
National Aeronautics Research Institute

# Adaptive Back Sheet Material for Acoustic Liner Application

Carl H. Gerhold and Michael G. Jones
Liner Technology Facility
NASA Langley Research Center

Dawnielle Farrar
Johns Hopkins University-Applied Physics Laboratory

Benjamin S. Beck
National Institute of Aerospace

NASA Aeronautics Research Mission Directorate (ARMD)

FY12 Seedling Phase II Technical Seminar

March 18-19, 2015

# Outline

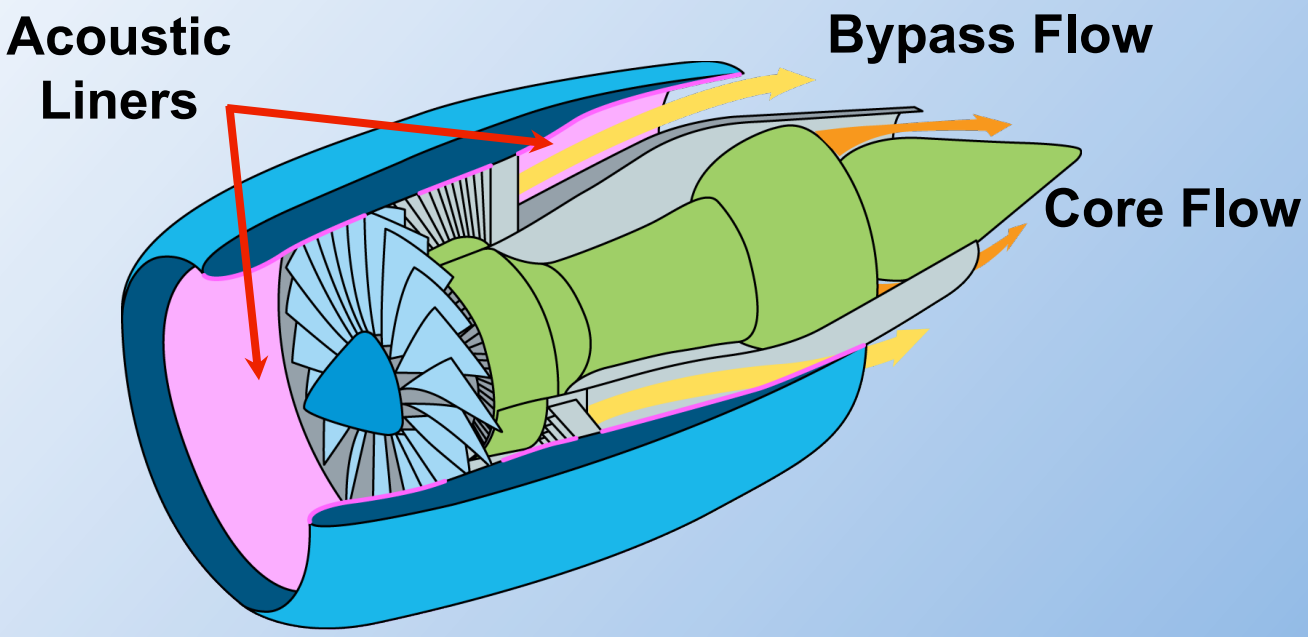



- Background
- Summary of Phase I Results
- Redesign of Piezo-electric
- Results to Date
  - Mechanical
  - Acoustic
- Summary and Conclusions

# The Challenge



## Aircraft Engine Nacelle

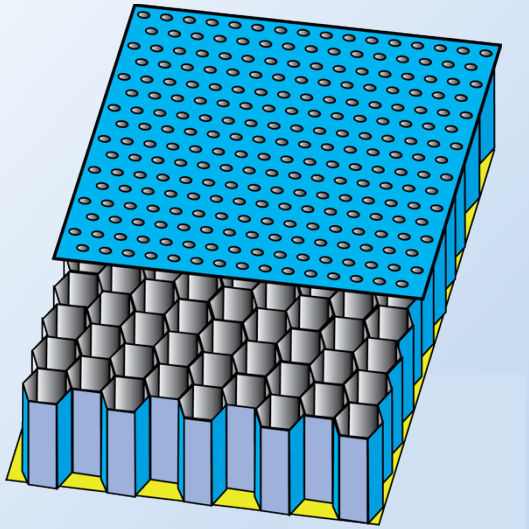


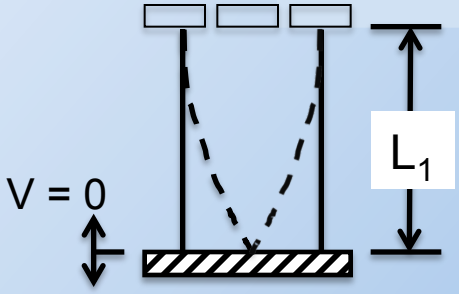

- Engine size increases
- Frequency of source decreases
- Nacelle treatment area decreases

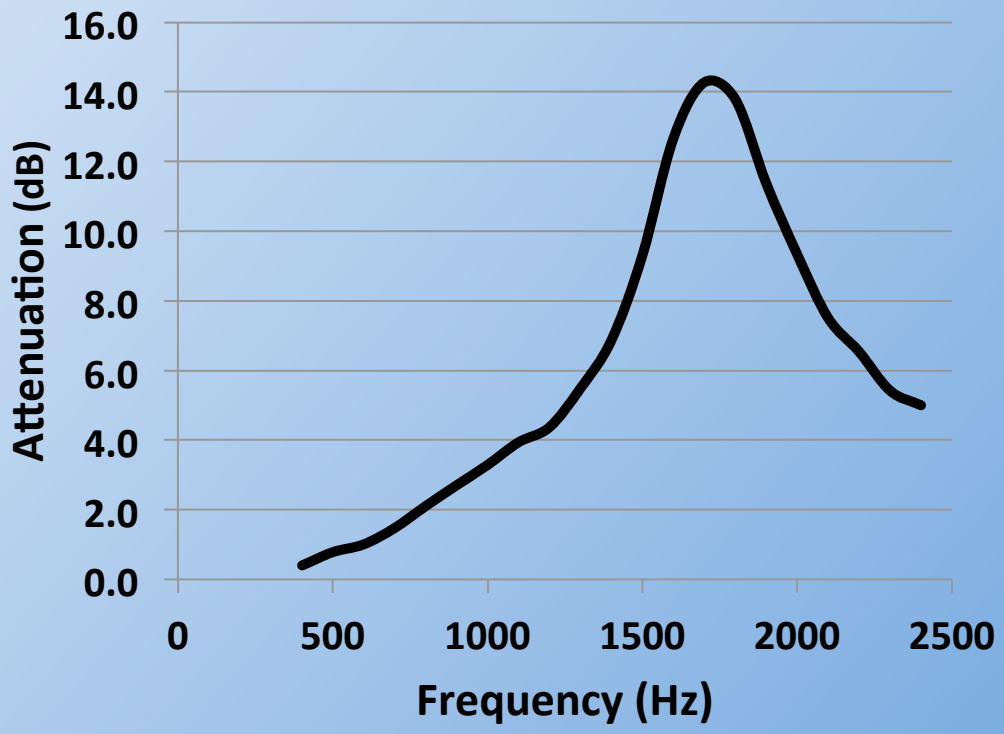
=> Need to get more performance out of less acoustic liner

# SDOF Liner - Solid Back Plane





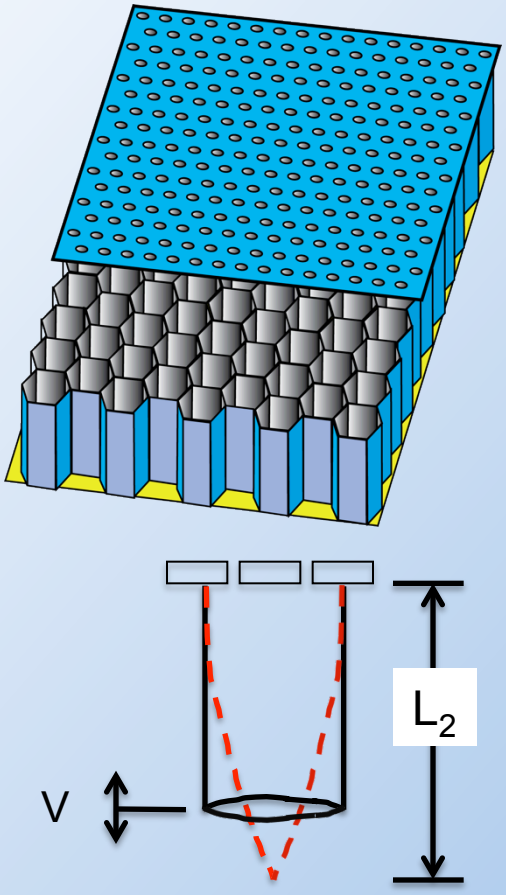


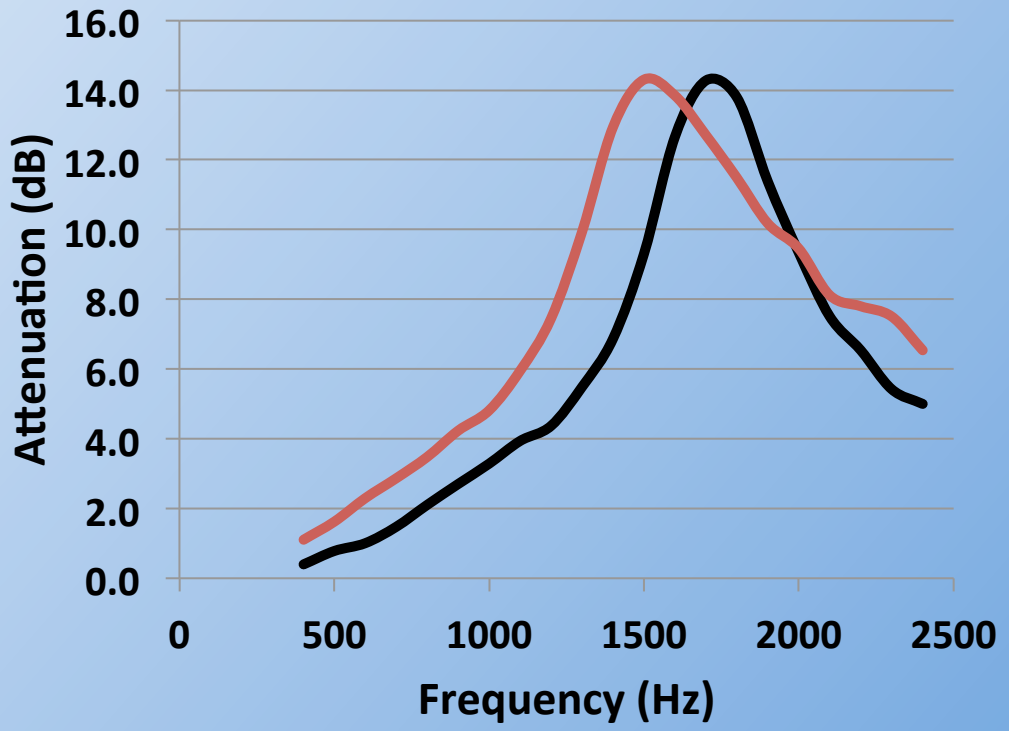




=> Frequency of peak attenuation fixed by $L_1$

# Liner-Compliant Back Plane






=> Compliant back plane can expand frequency range of attenuation

# Candidate Material



- PBLG Piezoelectric Composite Film
  - Composed of an a-helical polypeptide
  - Produced via corona charging to pre-align macroscopic dipoles along helical axis
  - Responds to external force (sensor)
  - Responds to electric field (actuator)
  - Responds at acoustic frequencies
- Developed at Johns Hopkins University Applied Physics Laboratory

# Objectives of Research

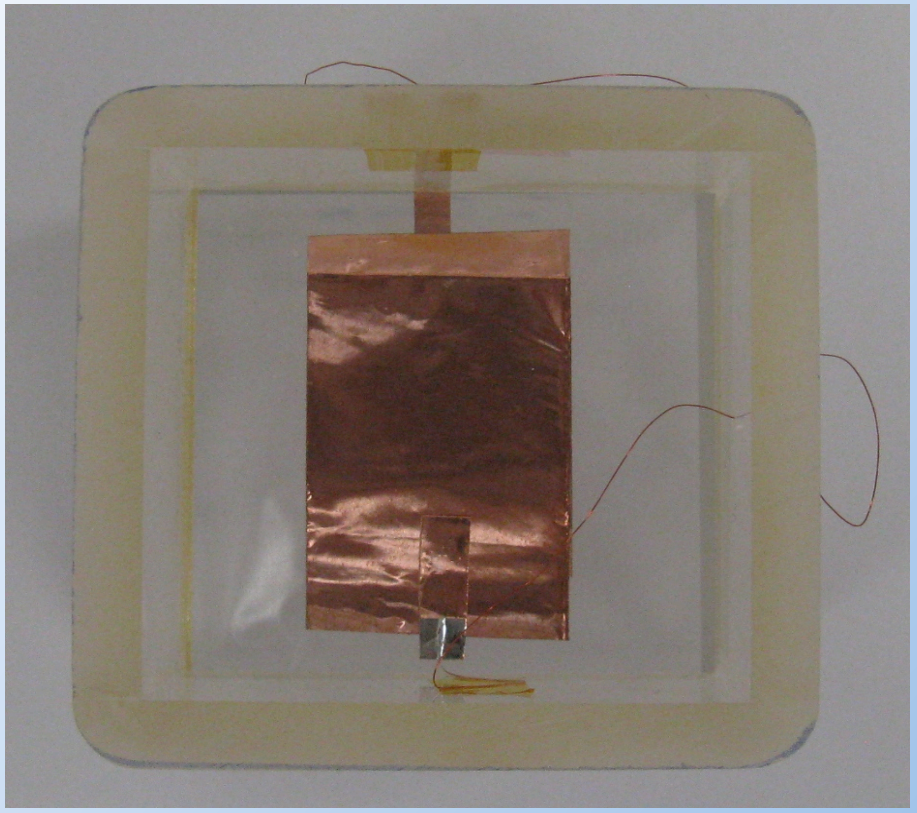


- Build sample coupons with piezo-electric material
- Determine acoustic and mechanical properties
- Estimate effect of material on liner attenuation

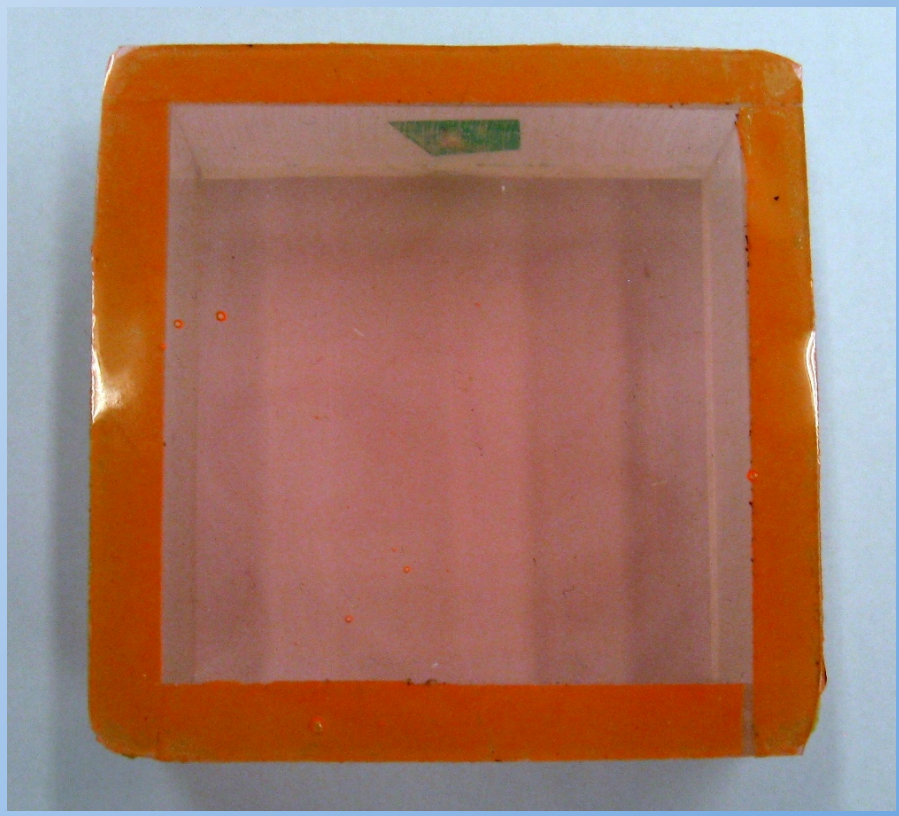
# Phase I Sample Coupons



Unencapsulated sample with electrode



Encapsulated sample (without electrode)



# Phase I - Results

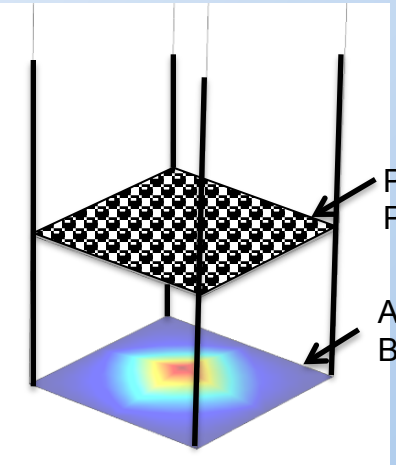


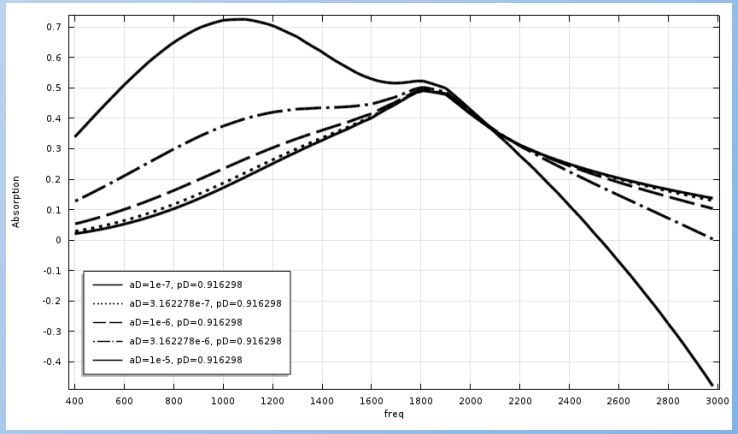

- Unencapsulated
  - Responds to acoustic excitation
    - Useful as sensor
    - Failed when SPL > 100 dB
  - Responds to voltage excitation
    - Use as actuator
    - Response much less than required
- Encapsulated
  - Survives up to 140 dB
  - Velocity response not improved
- Solved robustness problem
- Still have control authority problem

# Phase II Goal



- Revise Piezo-electric Sample Design
  - Incorporate improved robustness
  - Increase velocity response by 100x



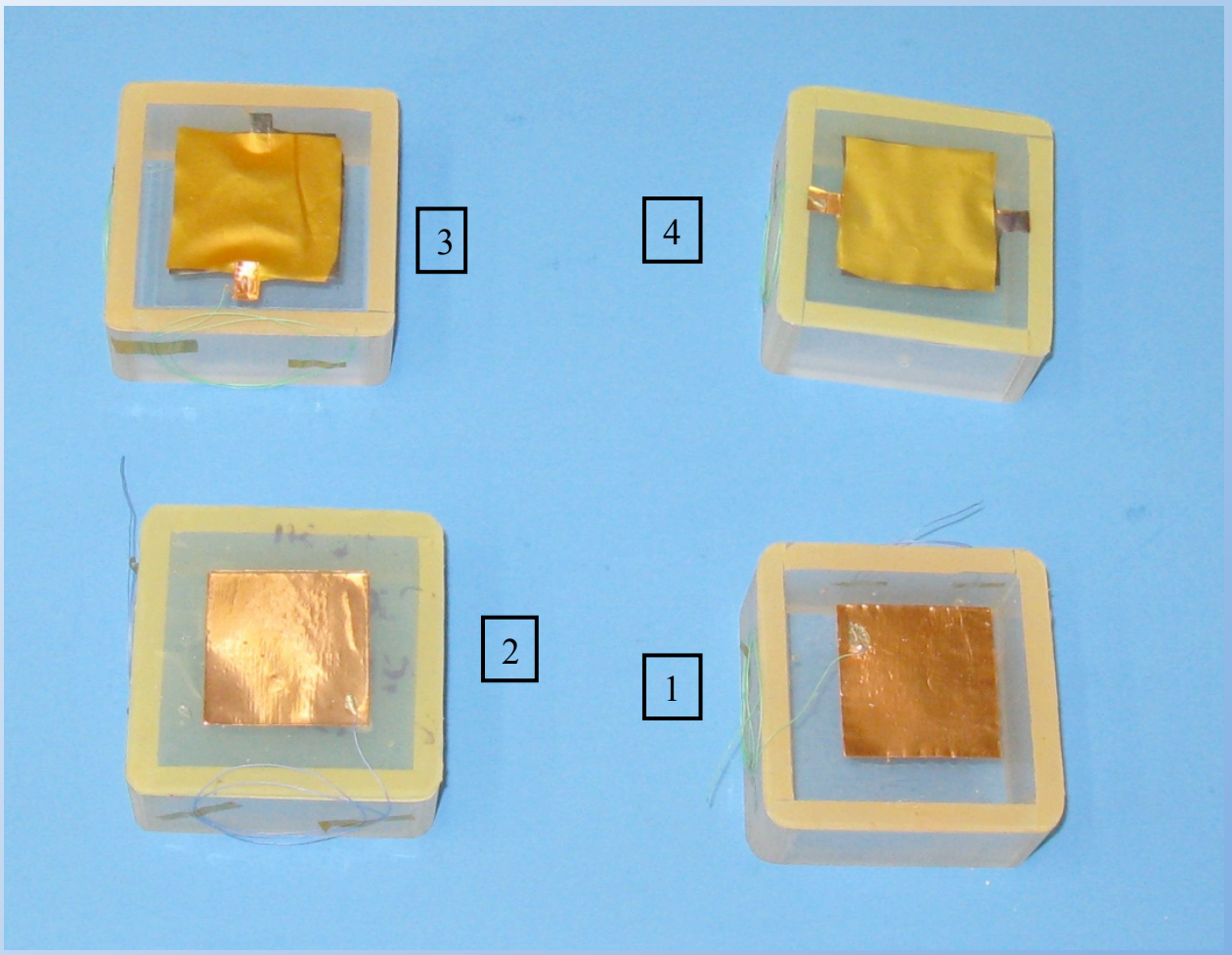




$2 \times 10^{-6} < X < 1 \times 10^{-5}$ m @ 1000 Hz

$0.013 < V < 0.063$ m/sec

# Investigate Electrode Designs

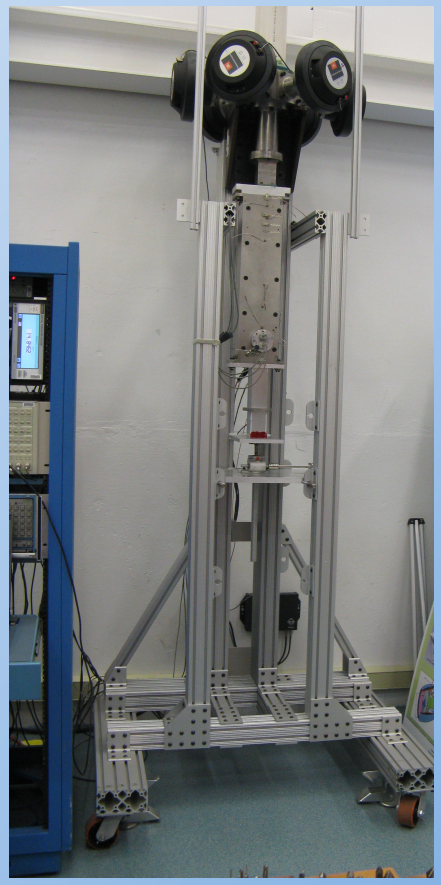
National Aeronautics Research Institute



# Evaluate Performance



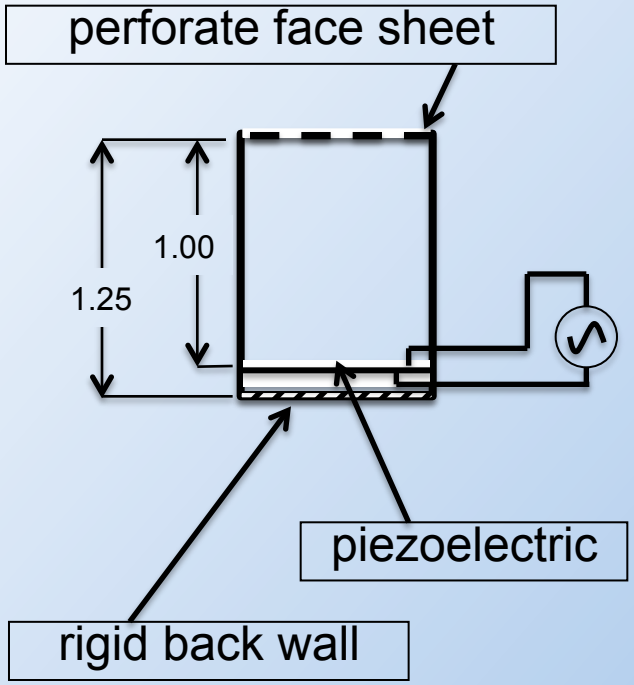
- Evaluate as Sensor
  - Measure voltage output with sound pressure input
- Evaluate as Actuator
  - Measure velocity with voltage excitation
- Evaluate as Absorber
  - Measure change of impedance with voltage excitation-calculate absorption

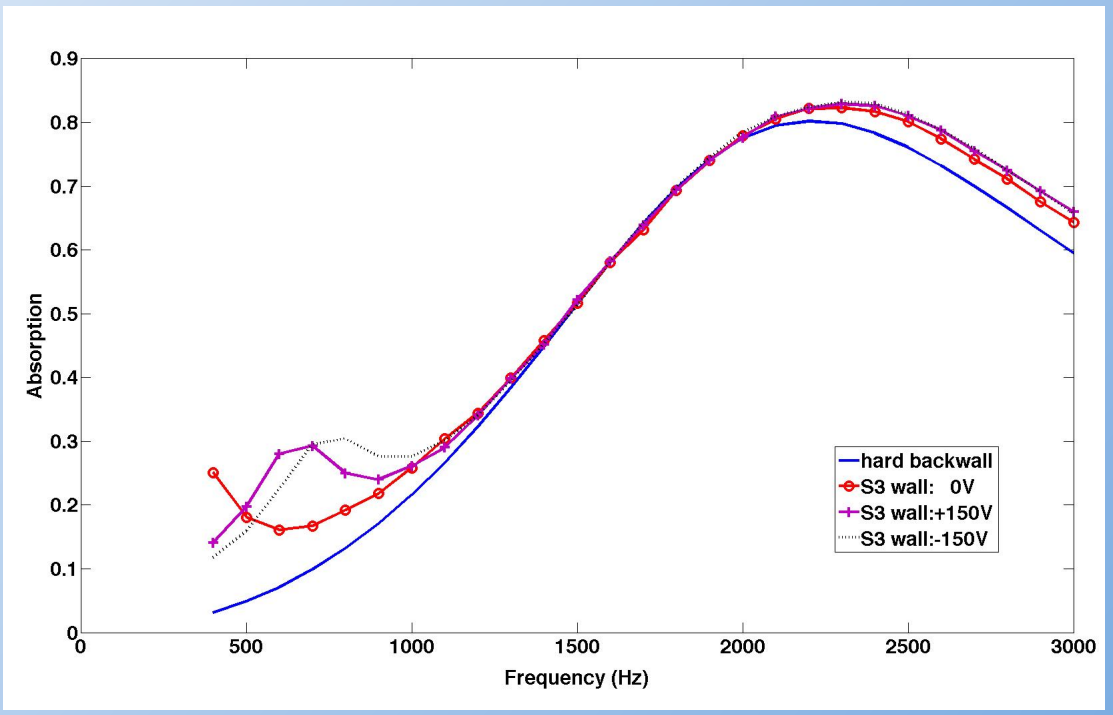


Normal Incidence Tube

# Evaluate as Absorber

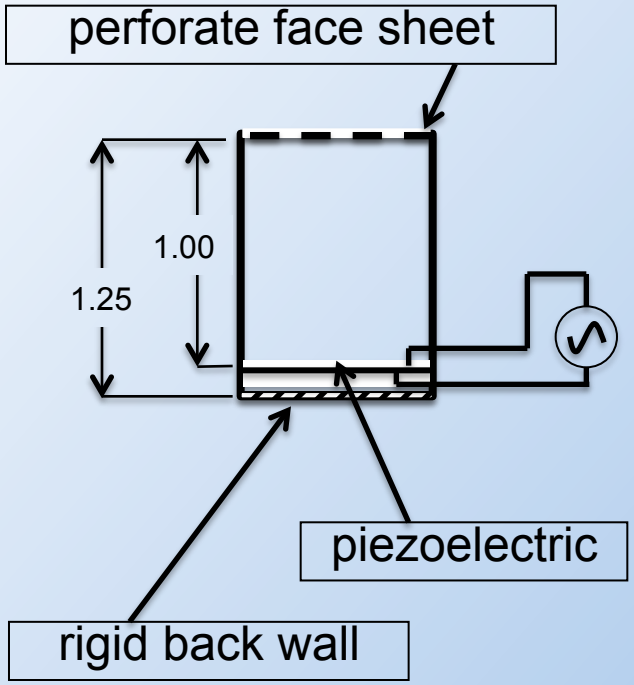


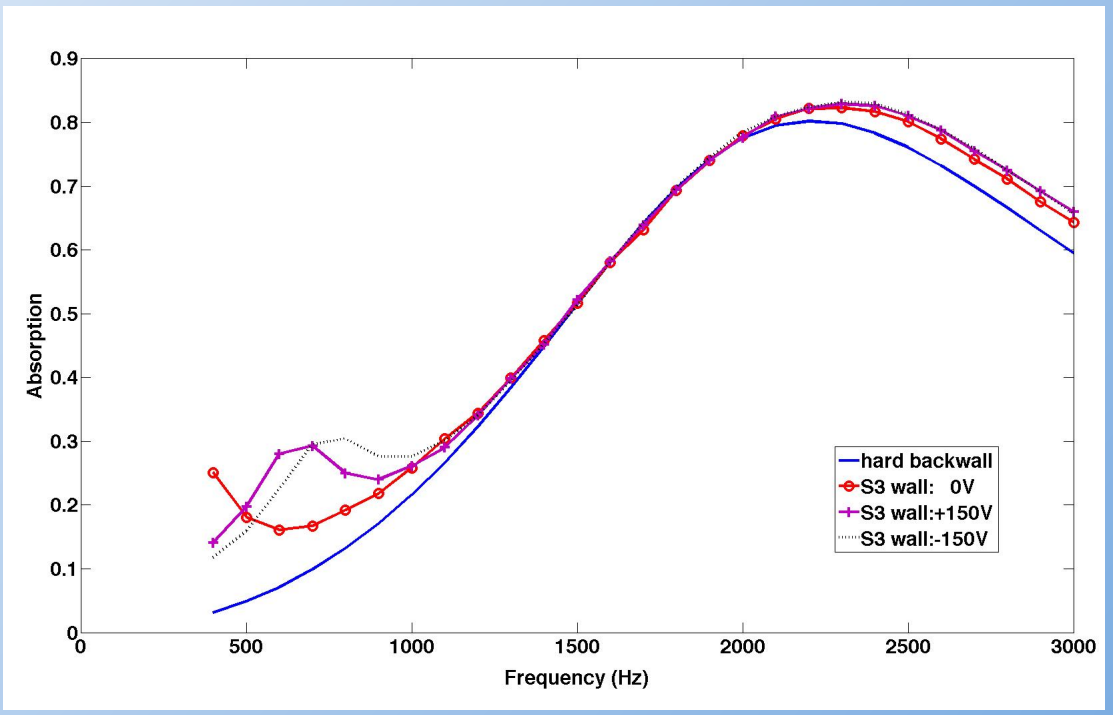


# Evaluate as Absorber





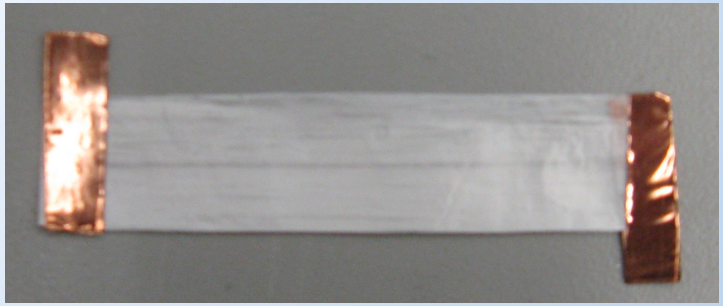




=> Control Authority Not Sufficient

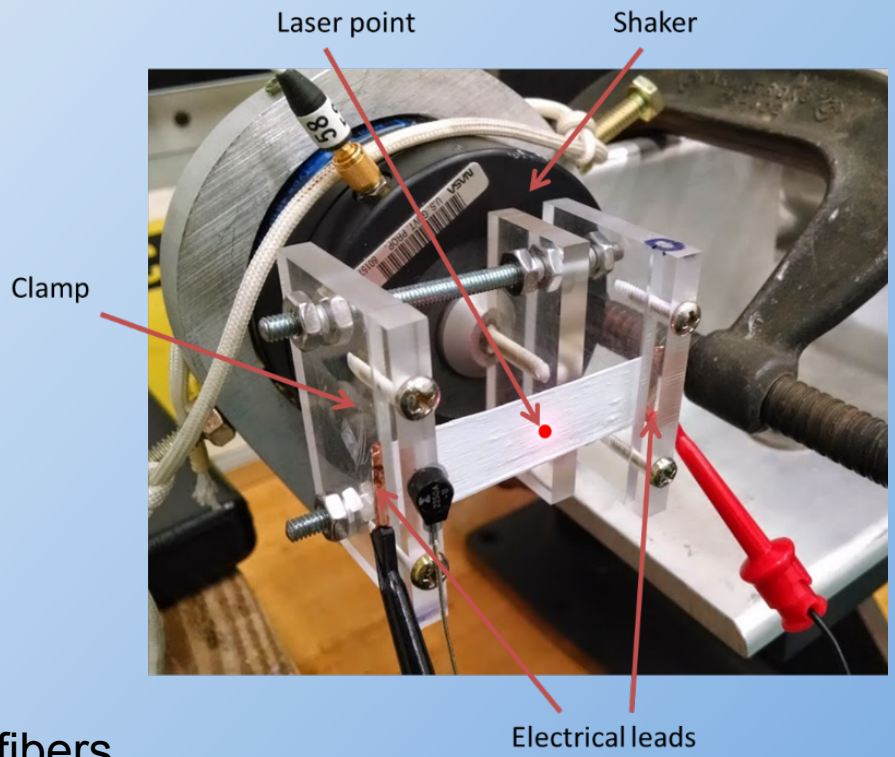
# Reformulated Design



Piezo-electric sample



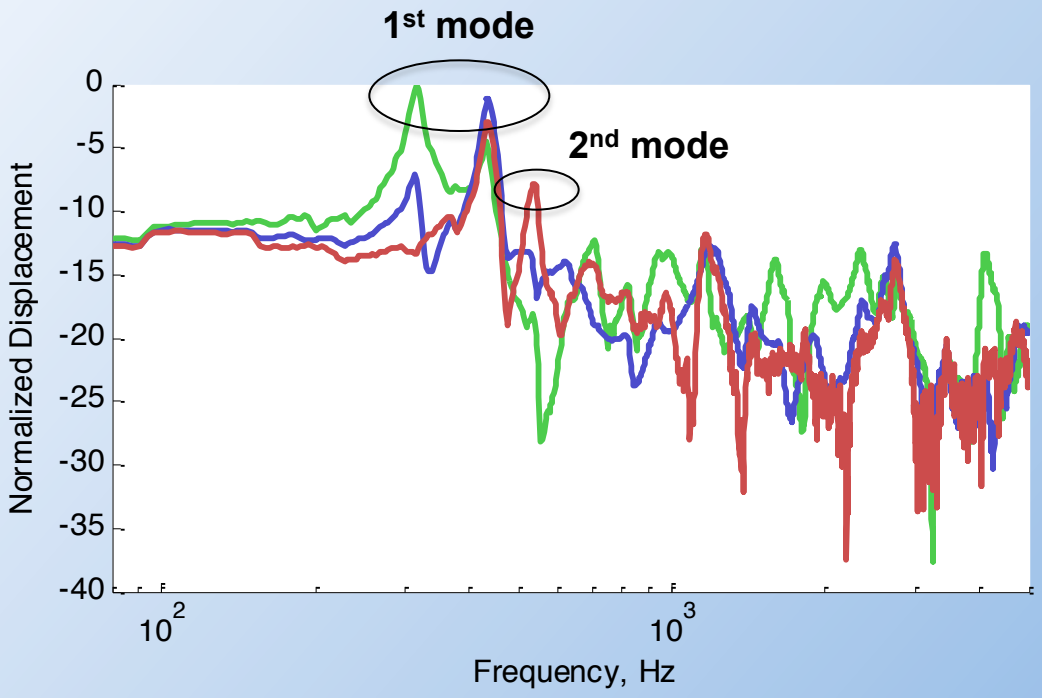
Sample in Vibration Test Set-up

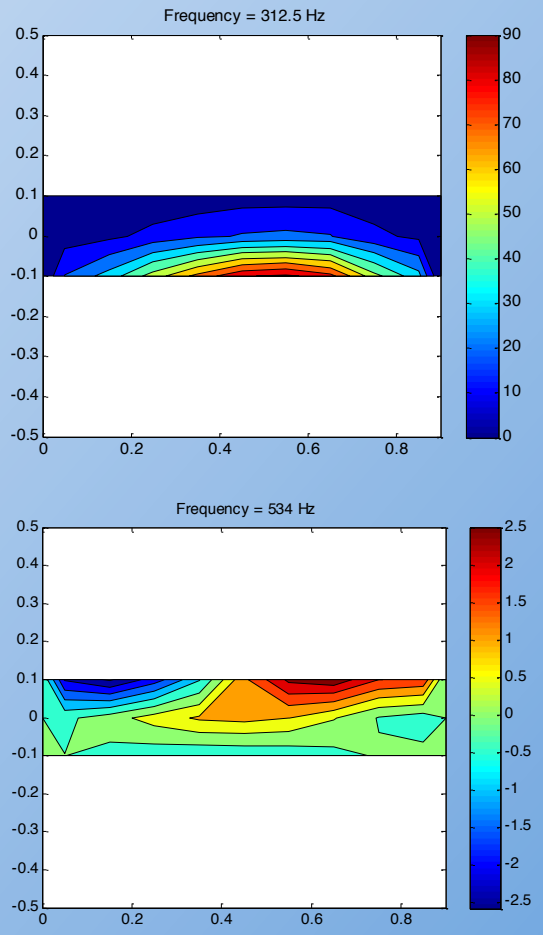



- Manufactured in bundle-type fibers
- Piezo-electric dipoles are polarized in the direction of strain
- Intended to improve coupling coefficient of piezo-electric material

# Vibration Analysis

National Aeronautics Research Institute

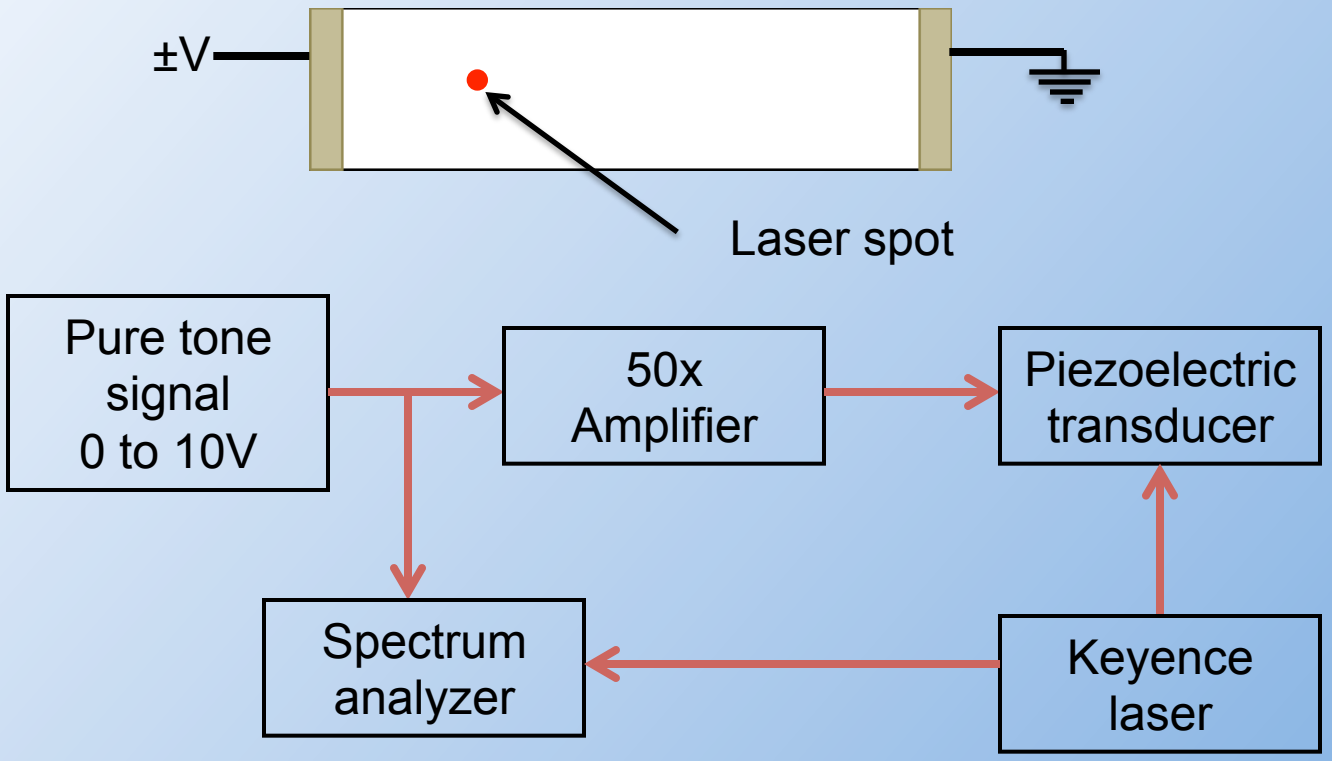



1st ('Drum Head') resonance response at ~300 Hz
2nd resonance at ~ 550 Hz

# Response to Voltage Excitation

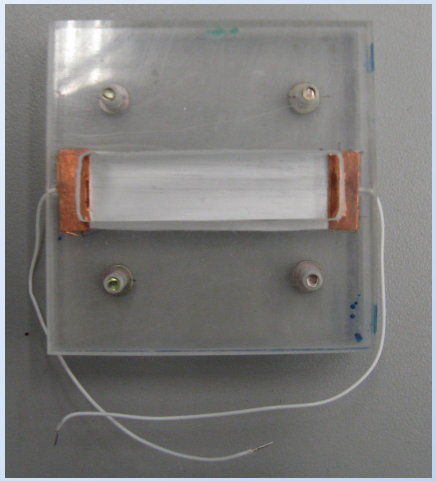




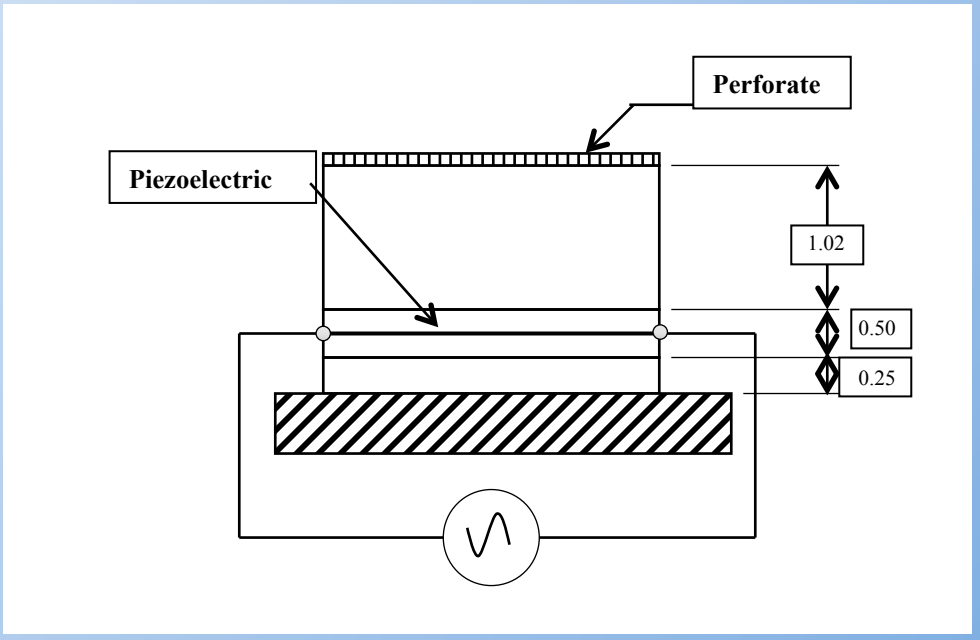

- No displacement response could be detected
  - Up to 500 volt excitation
  - 100 < f < 3000 Hz, including first two resonant frequencies.

# Evaluate Acoustic Performance





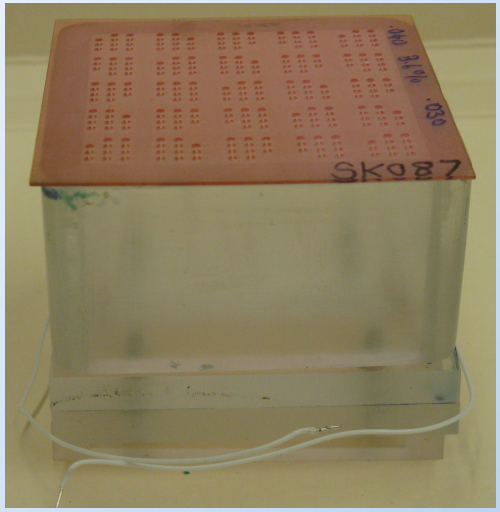
Piezo-electric in Impedance
Test Sample Holder



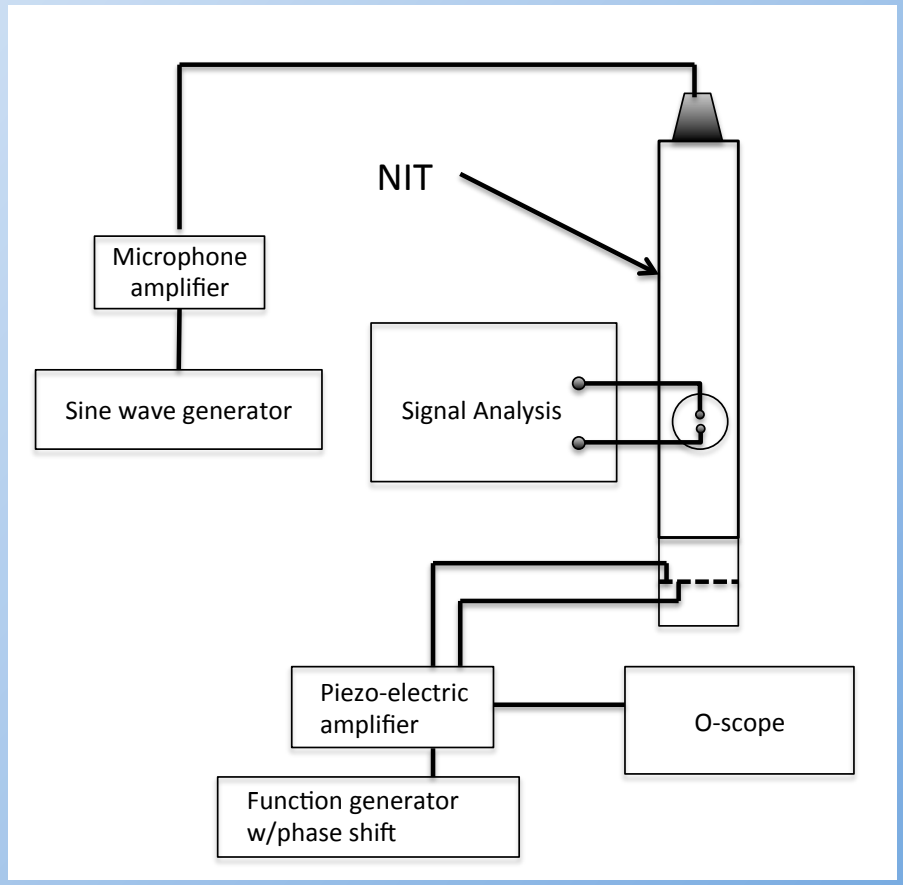

Normal Impedance Test Build-up
Incorporating Piezo-electric

# Evaluate Acoustic Performance





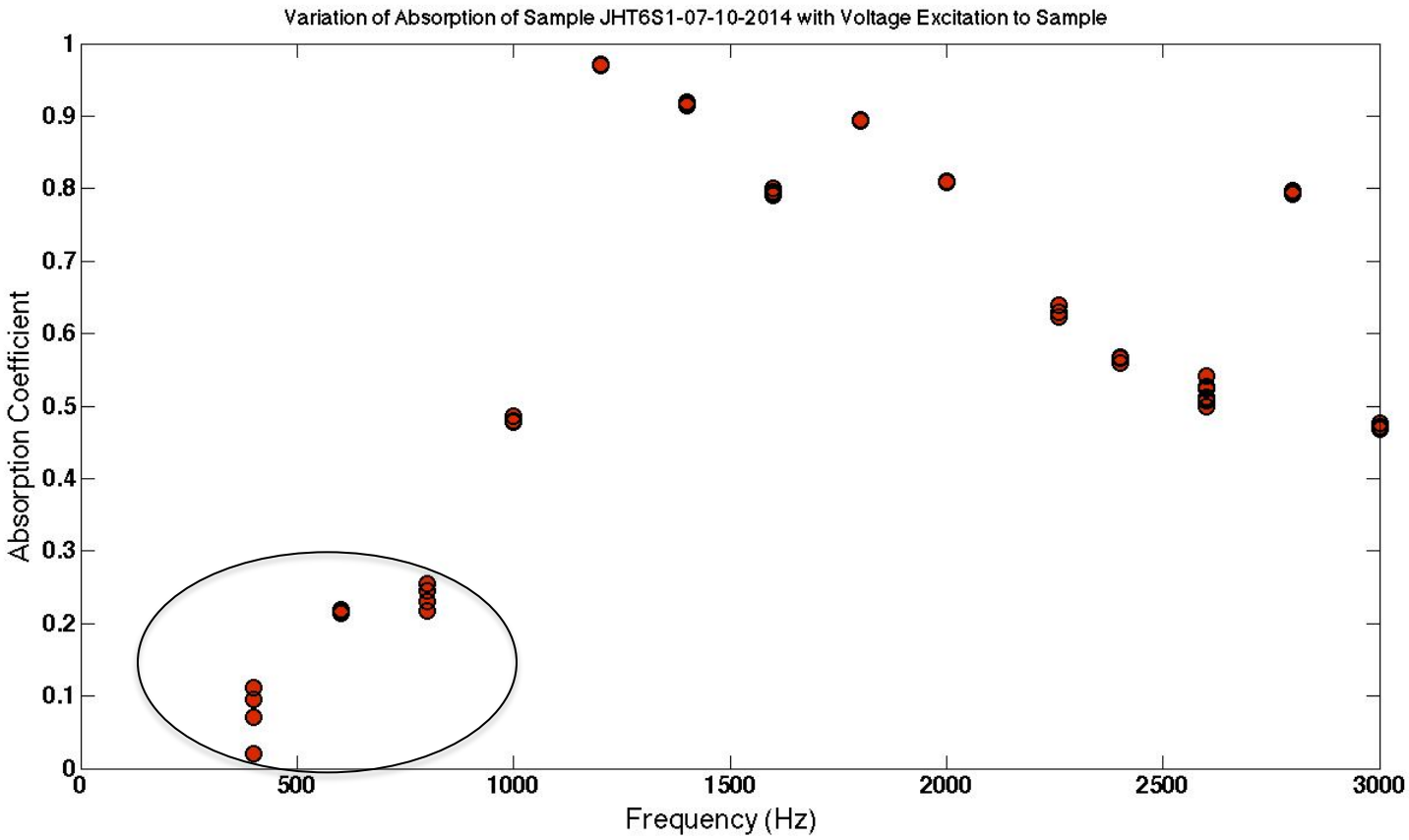

Built-up Coupon for Impedance Test




Impedance Test Set-up

# Measure Absorption Change

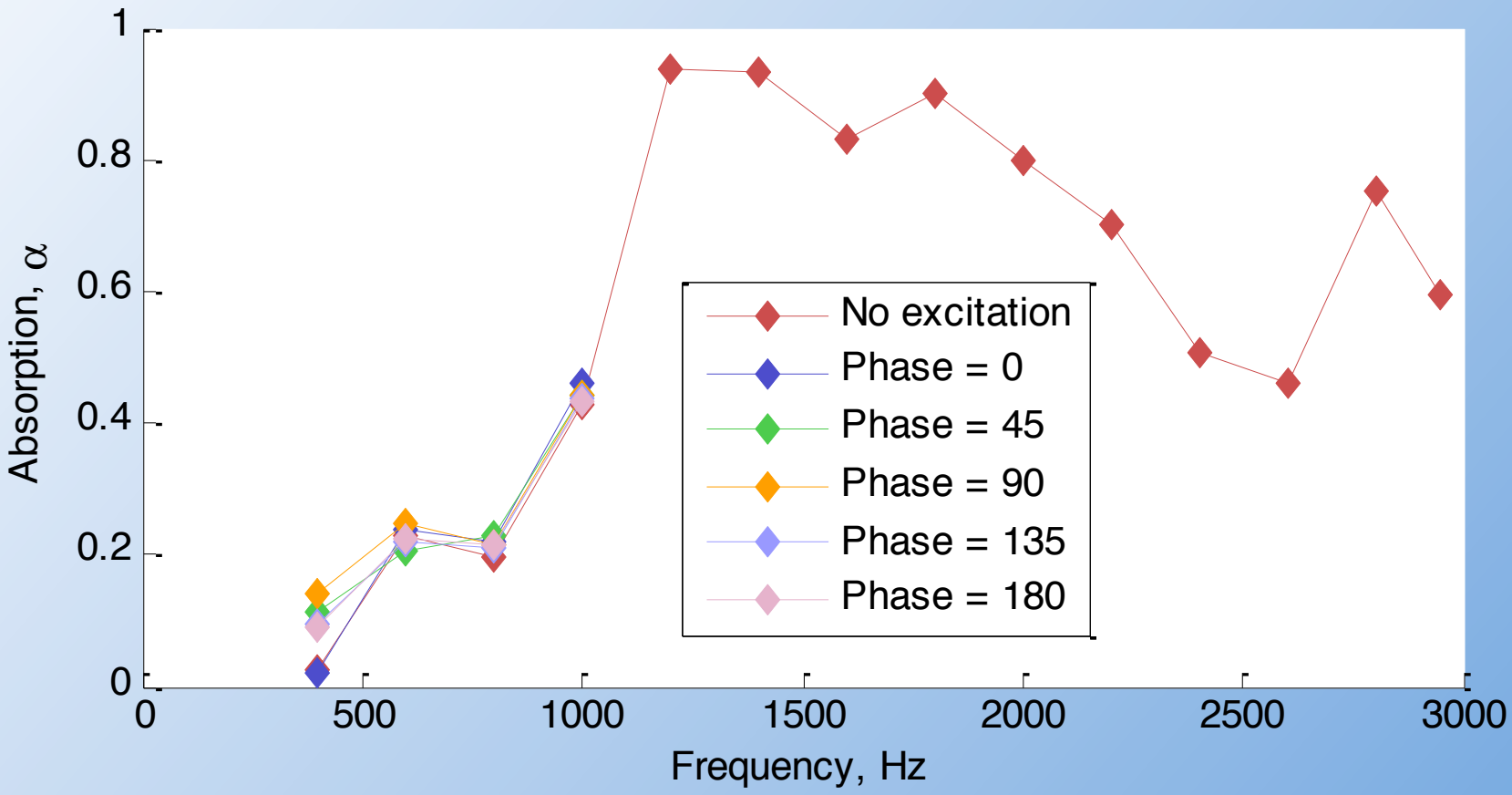





No effect on absorption except near piezo-electric sample resonance

# Vary Phase of Excitation






Absorption varies with phase, but no consistent trend found

# Conclusions



- Developed experiments to evaluate the piezoelectric film samples
  - Measured mechanical properties
  - Measured acoustic properties
- Developed mathematical model of liner absorption including compliant back wall
- Piezo-electric film properties achieved:
  - Robustness
  - Frequency response
- Property not achieved:
  - Control authority (out of plane displacement)

# Thank You

National Aeronautics Research Institute

## Adaptive Back Sheet Material for Acoustic Liner Application