Passive Acoustic Metamaterial Proppants for Advanced Hydraulic Fracture Diagnostics

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Motivation

- Problem:
  - Economic and environmental costs that burden the natural gas economy:
    1. Ineffective hydraulic fracture jobs
    2. Lost injected materials
    3. Workover jobs
    4. Well downtimes
  - *Poor zonal isolation and production control threaten environmental and public health.*

- Accurate propped fracture characterization includes:
  - Orientation and dimensions
  - Proppant bed height
  - Fracture coverage and flow directions
  - Perforation efficiency
  - Details of wellbore connectivity

- Understanding the well state is critical to predicting environmental risks and improving productivity.
- Current proppants and available tools do not consistently provide a fully detailed and accurate description of the created fractures' characteristics.

Benefit to the Program

- This project is developing acoustic tracer materials for use in advanced hydraulic fracture diagnostics.

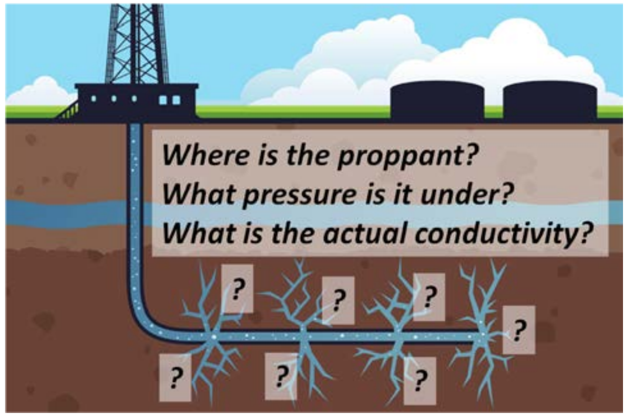
- The smart proppant additive has the physical properties of traditional proppants but also has unique acoustic signatures that allow detection of its location, concentration, and closure stress.

- The system uses locally resonant acoustic metamaterials that are acoustically opaque at specific frequencies and responsive to mechanical load.

- This project will support program goals of advancing technologies to improve hydrocarbon recovery efficiency and reducing the operational risks of production.

Acoustic Smart Proppant

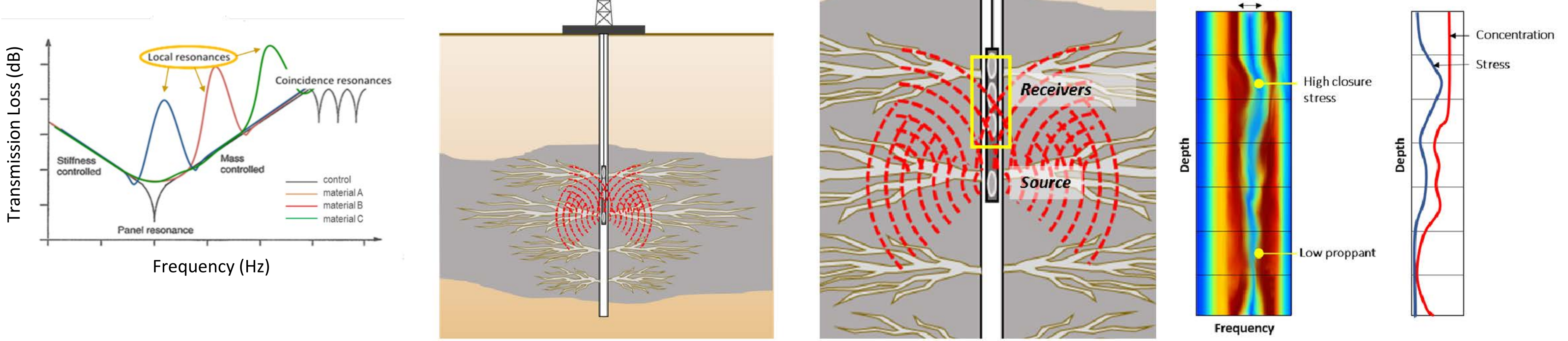
- Oceanit has created:
  - A novel proppant detection technology based on acoustic metamaterials
  - that allows detection of proppant location and environmental conditions
  - using industry standard acoustic logging tools and remote detection methods



- Specific acoustic band gap properties are engineered based on the geometry and mechanical properties of the proppant particles.
- The background well and formation properties can be measured at a frequency at which the smart proppant is acoustically transparent.
- Smart proppant location can be detected at an adjacent frequency at which it is acoustically opaque.

Acoustic Smart Proppant

Acoustic Metamaterial Proppants



- Features:
  - Added at low levels to traditional proppant
  - Safe and environmentally benign
  - Detection through standard acoustic logging
  - Uniform size and shape
  - Thermal and chemical resistance
  - Low cost starting materials and production methods

- Benefits:
  - High resolution propped fracture measurements
  - High sensitivity and contrast
  - No pretreatment log
  - Measurements throughout life of well

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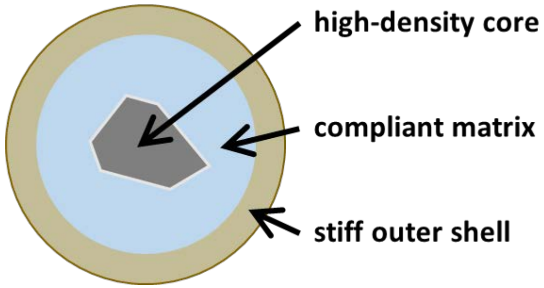
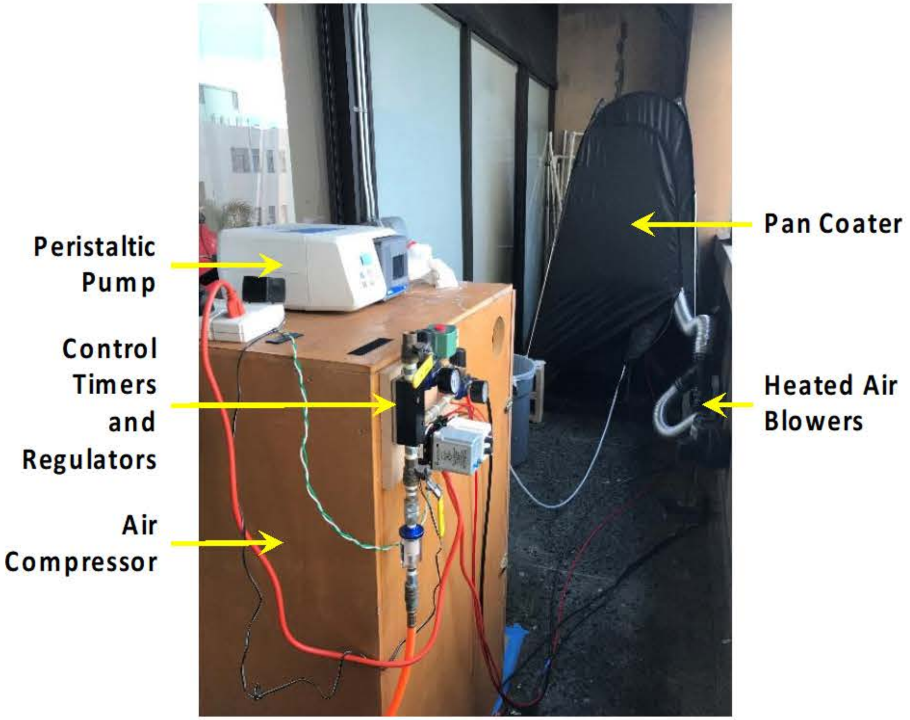
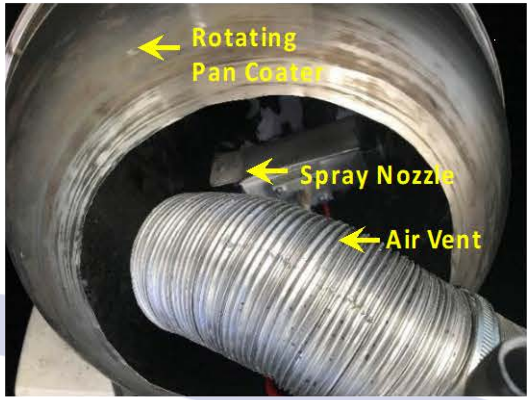
Technical Status

- Acoustic smart proppant lab production







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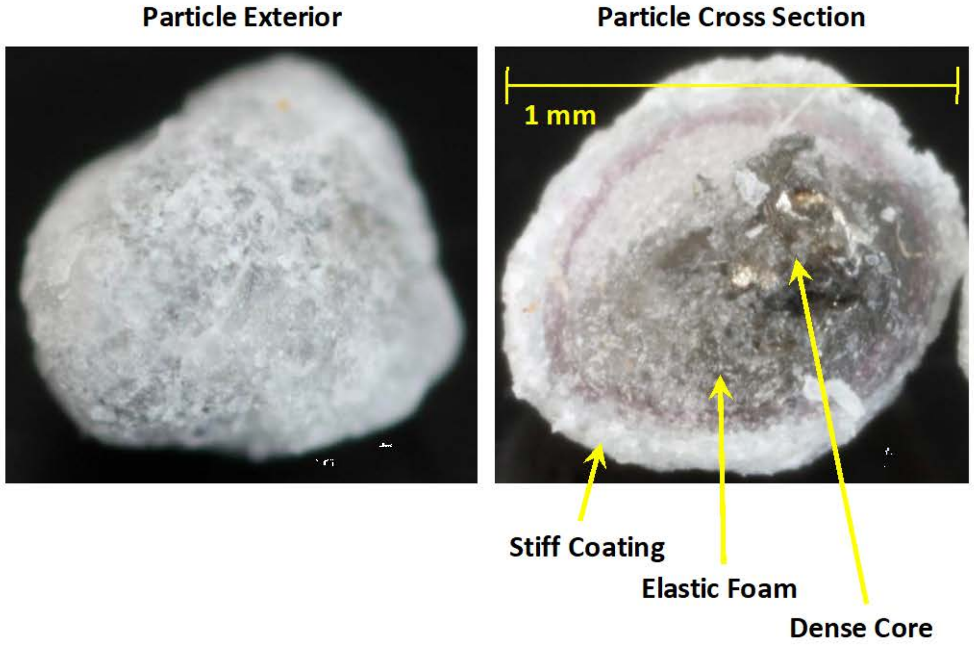

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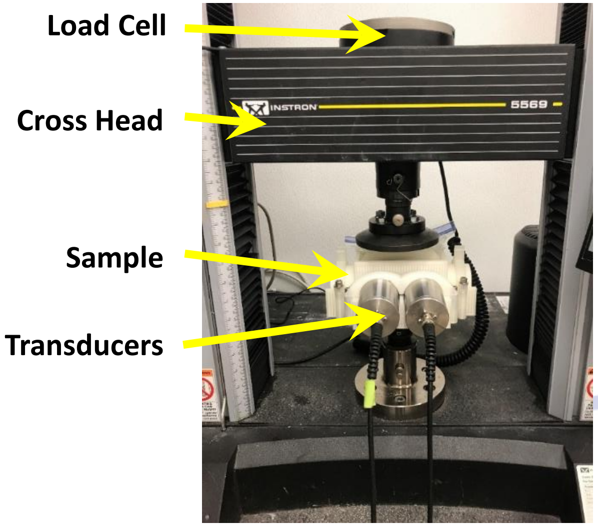
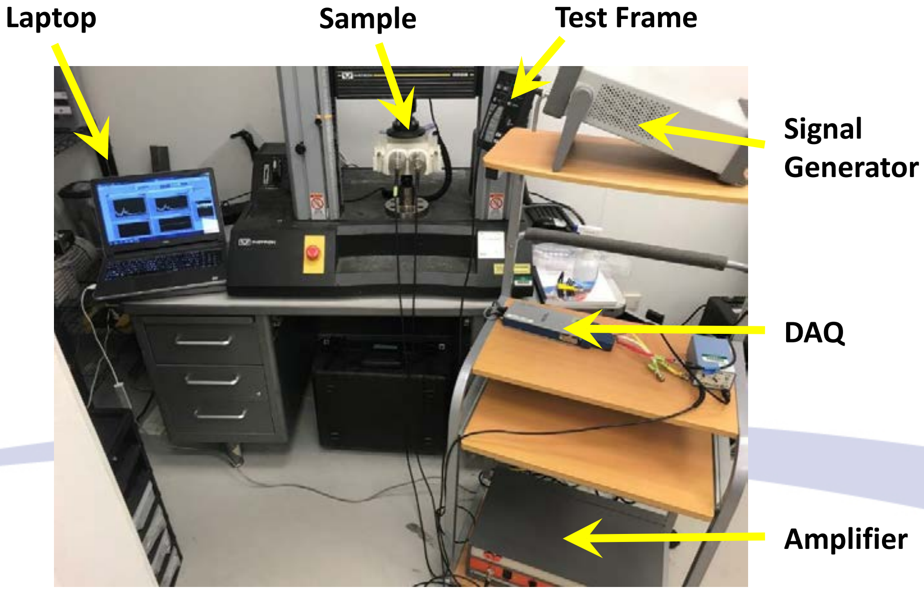
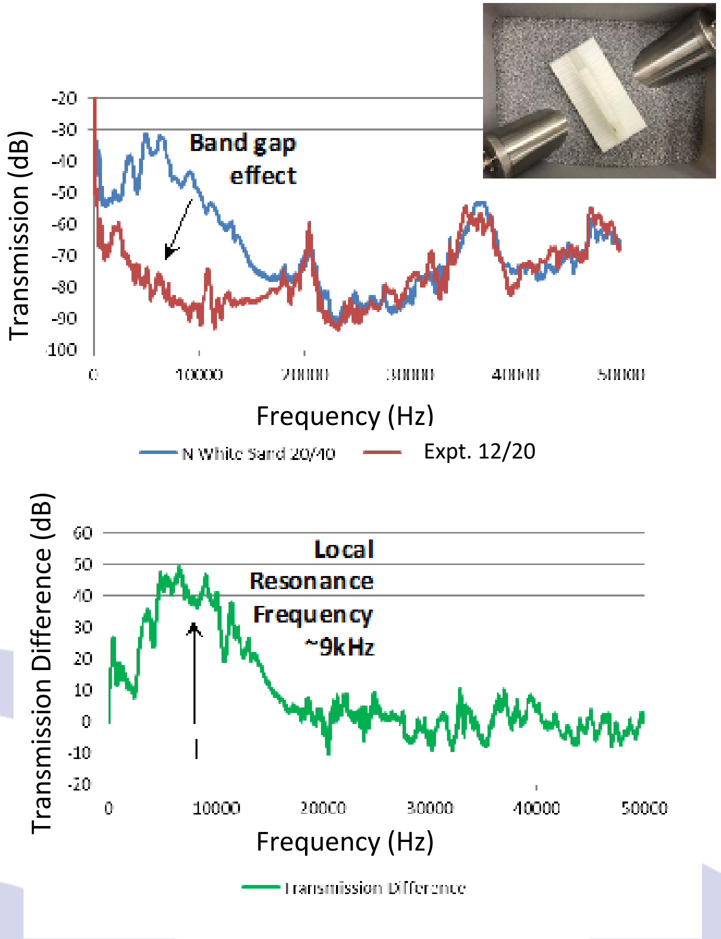
- Laboratory testing







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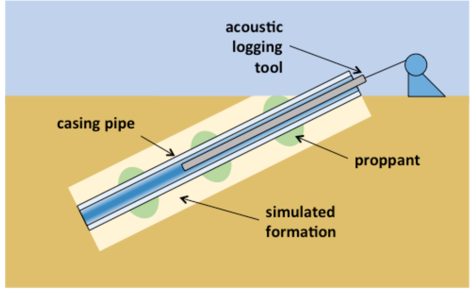
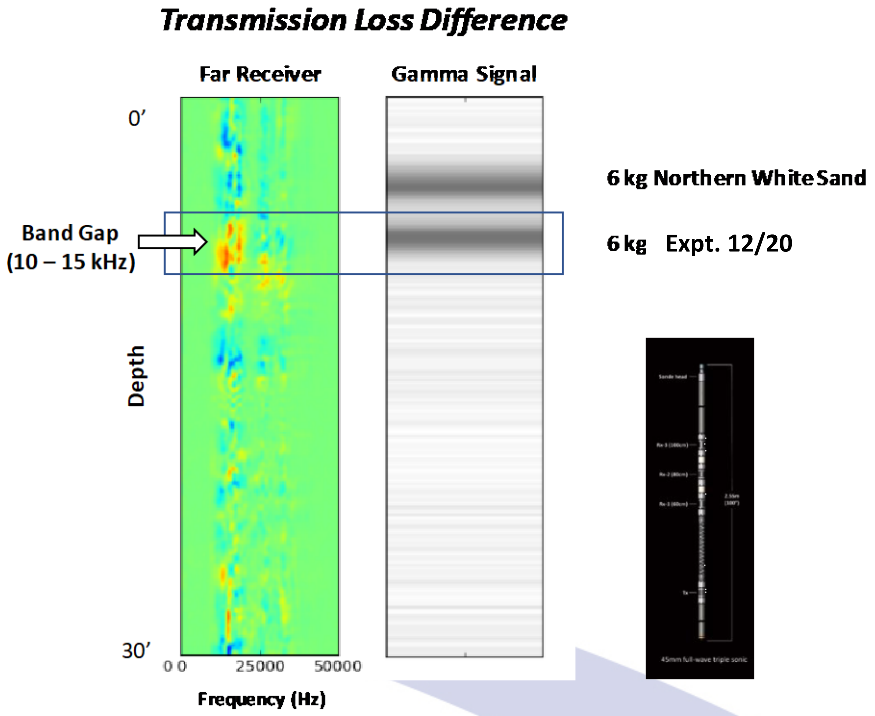
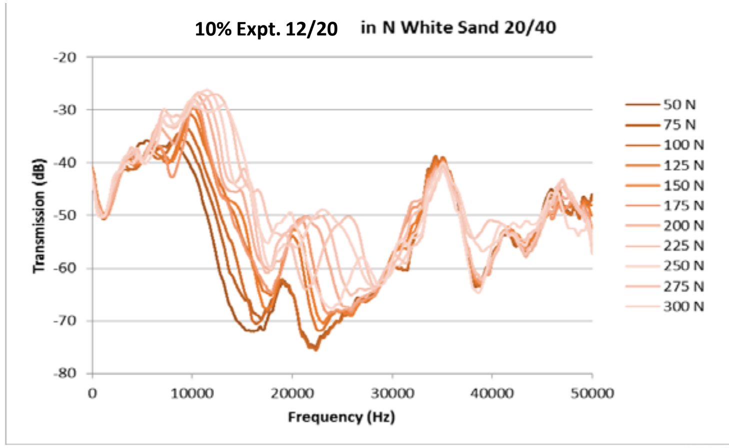
- Pilot field testing

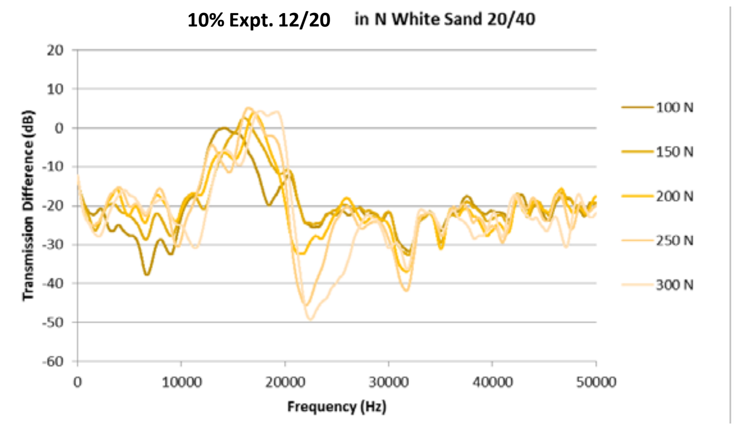


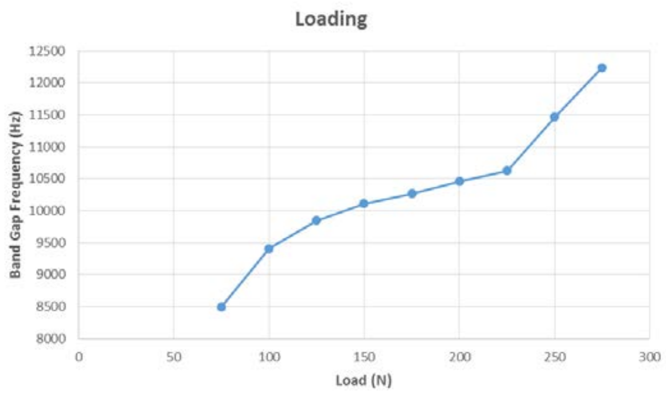


Technical Status

- Phase I results







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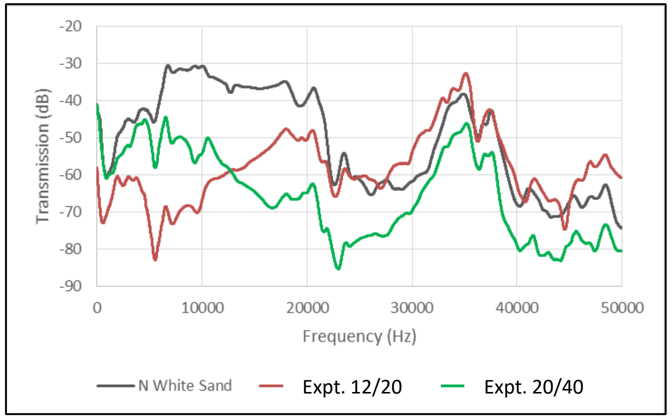
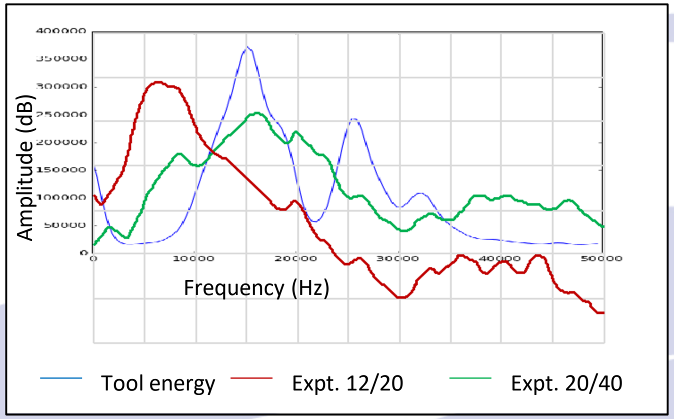


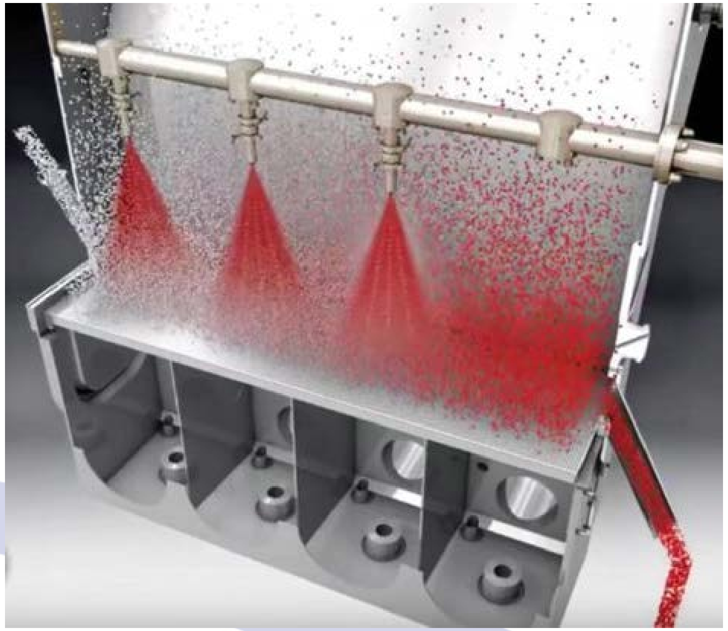
Batch	Mesh Size	Avg. Diameter (mm)
A	8/10	2.13
B	12/20	1.44
C	20/40	0.92



Technical Status

- Production scale-up





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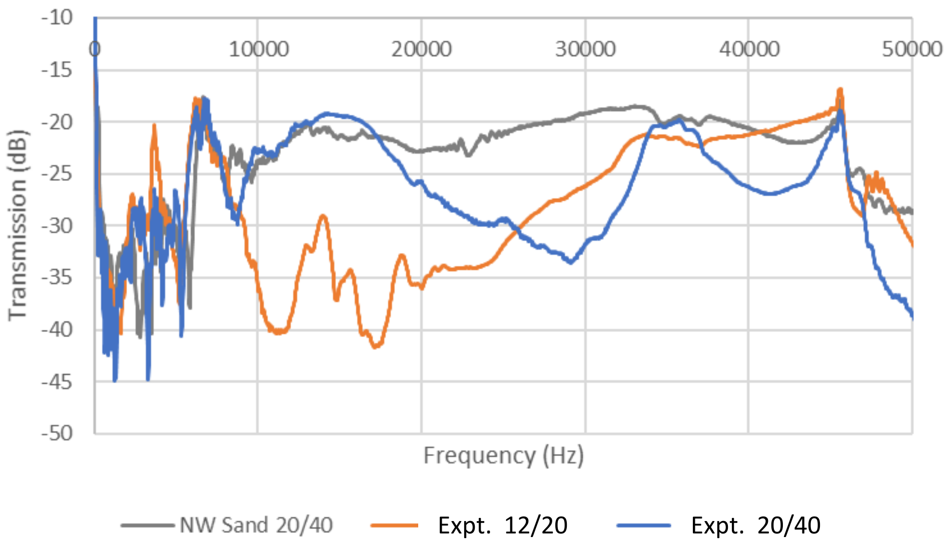
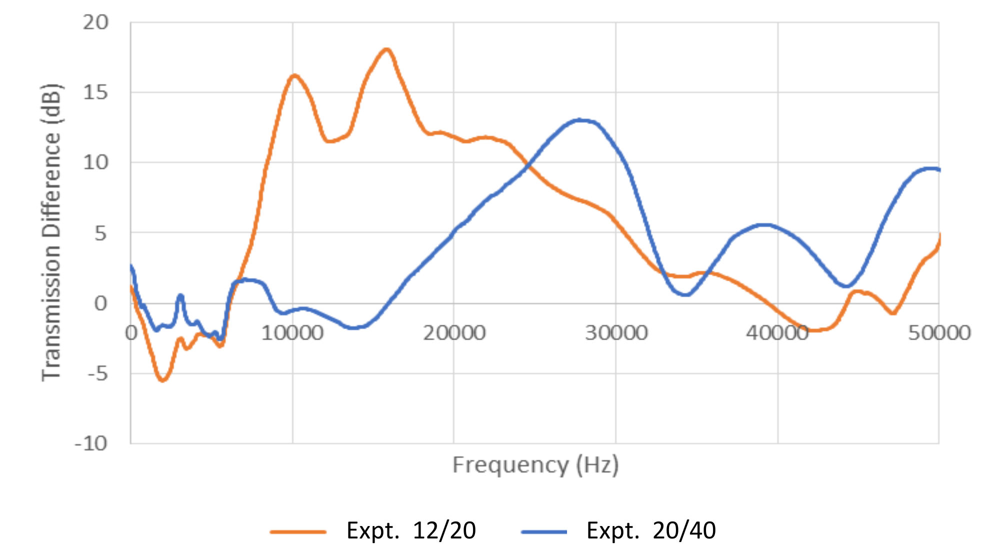
Technical Status

- Current Phase II results

FracScan 12/20 and 20/40 (dry) at 100%





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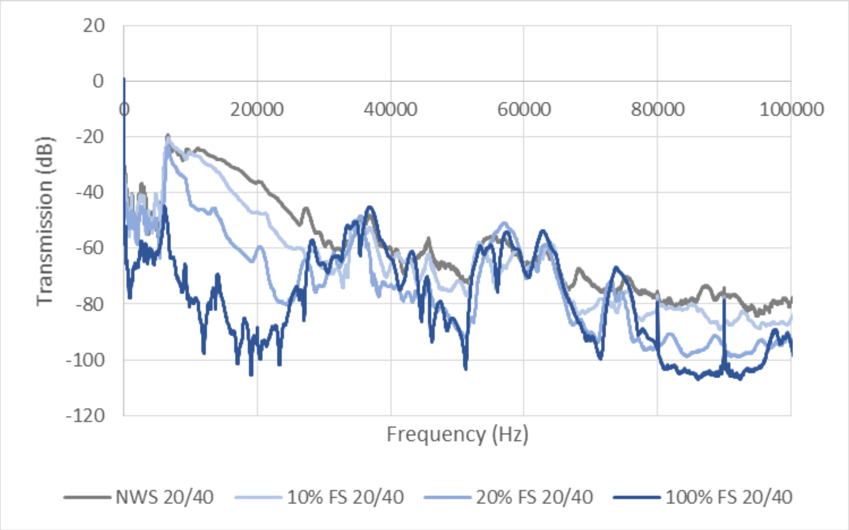
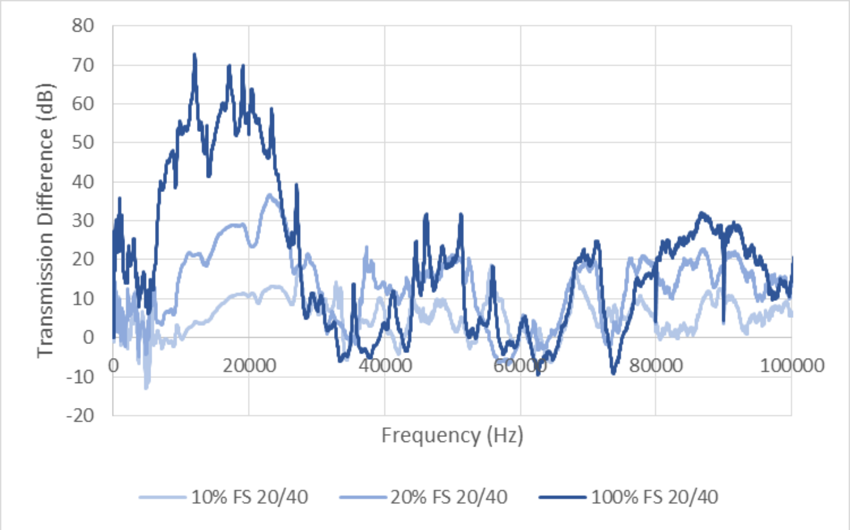
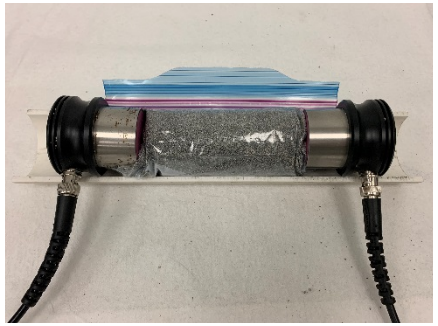
- Current Phase II results

FracScan 20/40 (dry) at 100%, 20%, and 10%







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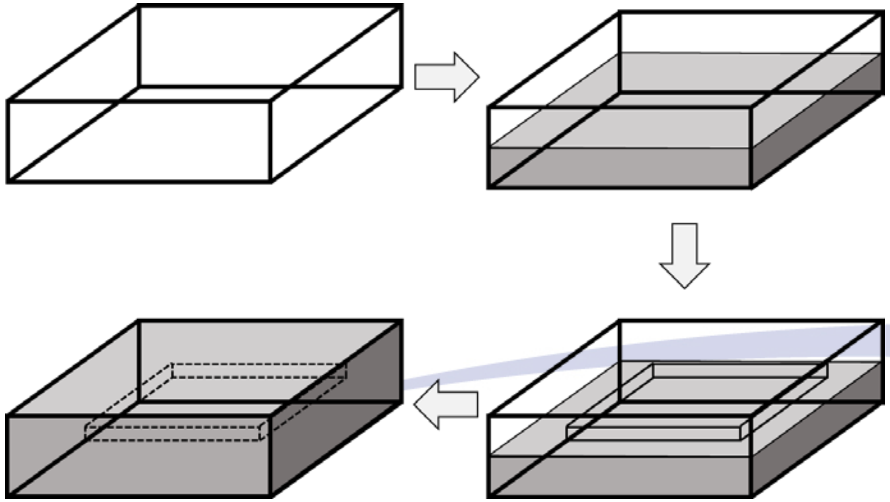
- Hydraulic fracture model development



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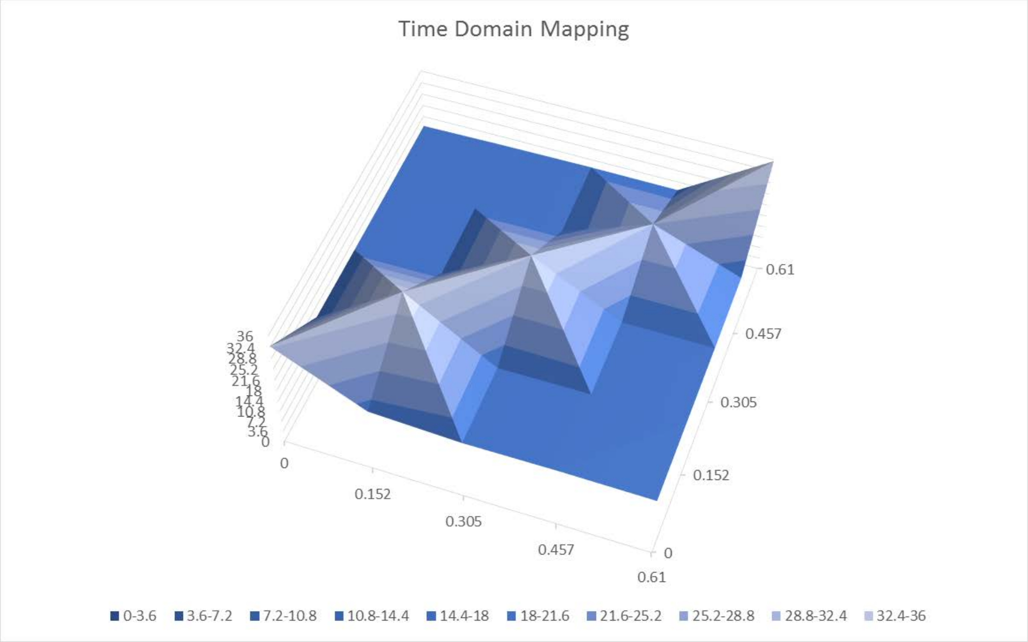

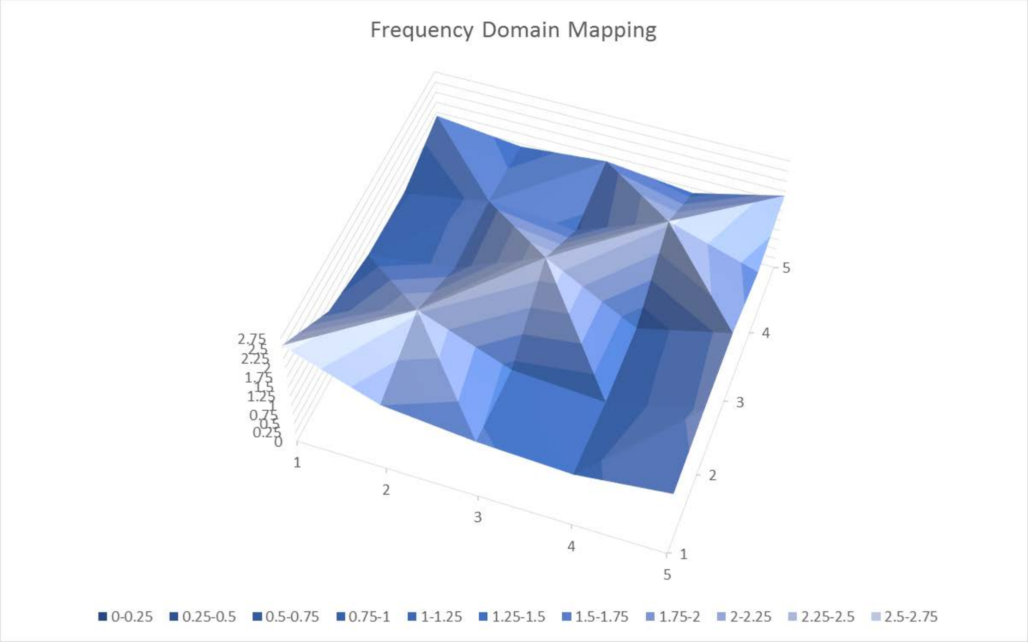

Smart proppant allows mapping of location in the time and frequency domain.

Accomplishments to Date

- Design and production of smart proppant particles.
- Preliminary physical and acoustic characterization.
- Pilot scale deployment as buried packets around the wellbore.
- Development of data analysis techniques to interpret acoustic data.
- Acoustic testing of proppant mixtures under load.
- Hydraulic fracture diagnostics model development.
- Commercialization transition planning and scale-up (on-going).
- Proppant full physical characterization (on-going).
- Acoustic tool selection and customization for measurement (on-going).

Project Summary

- Key findings
  - Novel metamaterial particles exhibit an acoustic band gap effect that is dependent on mechanical loading.
  - The acoustic smart proppant can be detected in proppant mixtures down to 2 wt%.
  - The particles can be engineered to have a band gap in the center frequency of acoustic interrogation methods.

- Lessons learned
  - Time and effort required to scale up production operations.
  - Importance of matching material acoustic response to tool capabilities for particular applications.
  - Balancing acoustic performance with size and physical properties.
  - Impact of materials selection on production economics and performance.

- Next steps
  - Continued production process scale-up
  - Proppant mixture full characterization
  - Material and detector optimization
  - Field trial