



Duct Acoustics Overview

Michael Jones
NASA Langley Research Center

ONERA Visit
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Background

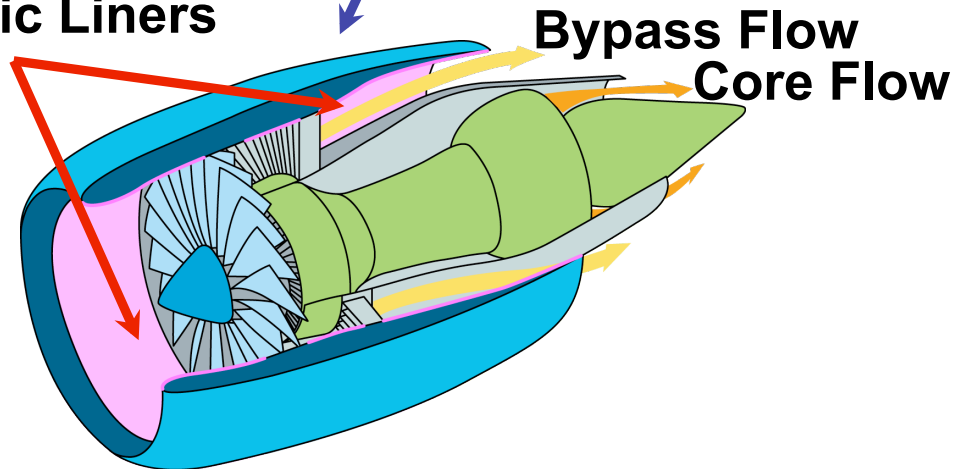


Increasingly stringent requirements

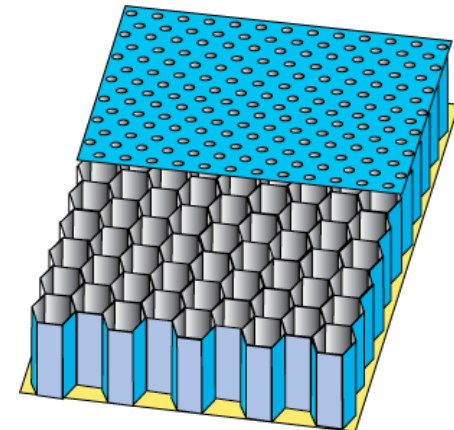
↓ **NEED** ↓

Improved fan-noise reduction concepts

Acoustic Liners



Key parameter
Acoustic Impedance, ζ



Single Layer Liner

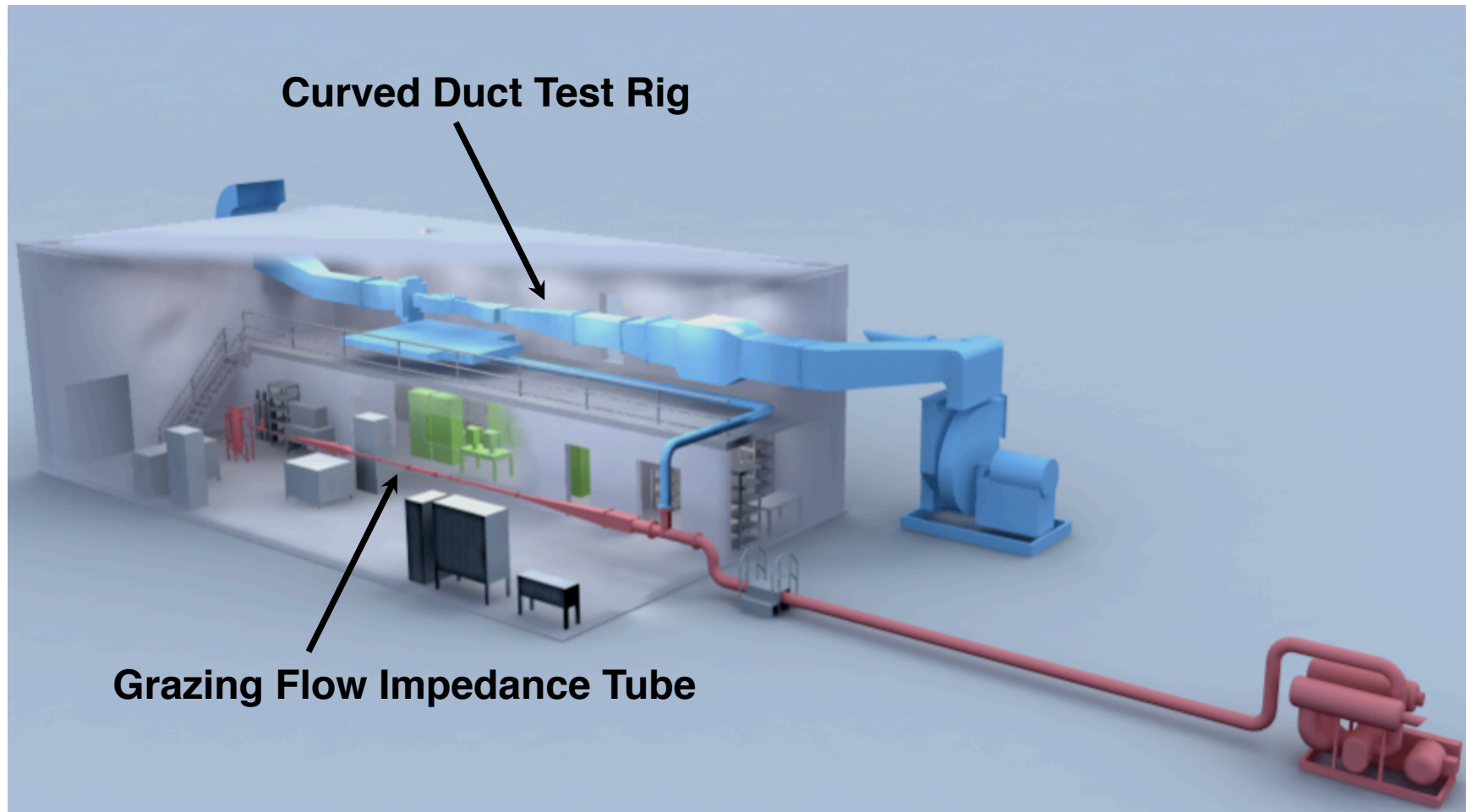
Nacelle Acoustics Mission



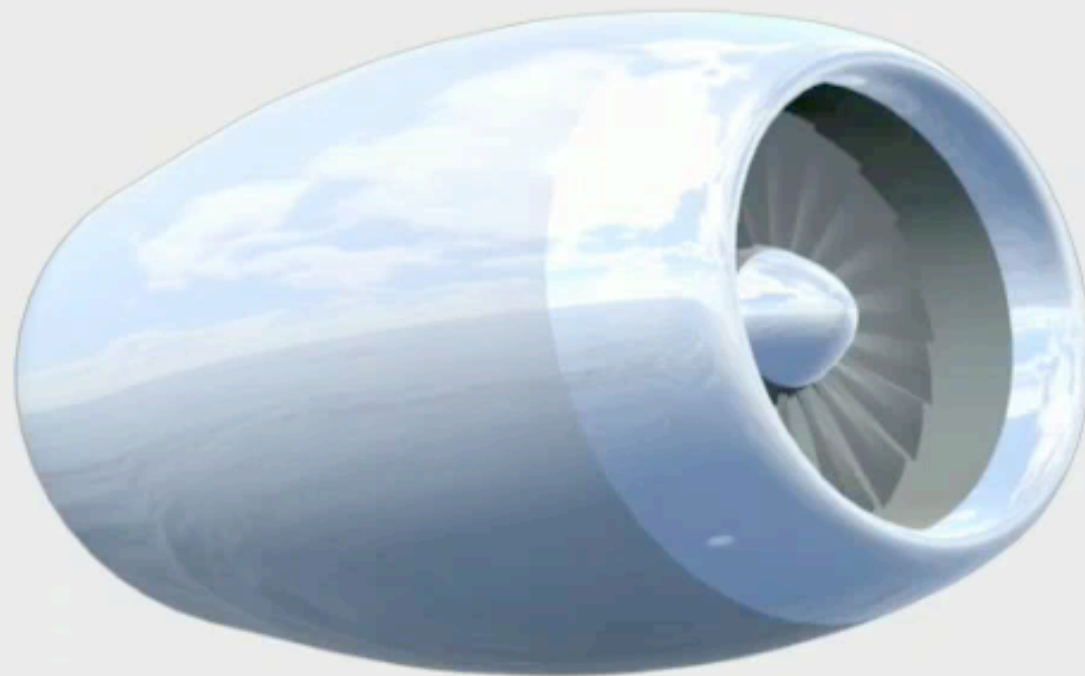
Develop and Evaluate

- Impedance prediction & measurement methods
- Duct acoustic propagation codes
- Fan-noise reduction concepts

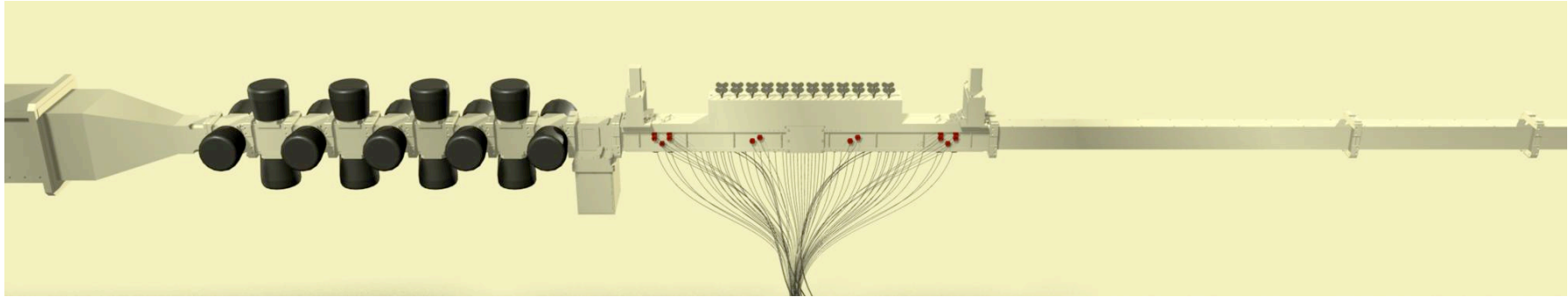
Liner Technology Facility



Grazing Flow Impedance Tube (GFIT)

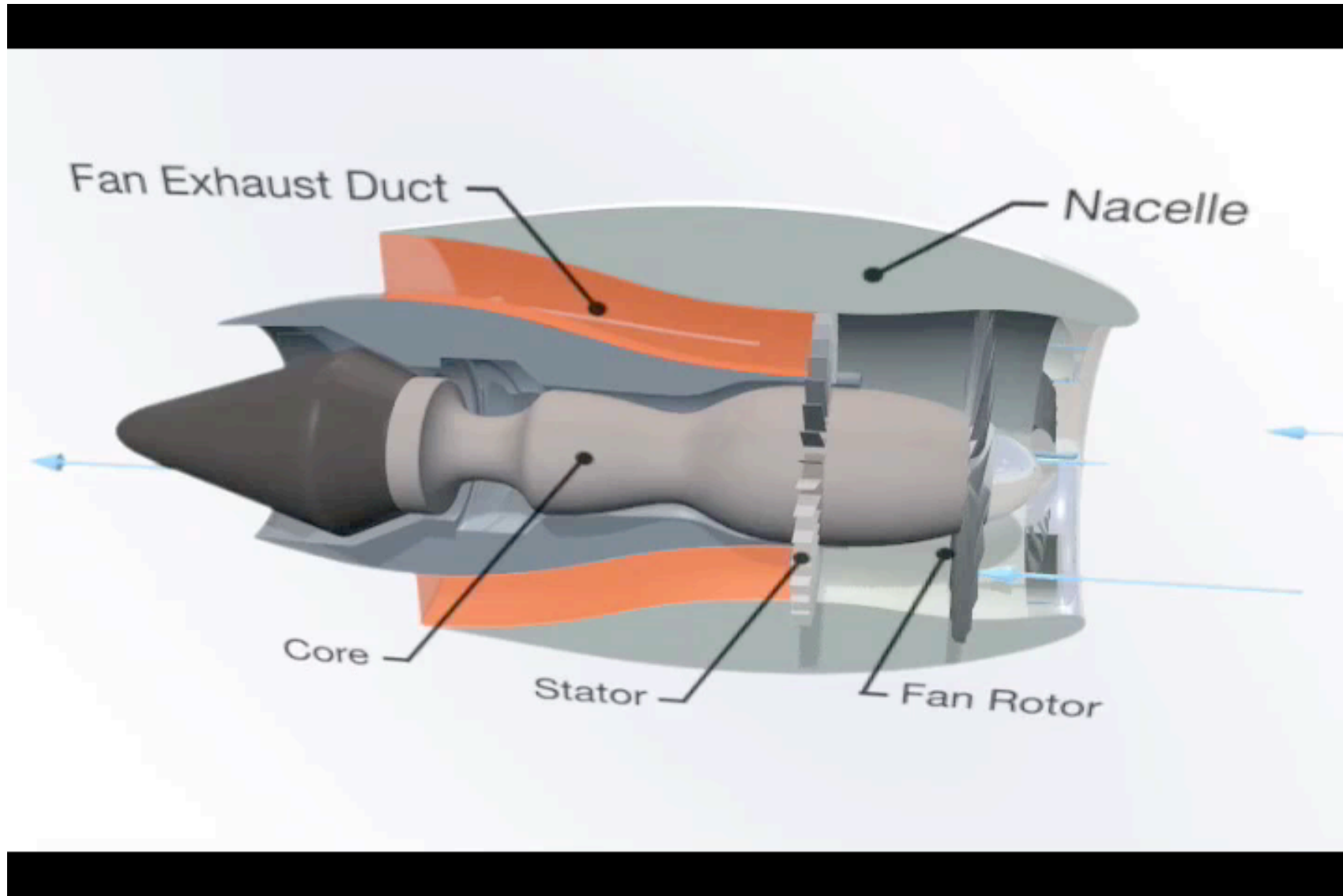


Grazing Flow Impedance Tube (GFIT)

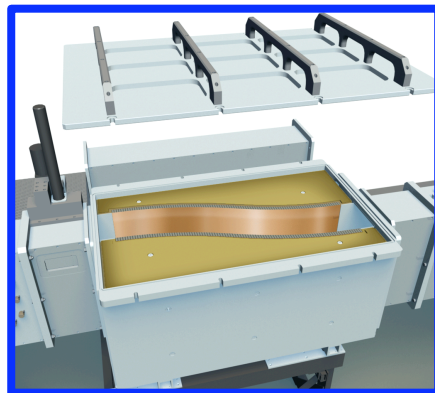


<i>Feature</i>	<i>GFIT</i>
Cross-Section	2" x 2.5"
Max Flow	Mach 0.6
Flow Profile	Laminar to Turbulent
Max Freq	3.0 kHz
Max SPL	150 dB
Key Characteristics	Impedance Eduction Flow Profile Effects Upstream or Downstream Propagation

Curved Duct Test Rig (CDTR)



CDTR Configurations



Test section configurations

- 0" offset (straight flow path)
- 3" offset (curved flow path)
- 6" offset (curved flow path)

Curved Duct Test Rig Features



<i>Feature</i>	<i>CDTR</i>
Cross-Section	6" x 15"
Max Flow	Mach 0.5
Flow Profile	Uniform
Max Freq	3.0 kHz
Max SPL	140 dB
Key Characteristics	Mode Isolation Curvature Upstream or Downstream Propagation



Aeroacoustic Computational Methods

- **Propagation codes** predict sound transmission through a duct
- **Acoustic liners** represented as impedance boundary condition

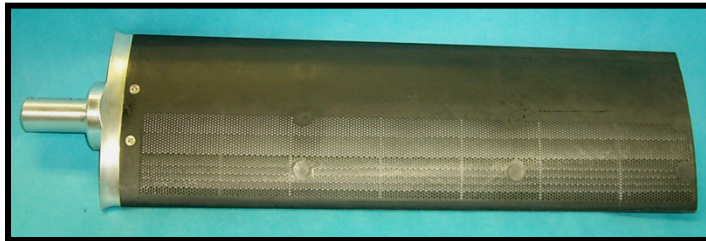
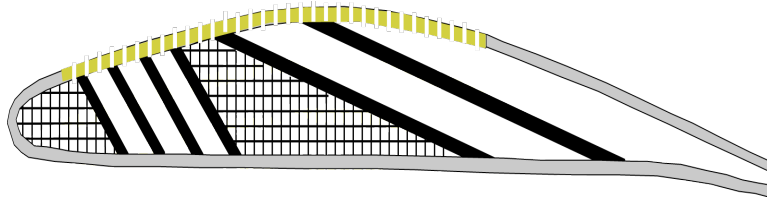
LaRC Propagation Code	Underlying Equations	Solution Method	Solution Fidelity & Computational Expense
CDUCT-LaRC	Convected Helmholtz	Parabolic Approximation	Low
3DFEM	Convected Helmholtz	Finite Element	Medium
LaRC-LEE	Linearized Euler	Finite Element	High

- Also work with external propagation codes
 - 3D-DNS (FSU) Eversman FEM (U of Missouri-Rolla)
 - LEE3D (Boeing) ACTRAN (MSC Software)

Noise Reduction – Soft Vane



Sketch of Side View



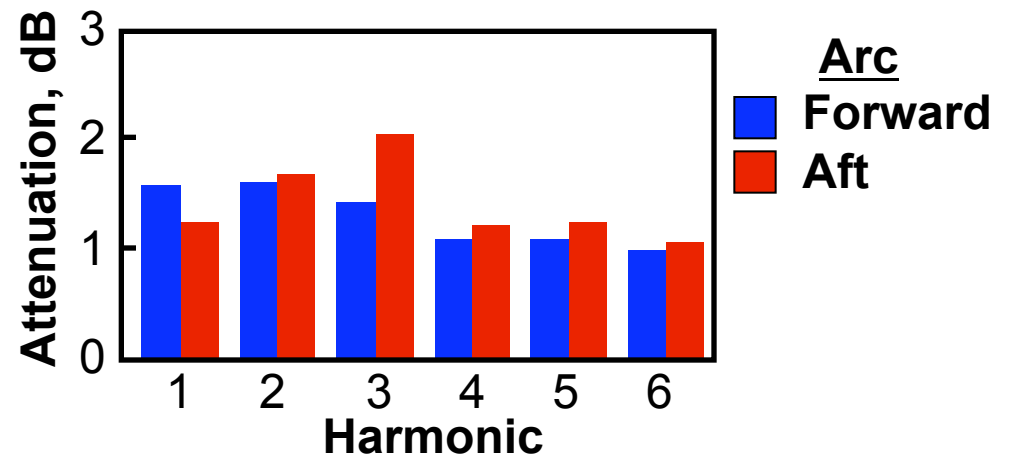
As Installed



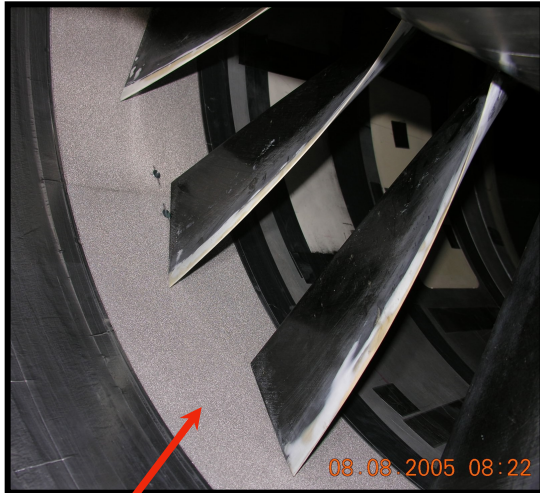
Testbed: ANCF Fan Rig

Reduction of 1 to 2 dB
over wide frequency range

U.S. Patent 7,334,998



Noise Reduction – Over-the-Rotor Foam



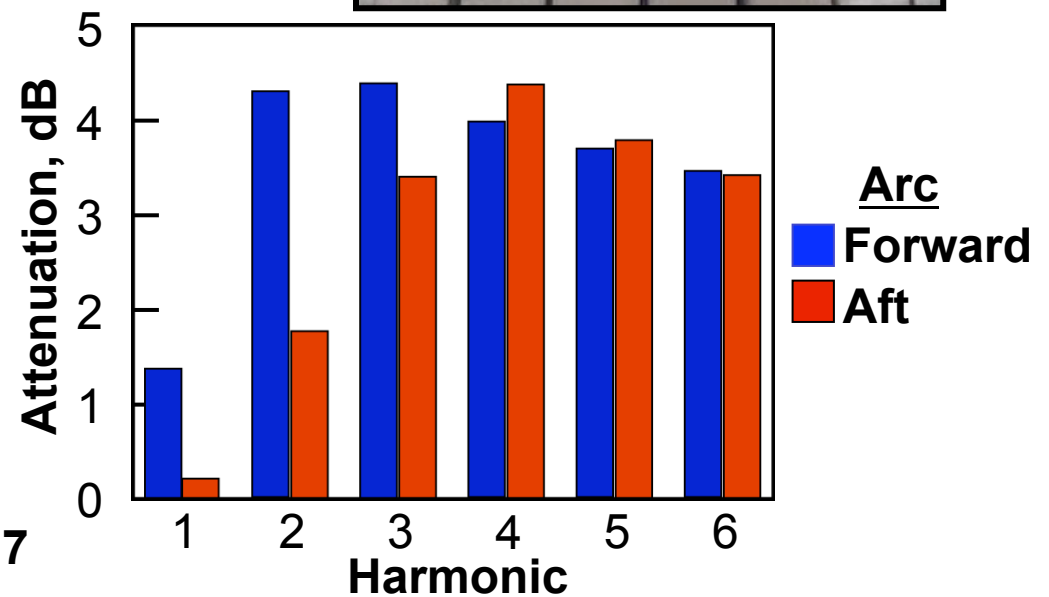
**OTR Haynes 25
metallic foam**

**Reduction of 3 to 4 dB
over wide frequency range**

Applied for U.S. Patent Jan-2007



Testbed: ANCF Fan Rig





Current and Recent Projects

Impedance Prediction and Measurement Methods

- Assessment of prediction uncertainty limits
- Liner Technology Facility on-line

Propagation Code Development & Validation

- Local-reaction liners (long-term legacy)
- Extended-reaction liners (recent activity)

Noise Reduction Concepts

- Duct Curvature
- Soft Vanes
- Over-the-Rotor Foam

