Project 79

Novel Noise Liner Development Enabled by Advanced Manufacturing

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Industry Partners: (1) Raytheon Technologies Research Corporation (Co-PI: Jeffrey Mendoza)
(2) Altair Engineering (Co-PI: Shannon Chesley)
NASA Langley Research Center (Space Act Agrmnt)
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 analysis, AM and test capabilities
- Identified and compared baseline design geometry
- Performed multi-fidelity acoustic analysis of variety of novel liner geometries
- Down-selected final liner designs for testing at PSU and RTRC

Future Work / Year 2 Schedule:

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

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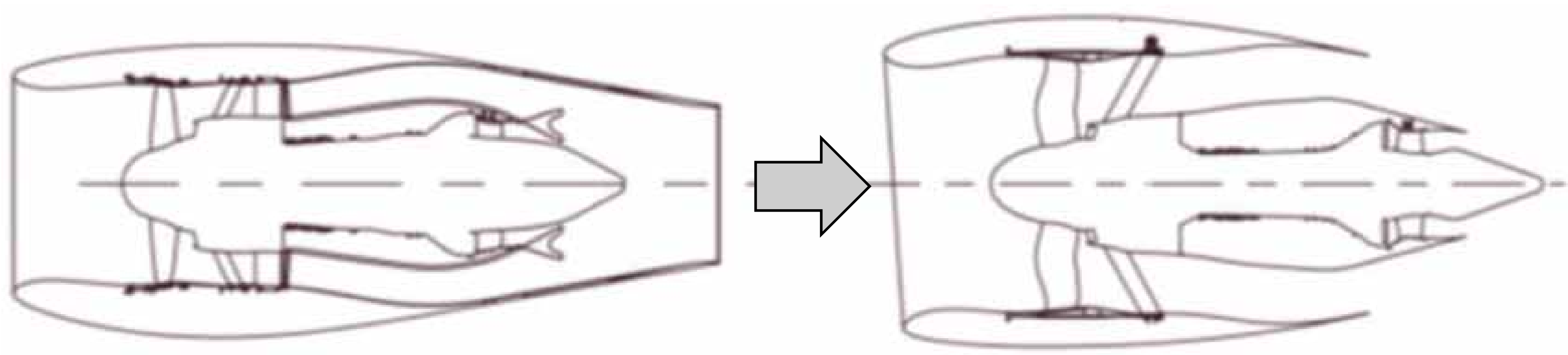
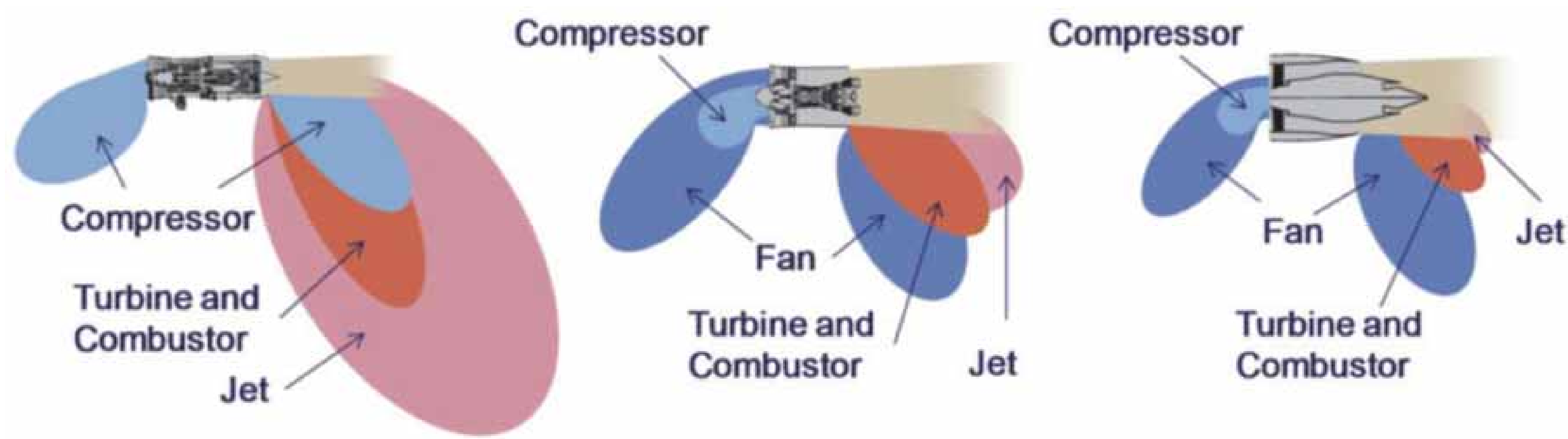
Trends toward ultra-high bypass ratio aircraft engines dramatically changes acoustic liner requirements

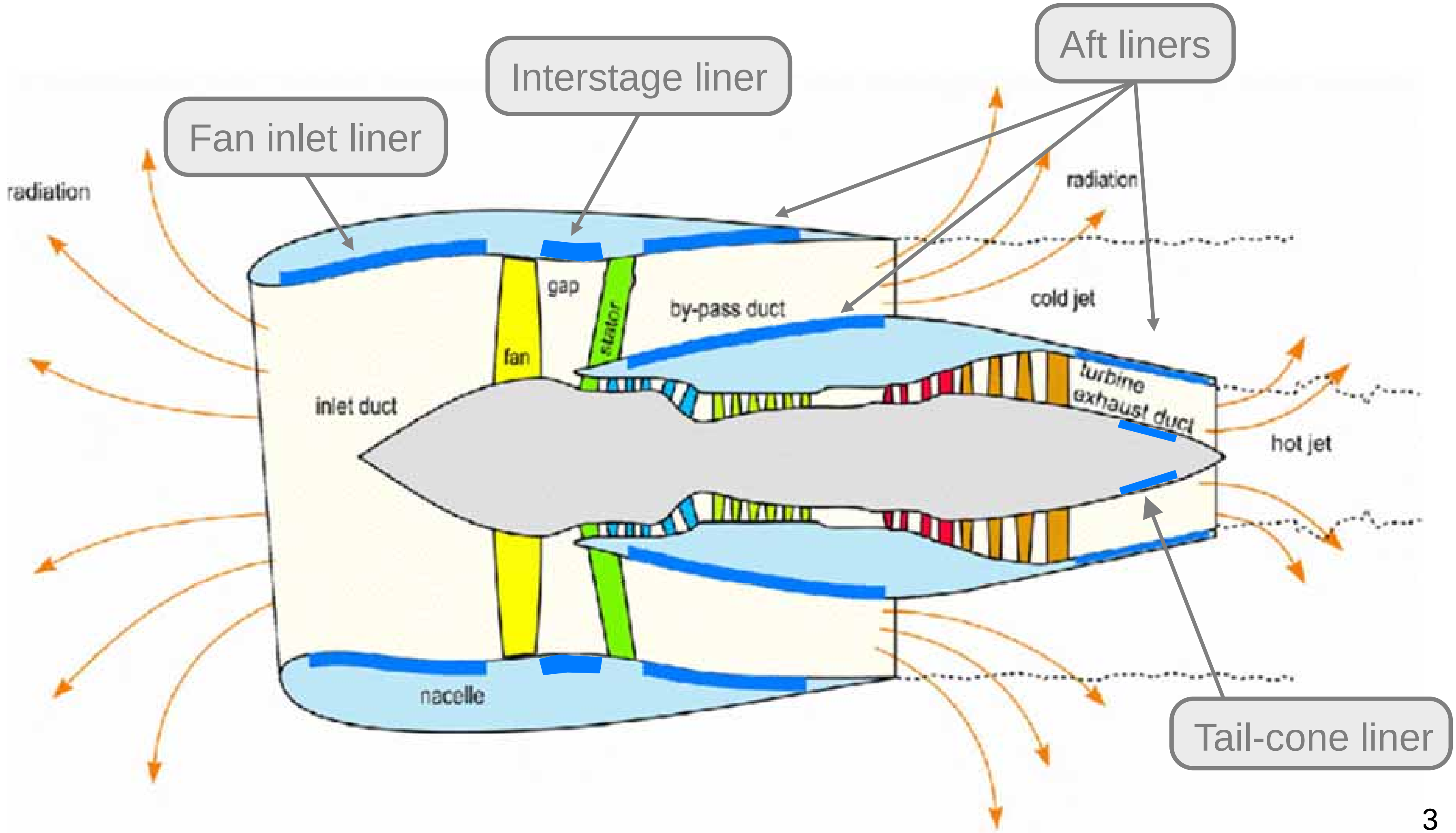


Growth in turbofan engine bypass (above) leads to wide variation in noise requirements, frequencies, and amplitudes (below)

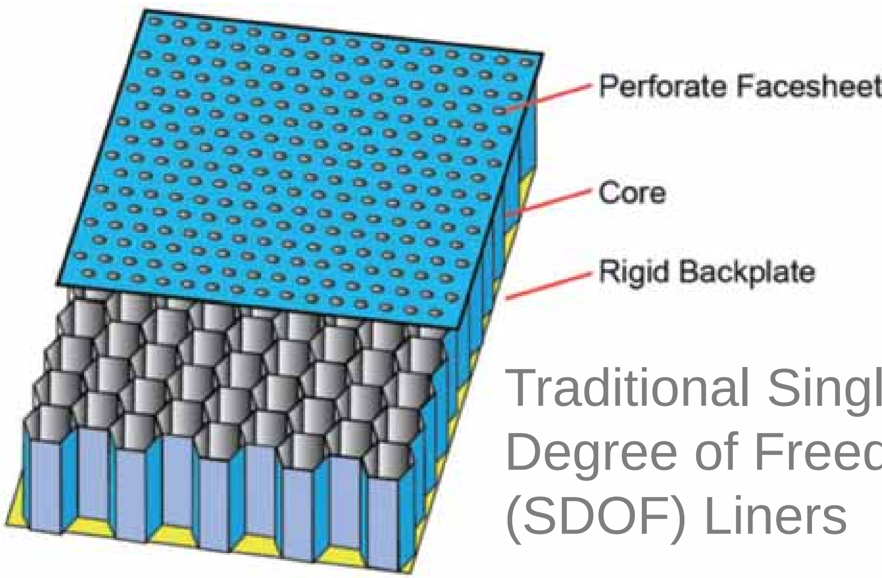


Changes to nacelle designs combined with drive to reduce weight necessitate new acoustic liner designs and placement

Traditional locations of acoustic liners

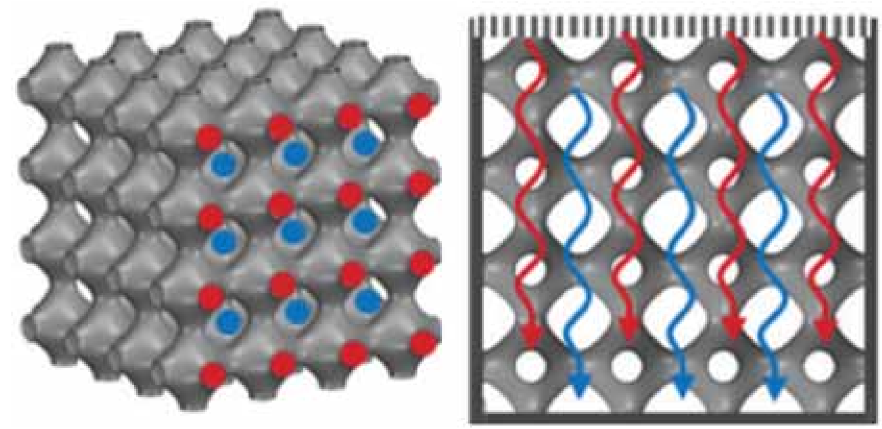


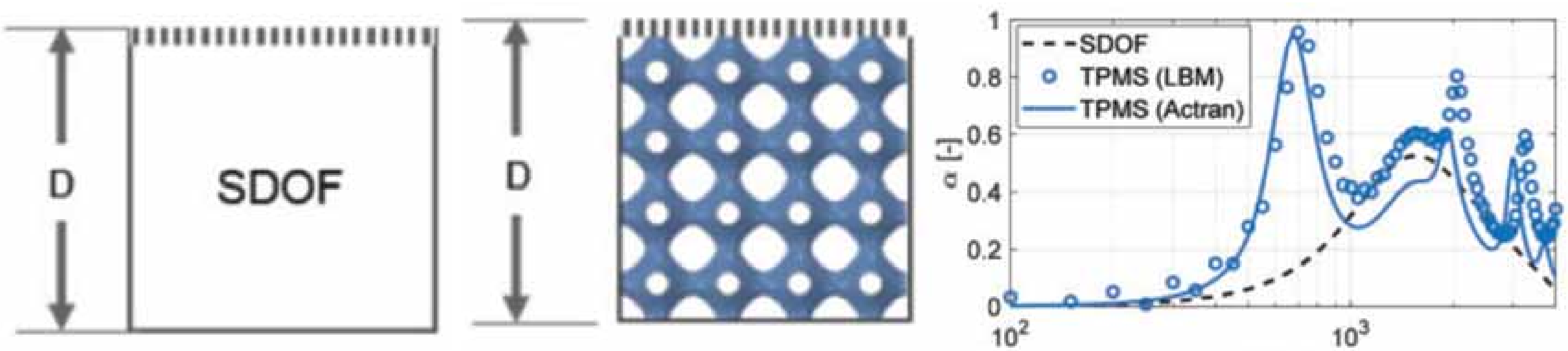
Additive manufacturing (AM) enables new acoustic liner designs that can enhance noise attenuation and save weight



Traditional Single Degree of Freedom (SDOF) Liners

Acoustic liner based on Schwarz P TPMS* design





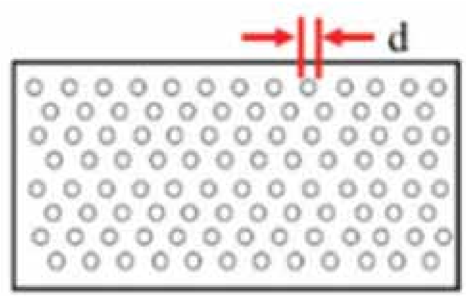
Enhanced attenuation with less material

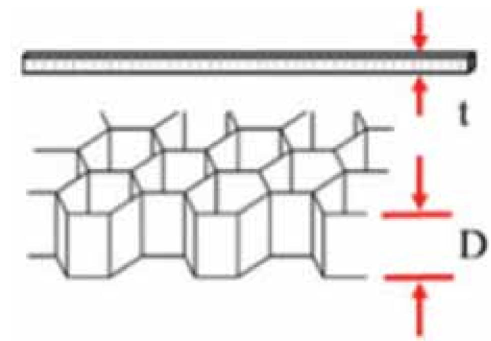
*Triply Periodic Minimal Surfaces

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

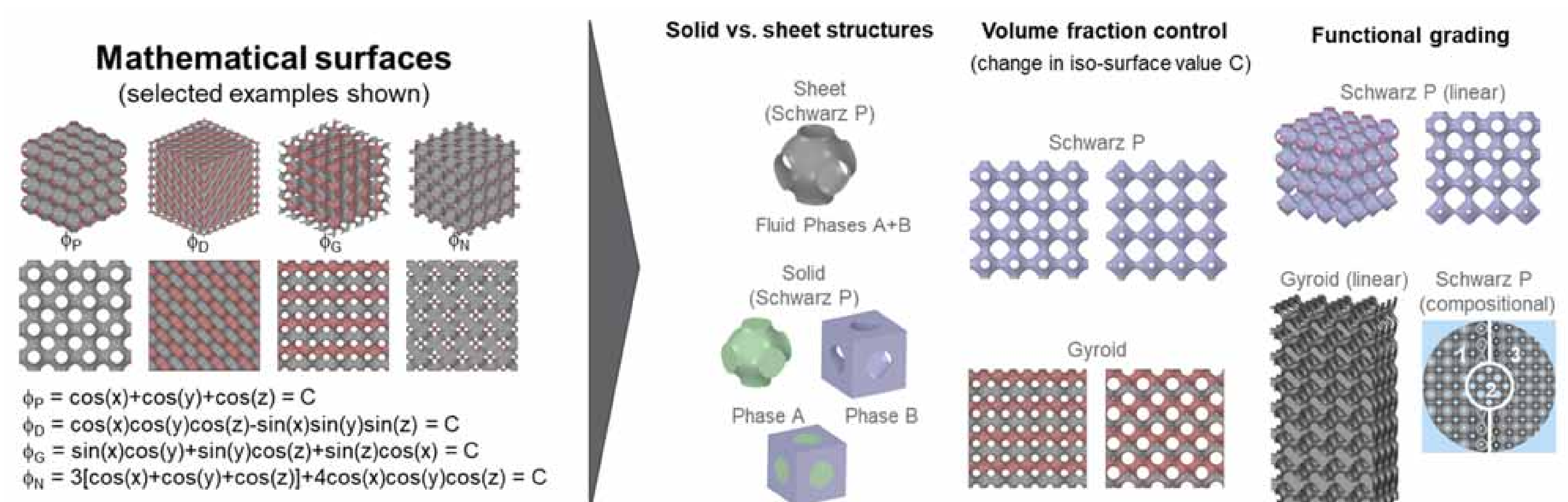
Design parameters for traditional SDOF liners

Vs.

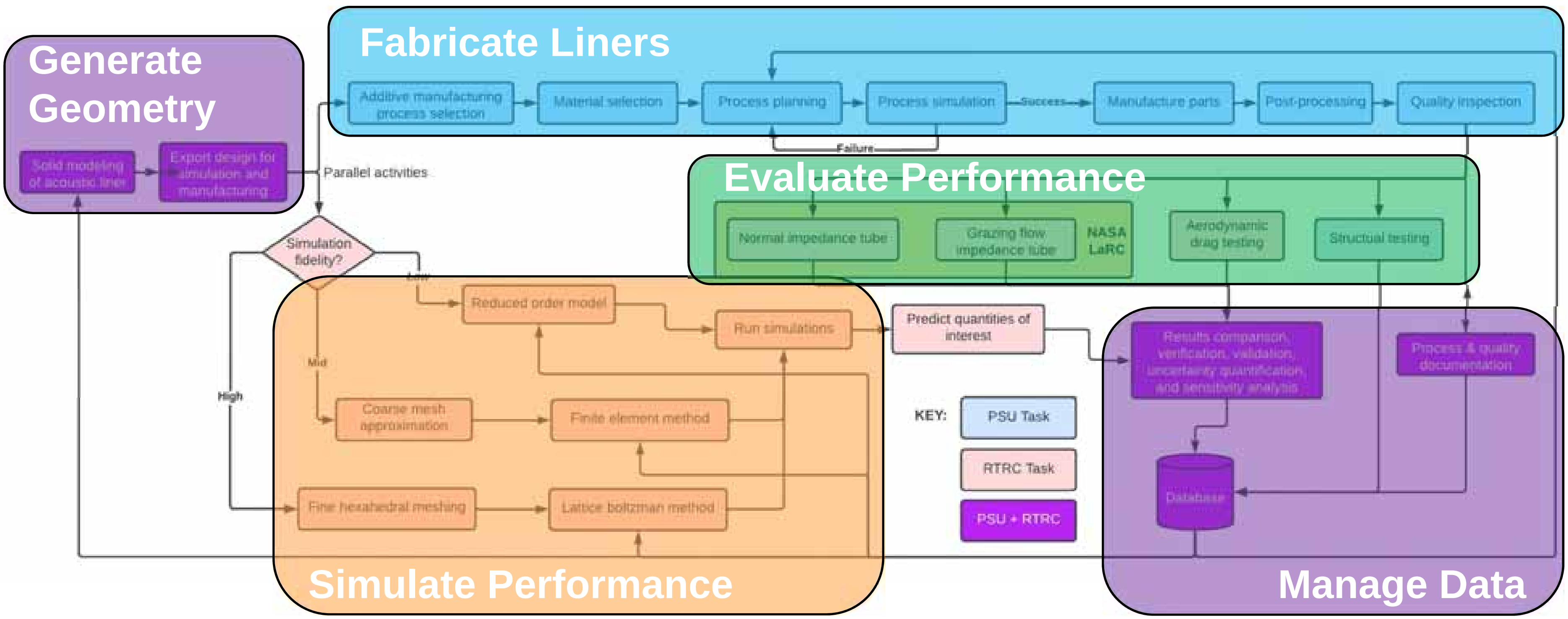




Infinite geometries with countless parametric variations



Established design-build-test framework to optimize 2-3 lattice designs in Year 2 in collaboration with Raytheon & Altair



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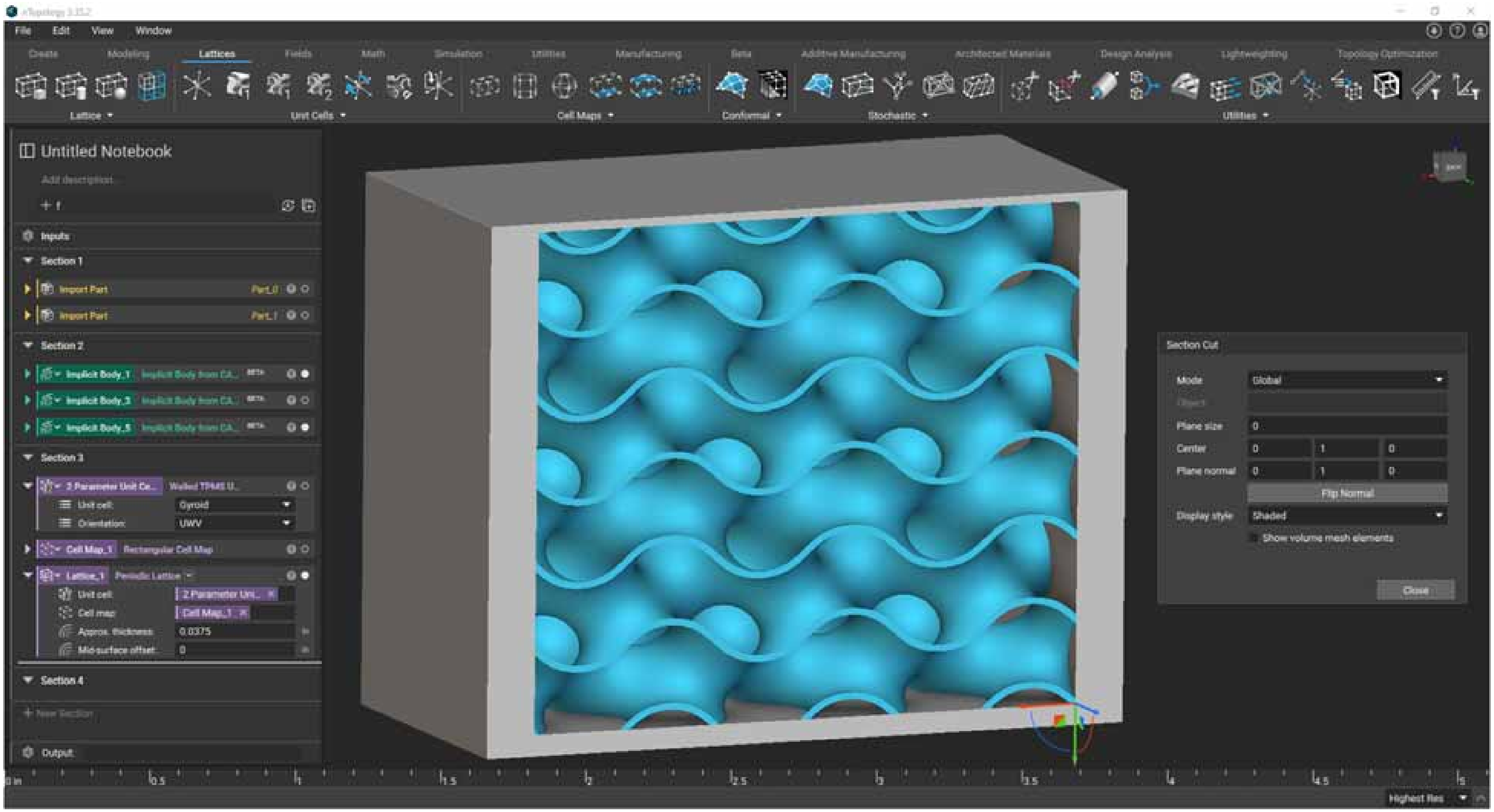
Developed workflow to rapidly generate parameterized acoustic liner geometries based on different lattice topologies

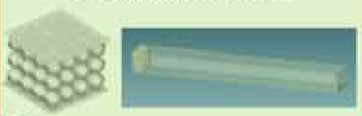


Lattice Generation using Implicit Solid Modeling in nTopology

Leveraging multi-fidelity modeling and analysis capabilities from Raytheon for complex acoustic liner designs

Rapid design screening (mid-fidelity)

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



Iterate designs

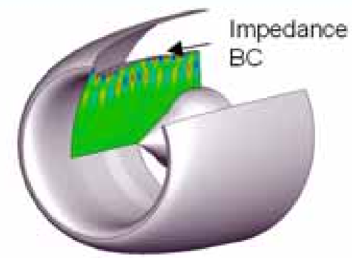
Acoustic impedance

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)

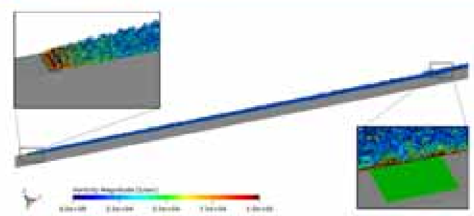
- FEM-based, linear
- Represent liner effect by Impedance BC
- Executes in minutes



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

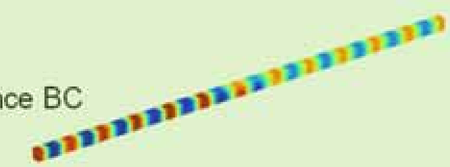
Grazing flow impedance tube (high-fidelity)

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



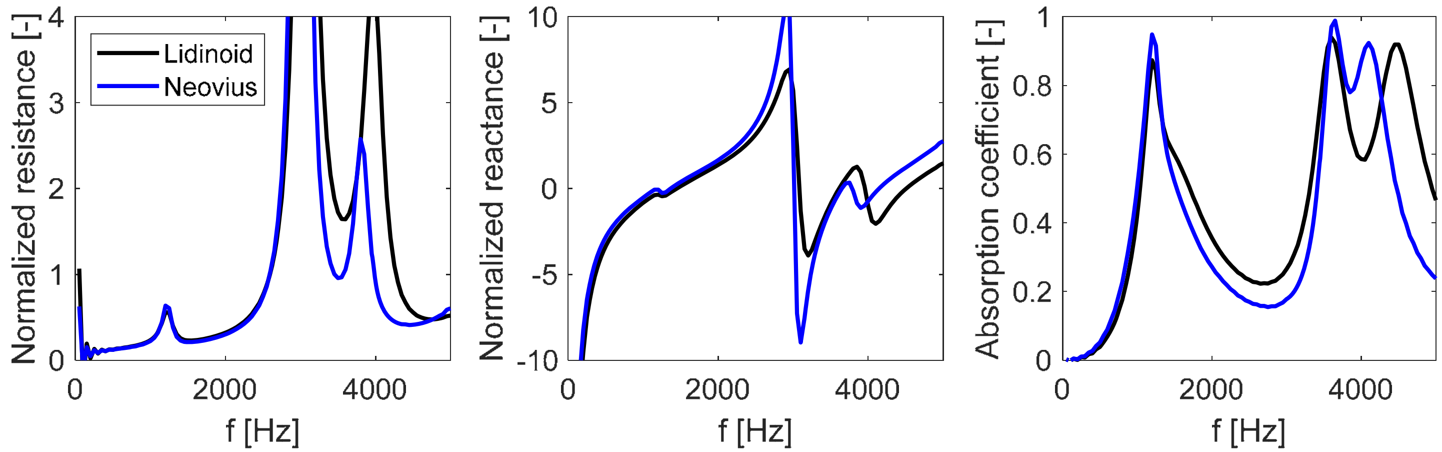
Grazing flow impedance tube (mid-fidelity)

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

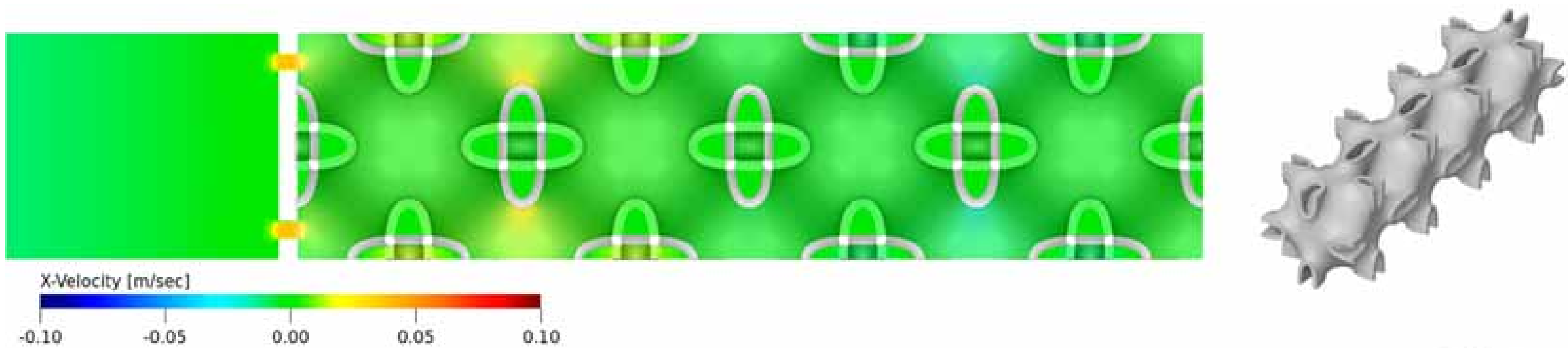


Insertion Loss [dB]

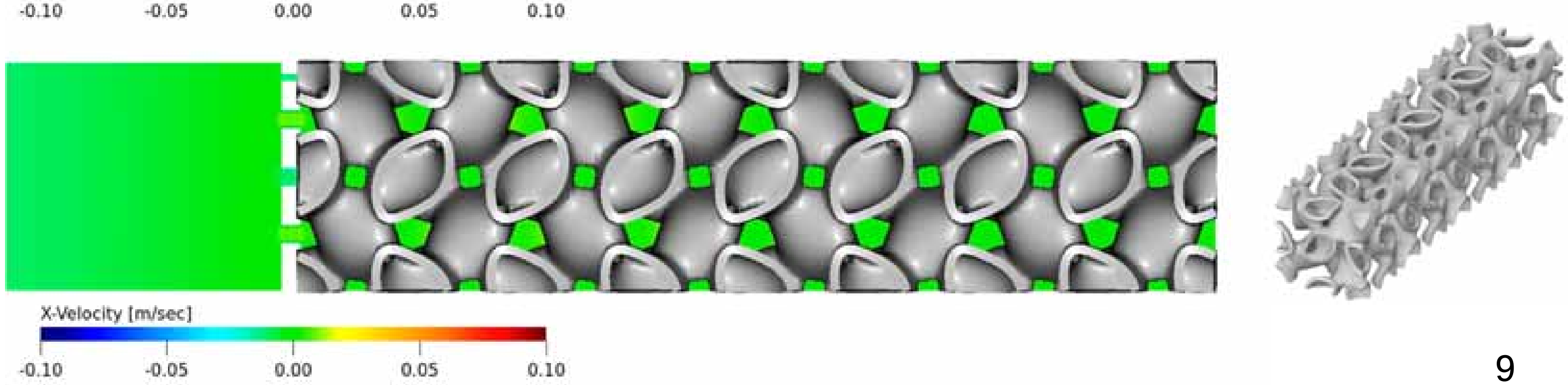
Validated use of high-fidelity simulations to assess acoustic performance of complex liner backings for physical insight



Neovius



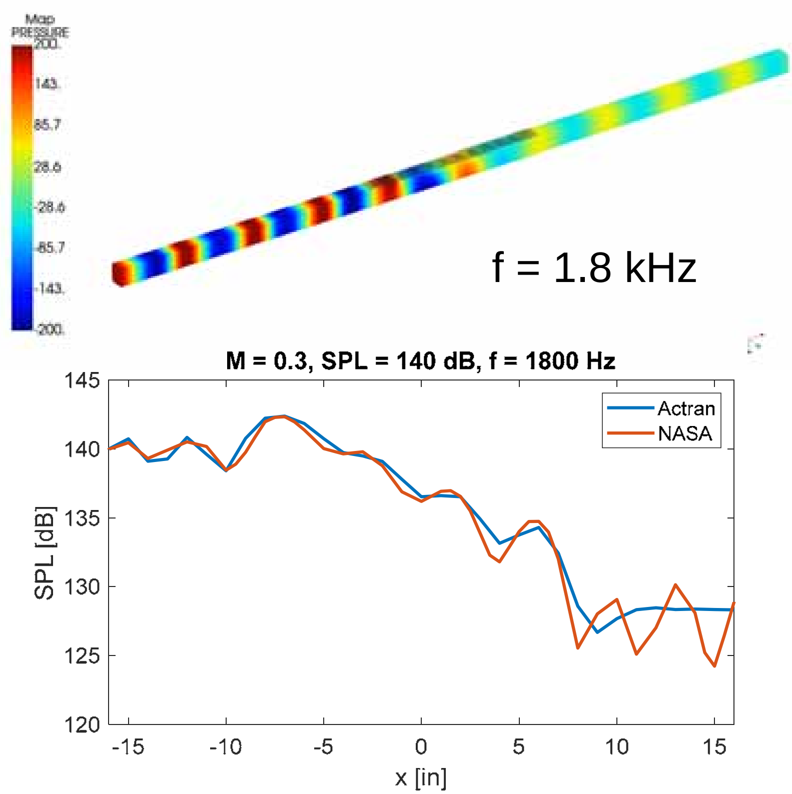
Lidinoid



Mid-fidelity simulations, informed by high-fidelity analysis results, used for design

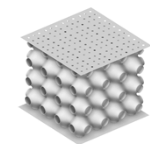
Virtual version of NASA grazing flow facility used for rapid assessment and concept down-selection during early phases of design development

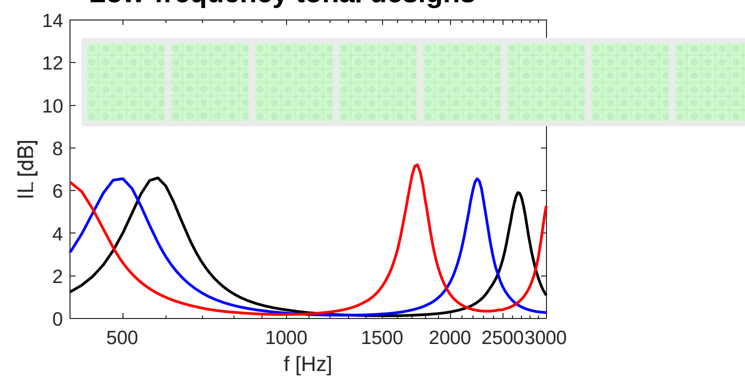
Model validation against test data

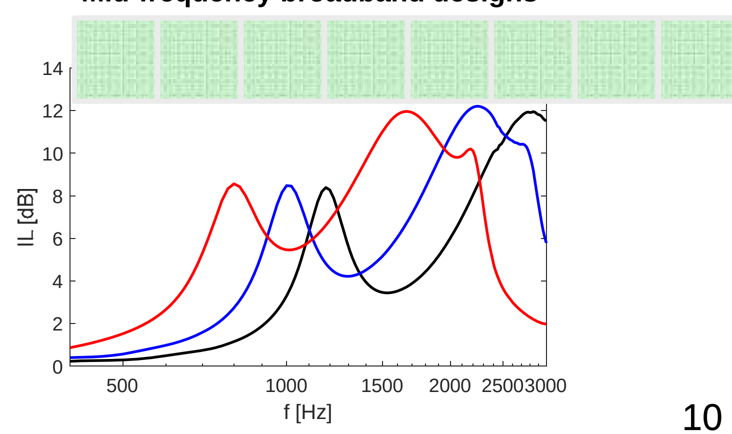


(NASA data from Howerton, B. M., Jones, M.G.. "A Conventional Liner Acoustic/Drag Interaction Benchmark Database". AIAA 2017-4190.)

Design concept screening (16" liner samples)







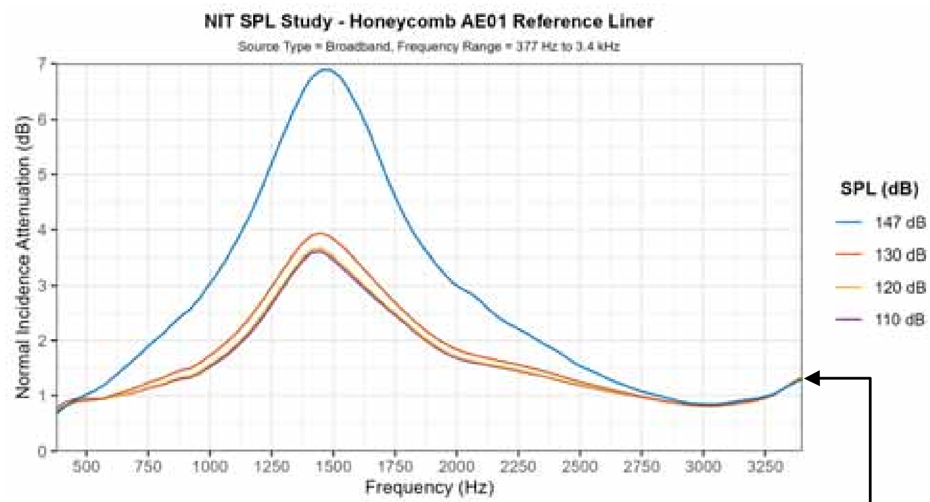
Combined team has a variety of normal impendence flow testing capabilities for experimental validation

NASA Langley

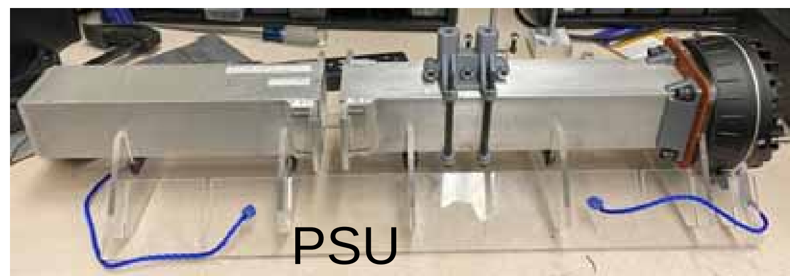
RTRC

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
NIT	Brüel & Kjær Impedance Tube Kit Type 4206 (Small Sample Config)	RTRC	Diameter = 29 mm Height ≤ 200 mm	Broadband	50 Hz to 1.6 kHz	140 dB	0.0	ISO 10534–2 ASTM E1050–12
NIT	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	ISO 10534–2 ASTM E1050–12
NIT	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	ISO 10534–2 ASTM E1050–12

Ascent project 79 NIT Testing Capabilities

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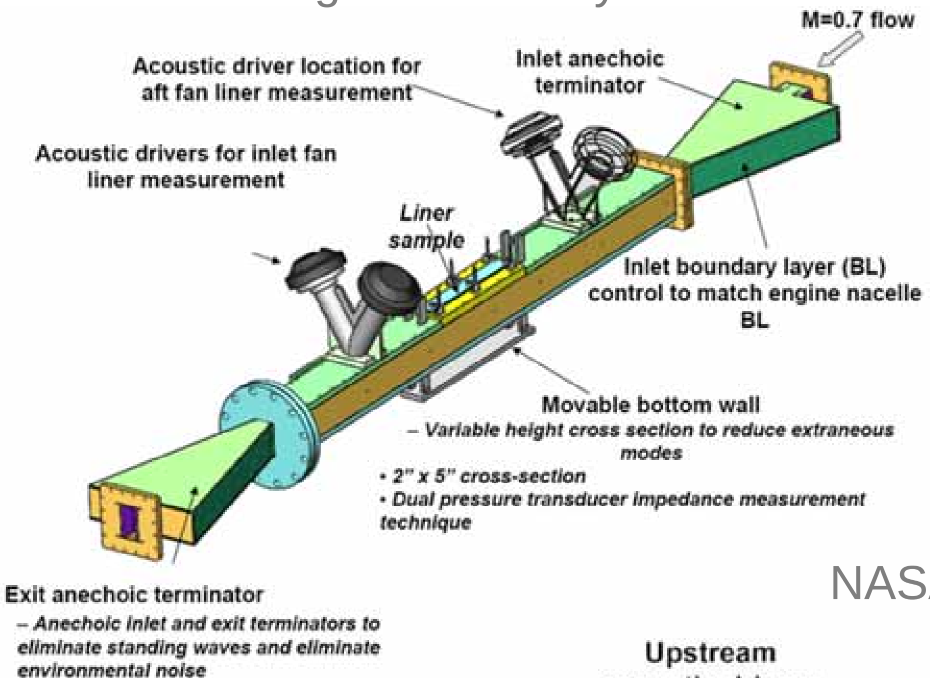
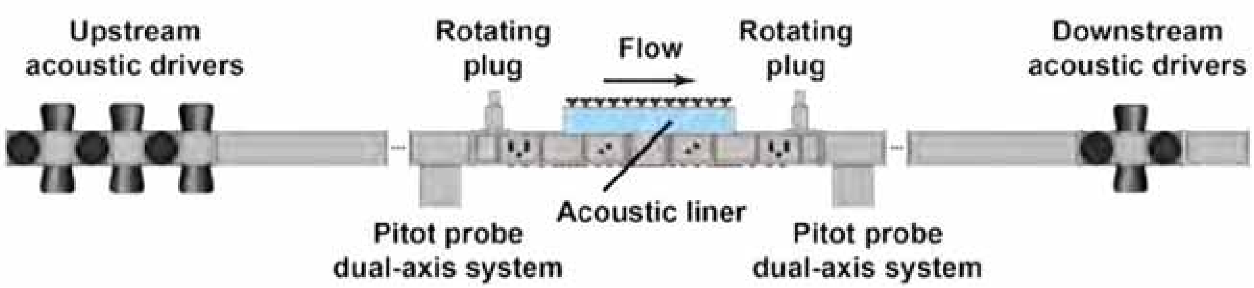
Grazing flow and advanced curved flow testing capabilities will also be utilized

RTRC Grazing Flow Facility



NASA Langley Curved Duct Testing Rig

NASA Langley Grazing Flow Impedance Tube



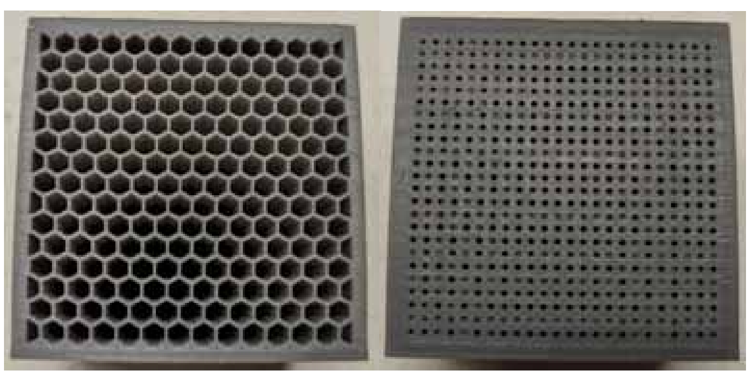
	FAA Ascent Project 79 Acoustic Testing Capabilities Summary	Location	Sample Dimensions	Source Type	Frequency Range	Maximum Acoustic Pressure	Centerline Mach Number	Testing Standard
GFIT	In-House Developed Grazing Flow Impedance Tube	RTRC	Length = 2 in Width = 16.375 in Height ≤ 5 in	Stepped Sine Broadband	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

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

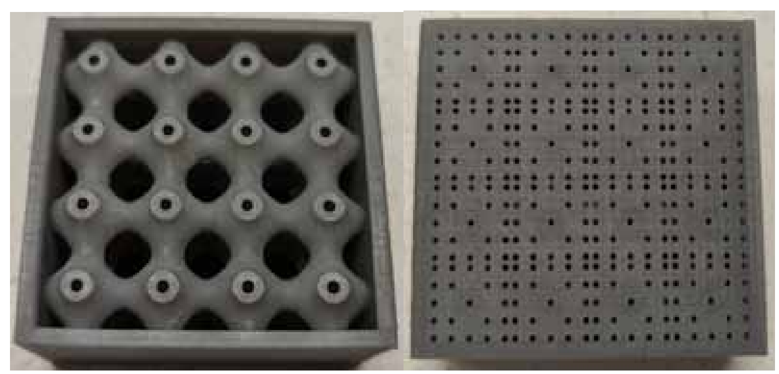
Material Jetting (Polymer Multi-Material)
- Stratasys Object350 Connex

Vat Photopolymerization (Polymer)
- Formlabs Form 3L
- 3D Systems Figure 4

Laser Powder Bed Fusion (Metallic)
- EOS M 280

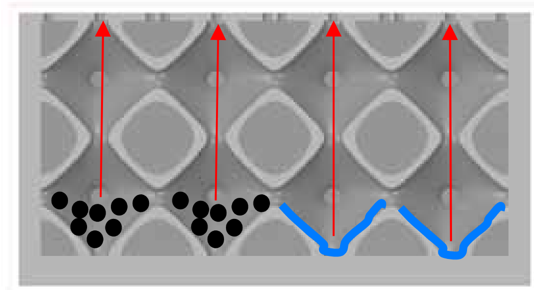


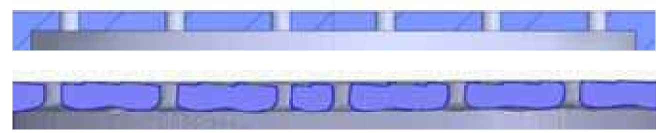
Honeycomb AE01 Reference Liner



Schwarz P NIT Liner Sample

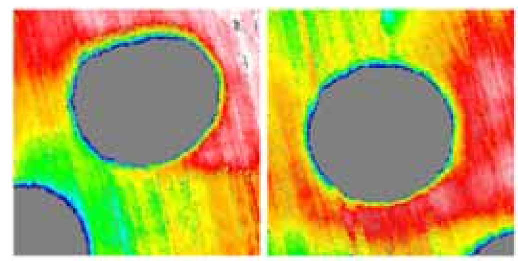
Technical challenges and risks associated with high computational costs, test facility calibration, and AM resolution accuracy





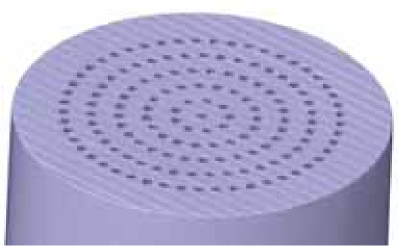
Identified component inspection capabilities

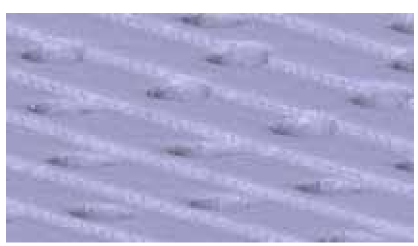
- Computed tomography
- Coordinate-measuring machine
- 3D scanning
- Optical profilometry
- Various structural load frames
- Material hardness

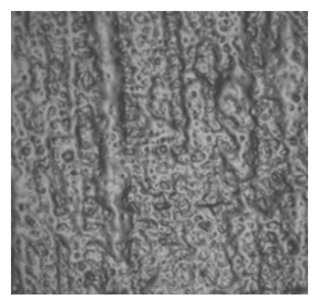


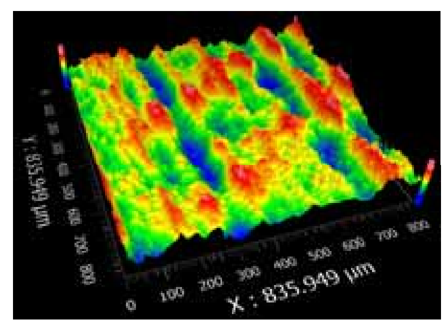
Mitigating significant manufacturing challenges

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



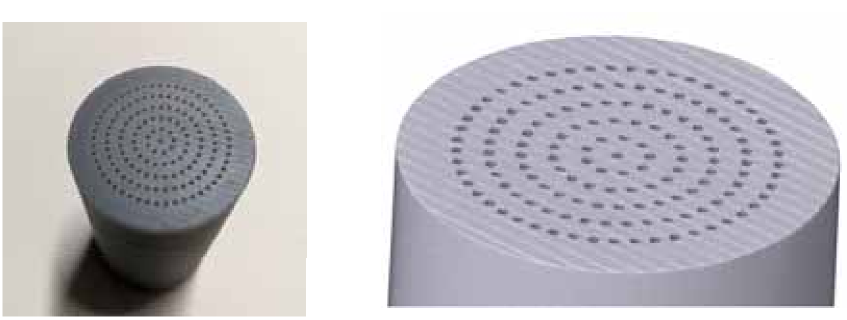




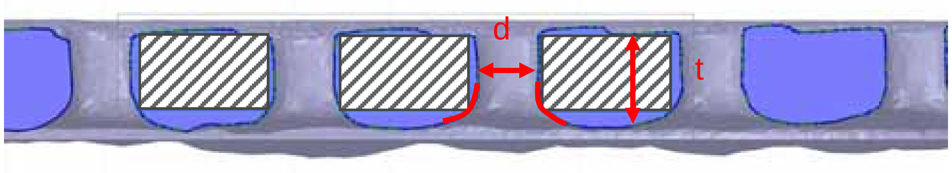


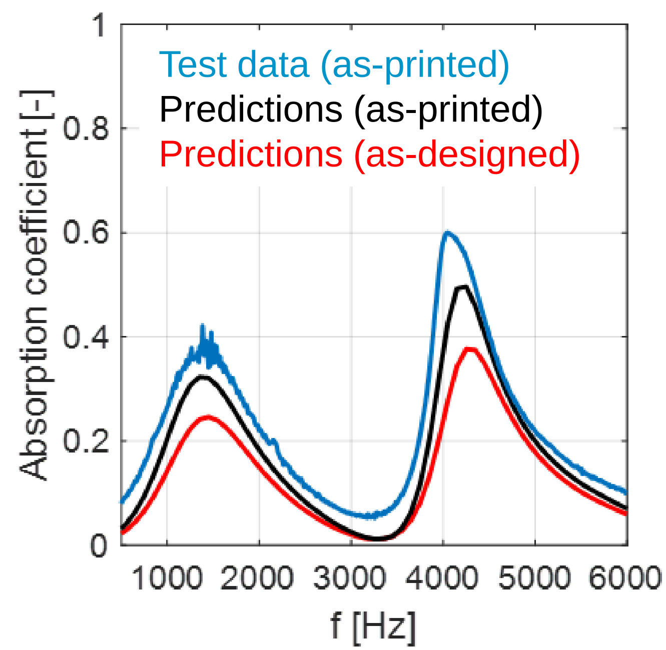
Used reference liner to assess modeling uncertainties and compare test facilities

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



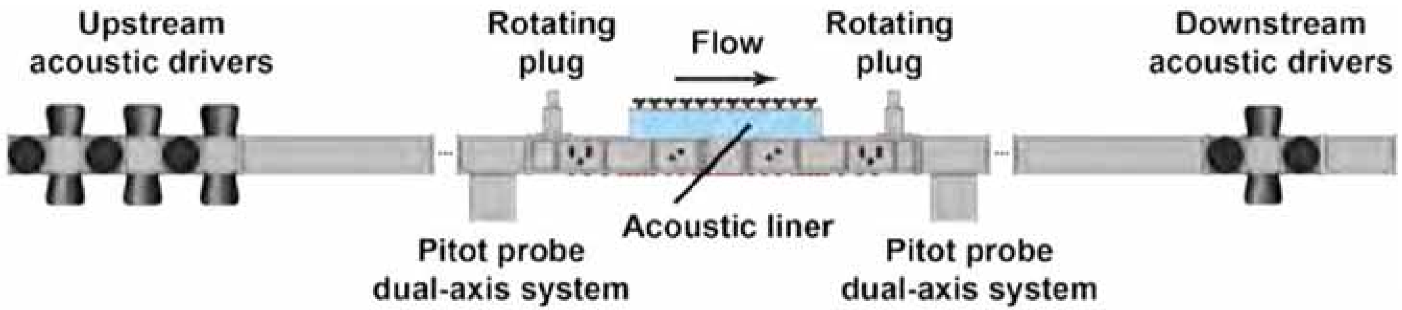
As-printed vs. as-designed

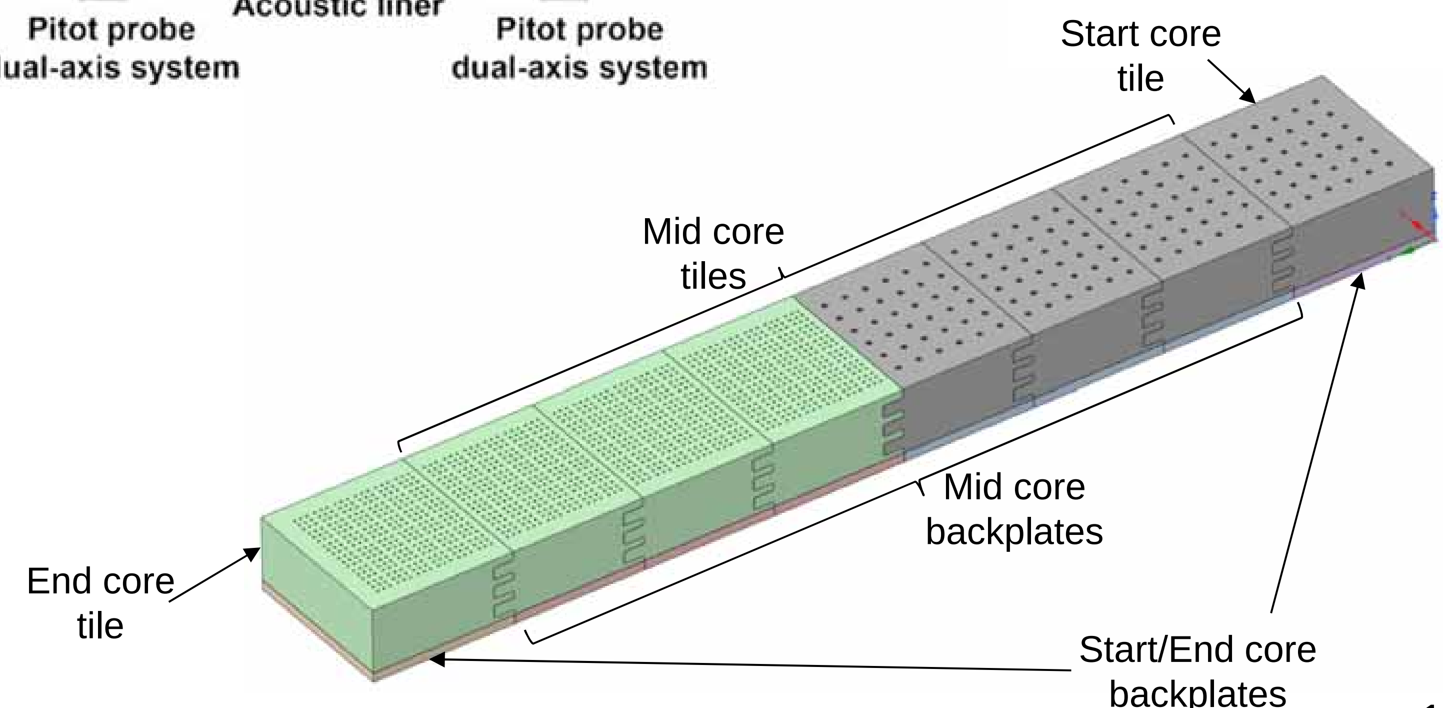




Plan to optimize 3-4 designs in Y2 and scale to large-scale testing in Y3 as we learn how to tailor local resonance and tune frequency

Scale samples to NASA Langley Grazing Flow Impedance Tube





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

ASCENT
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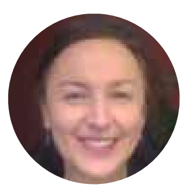

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