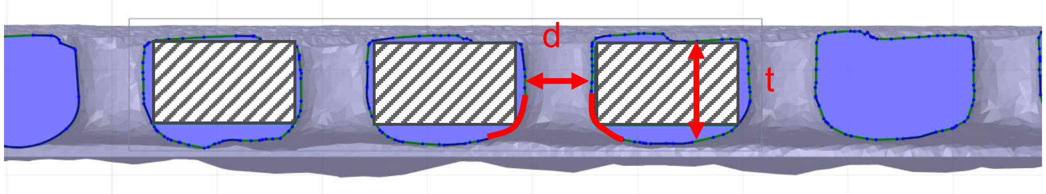


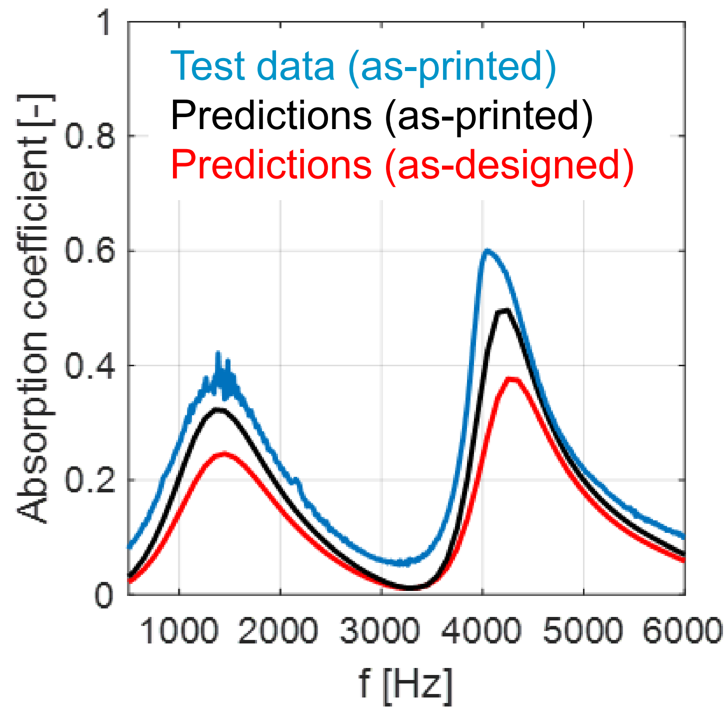
Used reference liner to assess modeling uncertainties and compare test facilities

Demonstrated ability to capture manufacturing effects by incorporating the as-printed geometry in the high-fidelity prediction tools, thereby closing predictive gaps



As-printed vs. as-designed





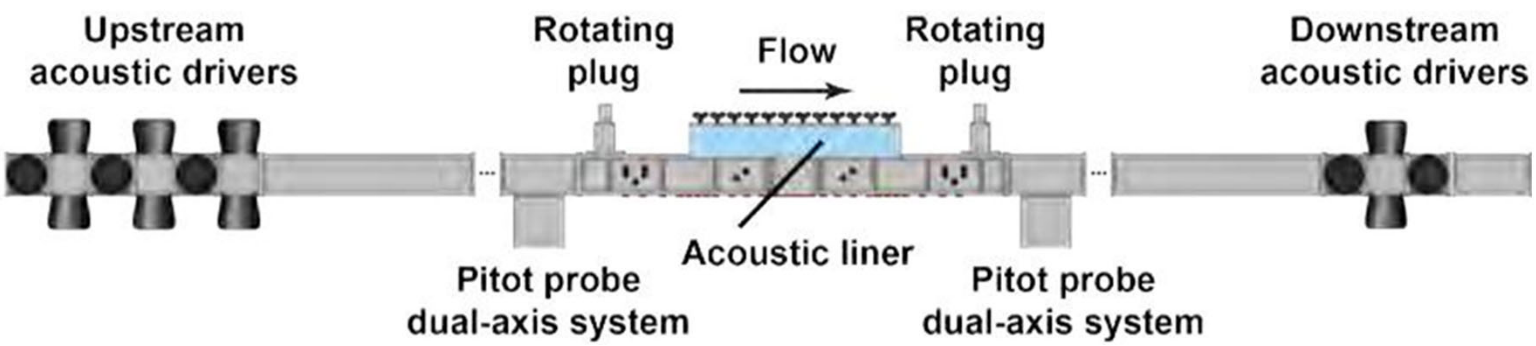
AM Risks & Lessons Learned in Y1

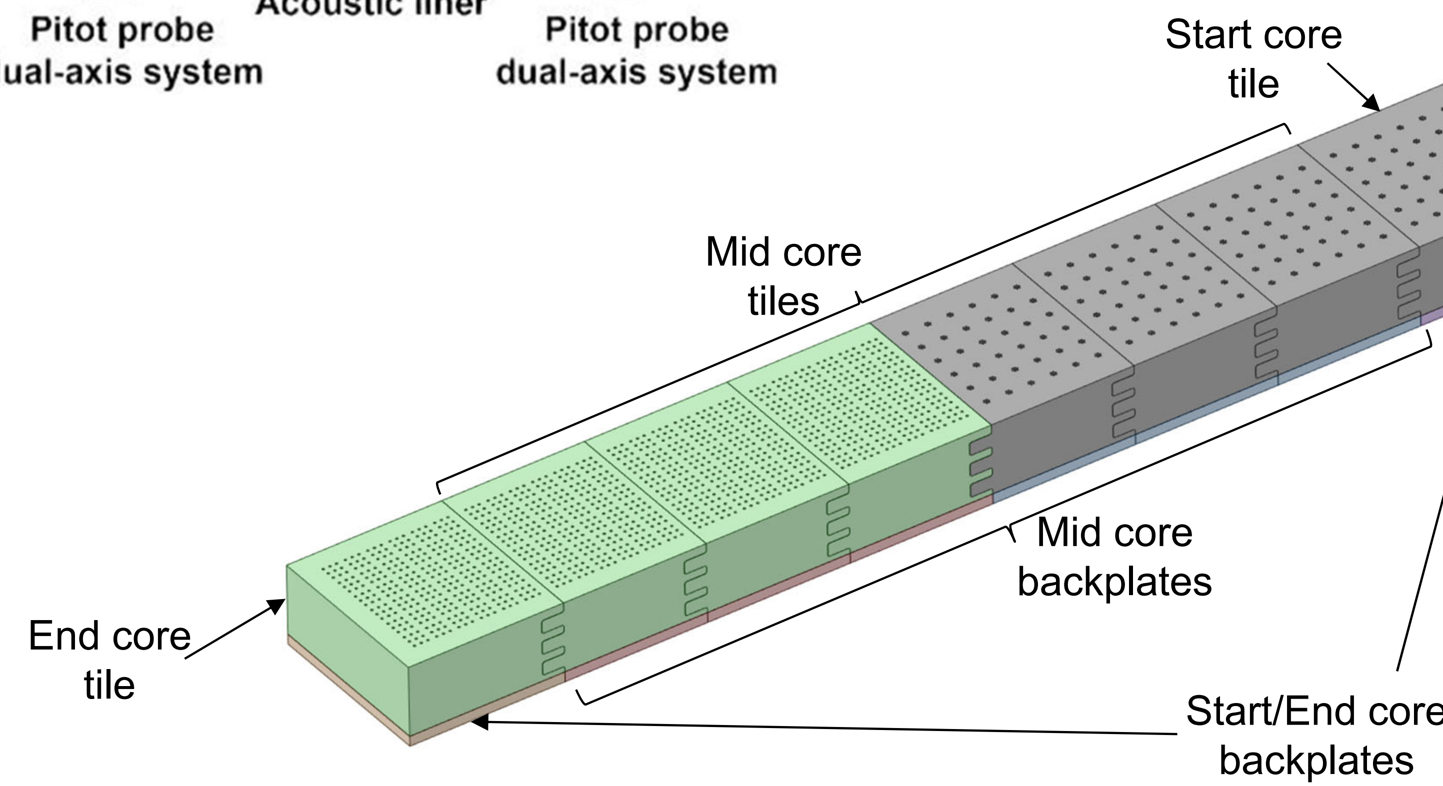
AM Risk	Correlation	Solution(s)
Non-Circular Holes	Layer-Wise Build	Print Orientation, aligning holes with core geometry
Rounded Geometry	Layer-Wise Build	Resin exposure settings, print orientation
"Stairstep" Surface Finish	Layer-Wise Build	Print Orientation, choose material and parameters to minimize layer height
Sagging/Buckling	Unsupported Thin Walls	Supports on non-critical surfaces and self-supporting geometry, thicken where possible
Trapped Resin/Powder	AM Tech. Used	Thru-holes and assemble with backsheet*
Bulging/Warping Core Geometry	Washing Solvent Absorption	Customized manual cleaning procedure, solvent chosen

*This allows facesheet and core to manufactured together for reliability and alignment and also allows for backsheet of different material to be used if wanted

Plan to optimize 3-4 designs in Y2 and scale to larger testing in Y3 as we learn how to tailor local resonance and tune frequency

Scale samples to NASA Langley Grazing Flow Impedance Tube





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

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