Defect Characterization of Navy Ship Structures with Broad Spectrum Active Ultrasonic Mode Imaging

Presented by Dr. Steve Ziola

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Ultrasonic Mode Imaging

ULTRASONIC

The frequency range in which the measurements are performed.

MODE

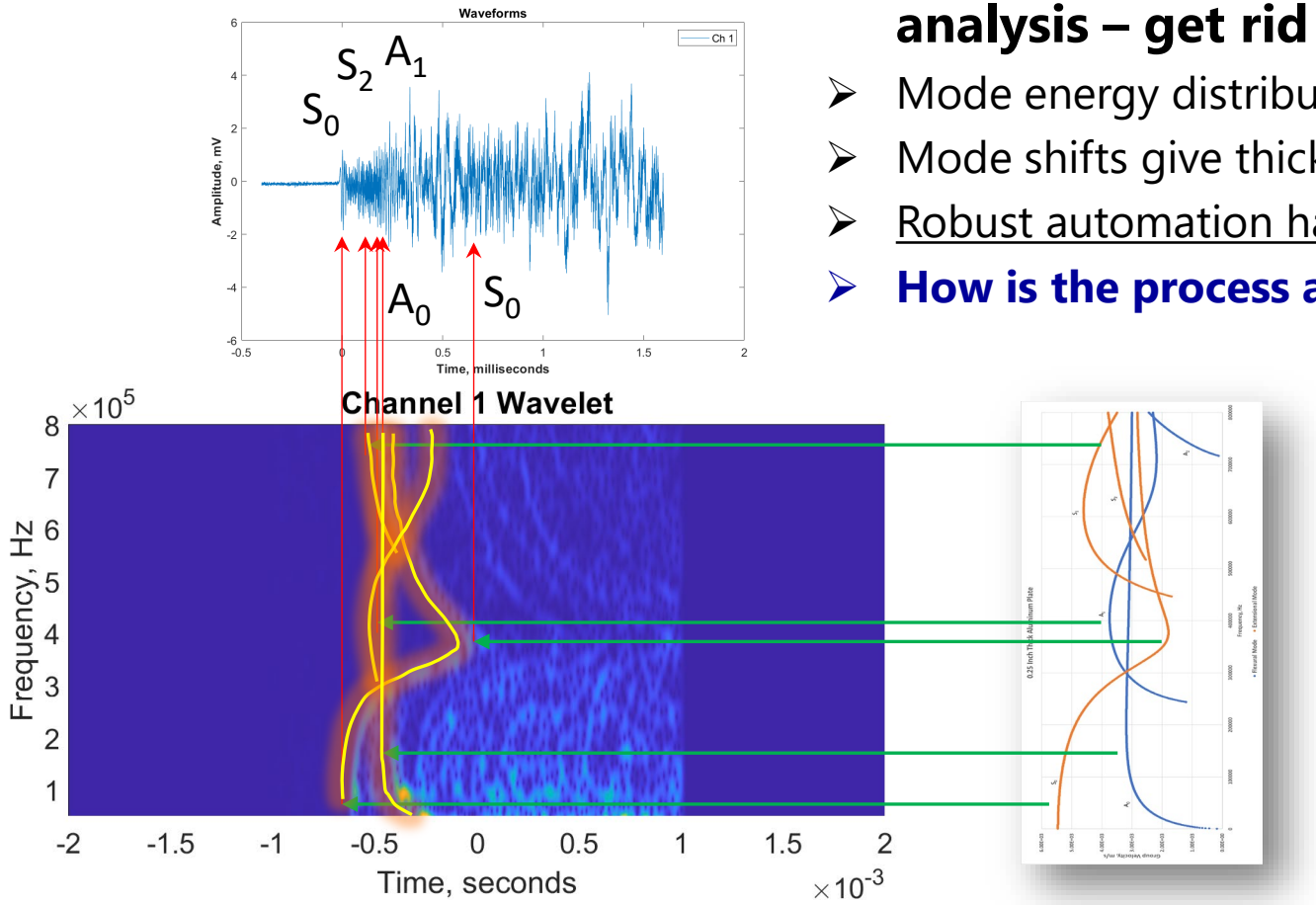
Using the wave modes in the signal to measure the effects of the source and structure on the wave propagation.

IMAGING

Using the measurements from the modes to image the flaw source or the structure.

Image Analysis

Guided waves are very complex and difficult to analyze



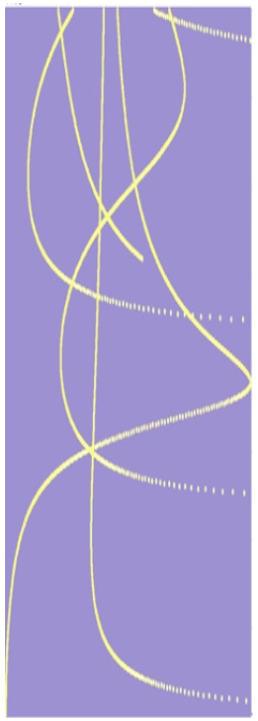
- **This becomes a pattern recognition analysis – get rid of PhDs**
- Mode energy distribution gives flaw criticality
- Mode shifts give thickness changes
- Robust automation has never been performed
- **How is the process automated?**

Plot 1 - Wavelet Transform Time/Frequency/Amplitude

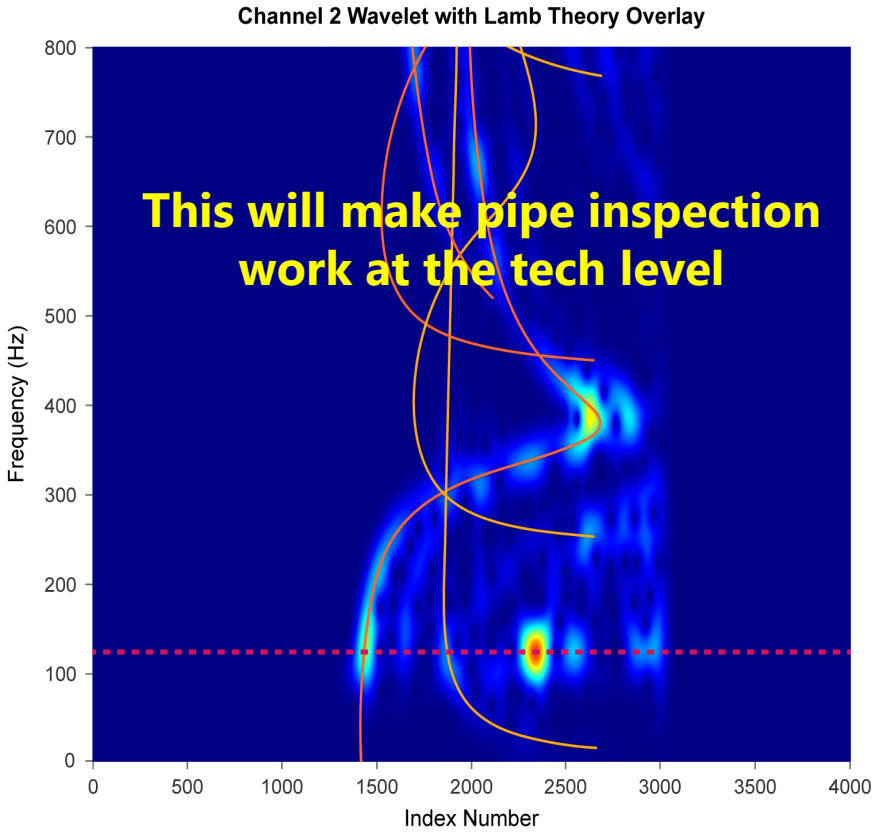
Plot 2 - Lamb mode theory dispersion curves

Image Correlation

Create image of theory (Known face)



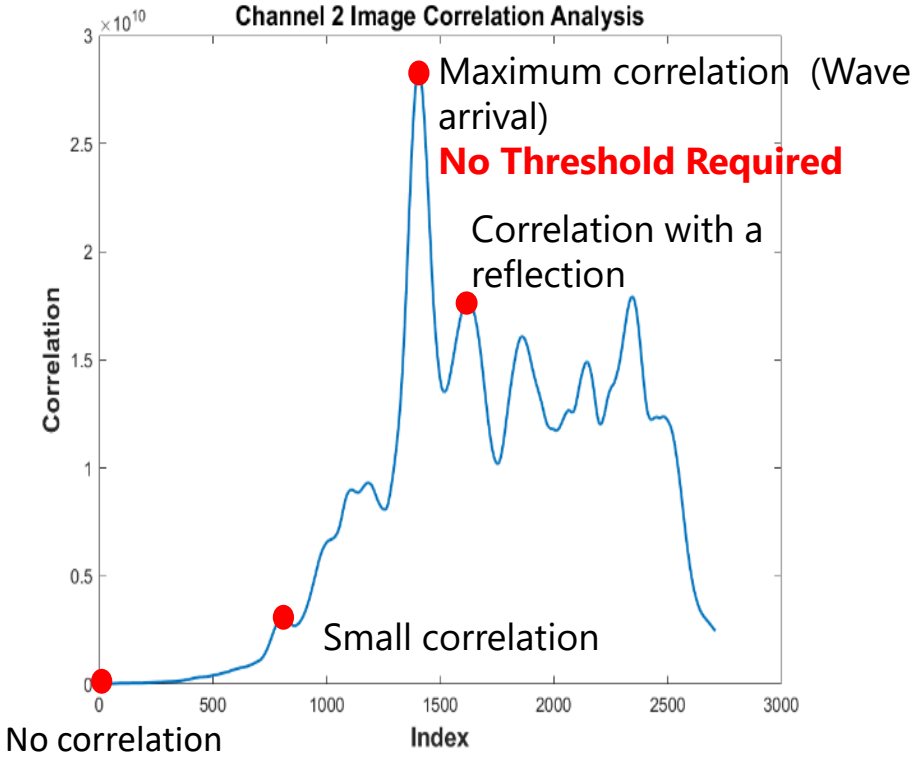
Create image of waveform using the wavelet transform (Unknown face)



Computer correlates the two images

Turns the very complex waveform into a peak search to determine the signal content with a high degree of accuracy

This is the new idea



Objectives

- Define, develop, and demonstrate the technical feasibility of an active Ultrasonic Mode Imaging (UMI) system:
  - For onboard inspection of metallic plate structures with penetrations (holes). E.g., partially accessible tank tops
  - Function in hard to access, coated or insulated structures
  - Identify areas of corrosion and plate thinning in accordance with Planned Maintenance and “Corrosion Control Assessment and Maintenance Manual” (CCAMM) inspections.
- Advance TRL of the UMI system
  - From a TRL 4 to a TRL 5.

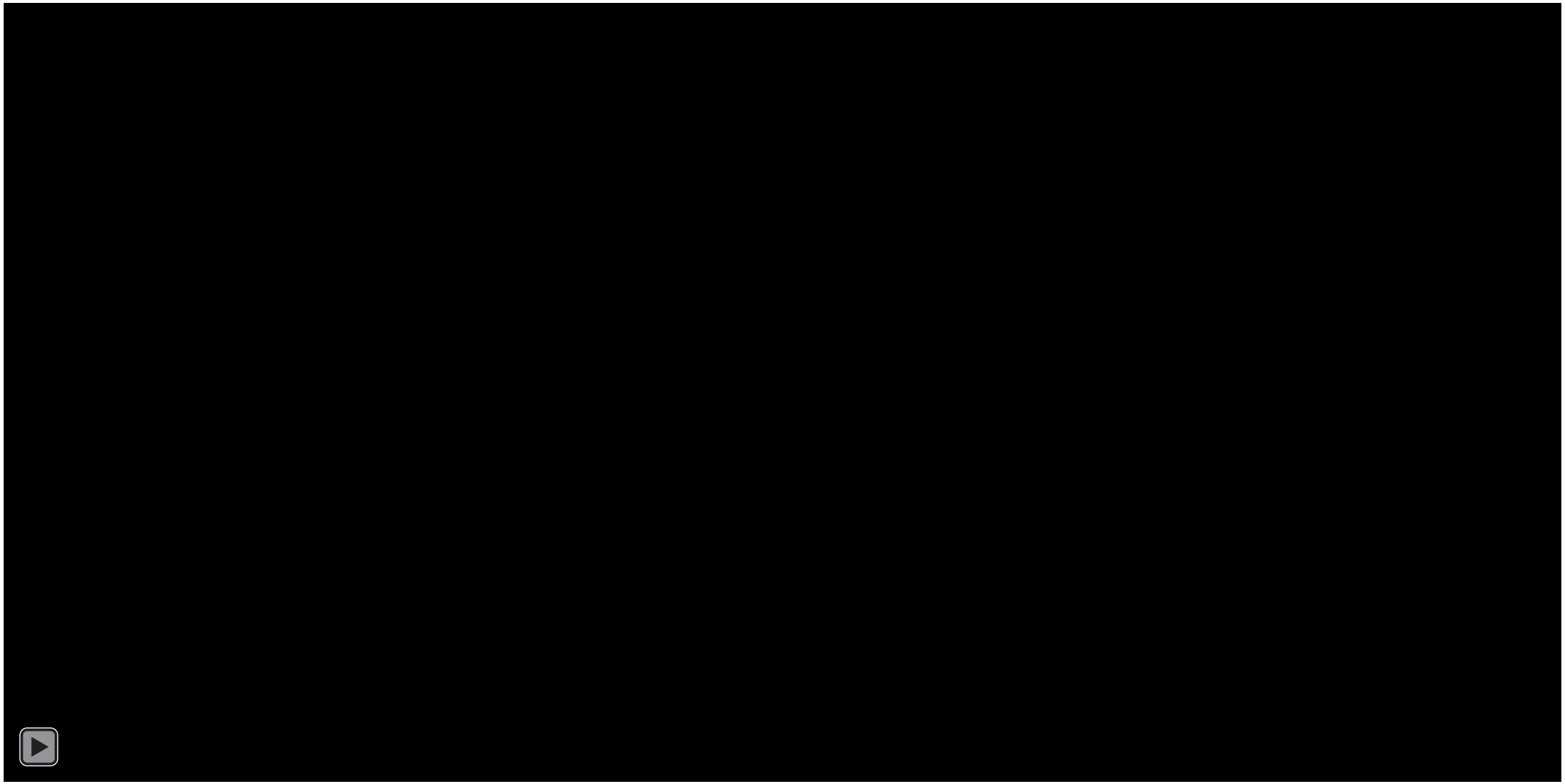
Project Goals

- Model how the penetration(s) affect the wave propagation
- How to modify our UMI technology to work with penetrations in plates
- Develop concepts for user interface software for the system to address penetrations.
- Conduct field tests at the shipyard to demonstrate the ability to locate defects in plate and plate-like structures.

Technical Progress – Wave Simulation

- **Task:** Perform Finite Element Analysis (FEA) using EFIT to simulate the effects of penetrations and thinning on plates
- Compare to data from the plate
- Progress – 80% complete.

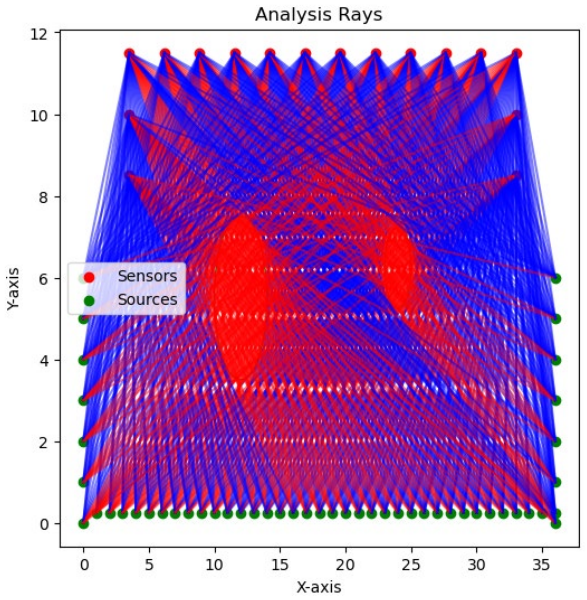
Video of FEA Waveform Simulation



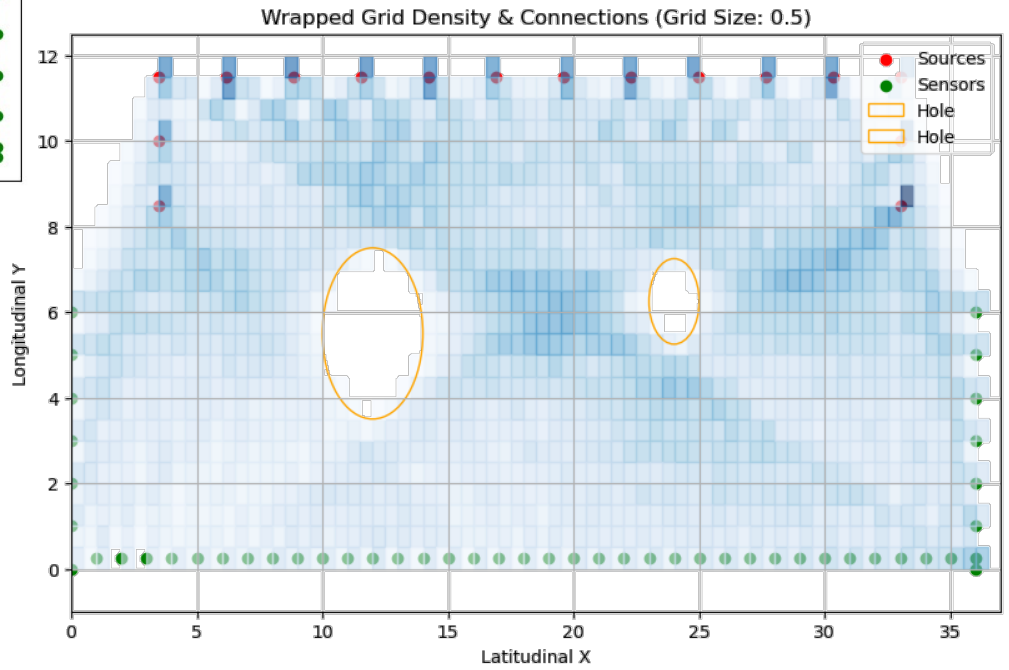
Technical Progress - Software

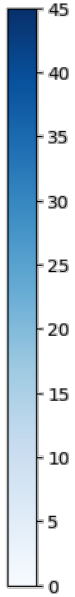
- **Task:** Software User Interface Conceptual Definition
  - User can define plate size
  - User can select penetration location and size
  - User can select source and sensor geometry
  - User can see scan coverage
- Progress – 90% complete.

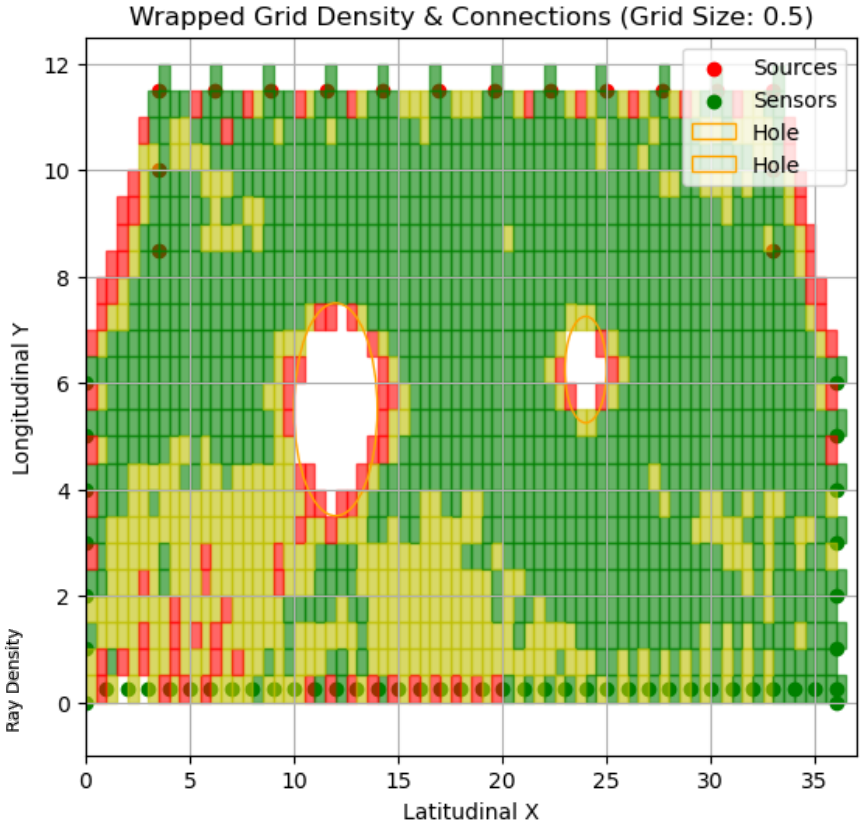
Initial Demonstration of Rays Around Holes



Simulated Rays
Red – not used in analysis
Blue – used in analysis







Plots showing only rays that are used in the analysis

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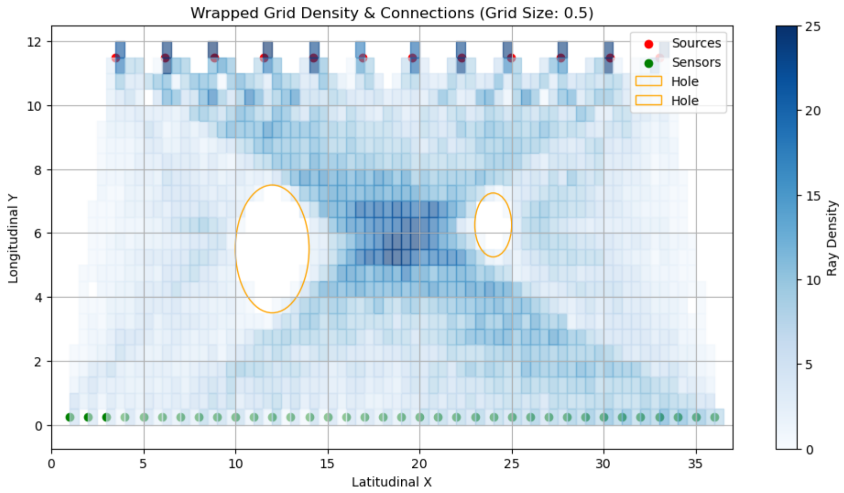
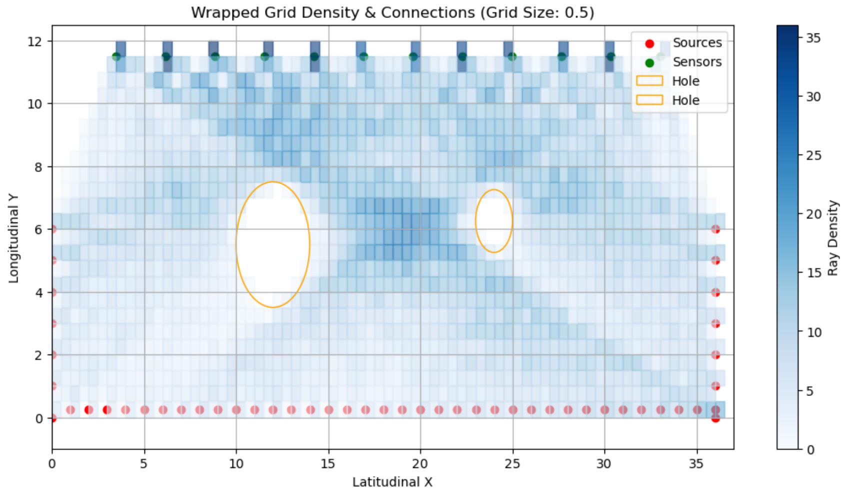
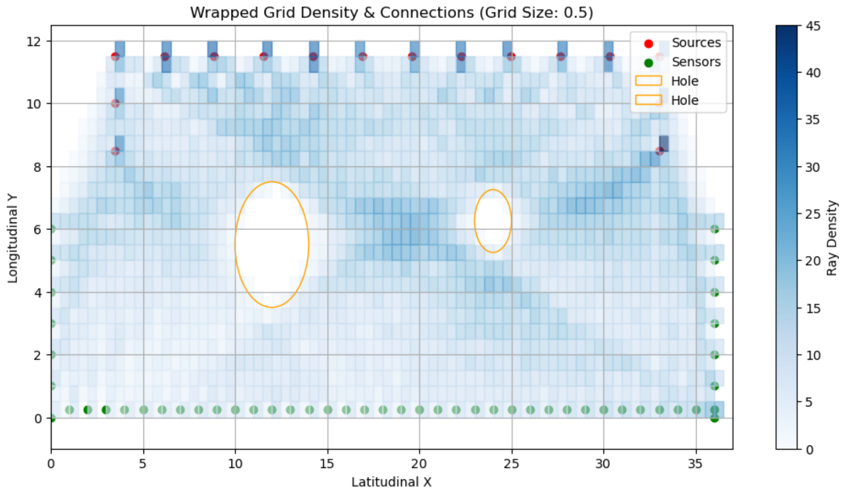
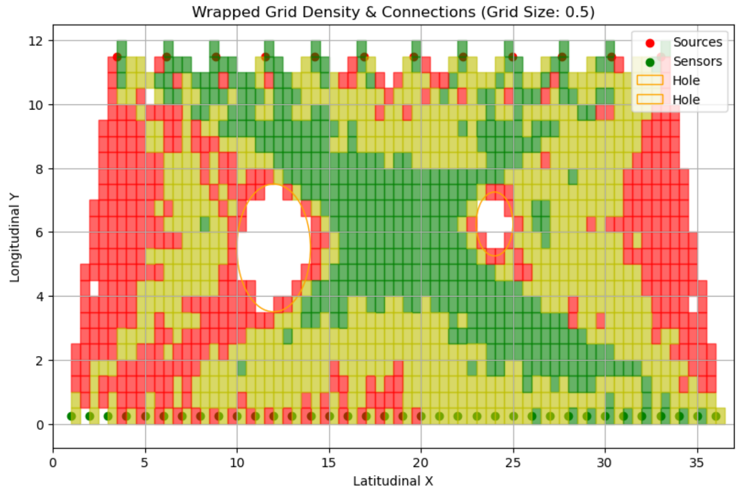
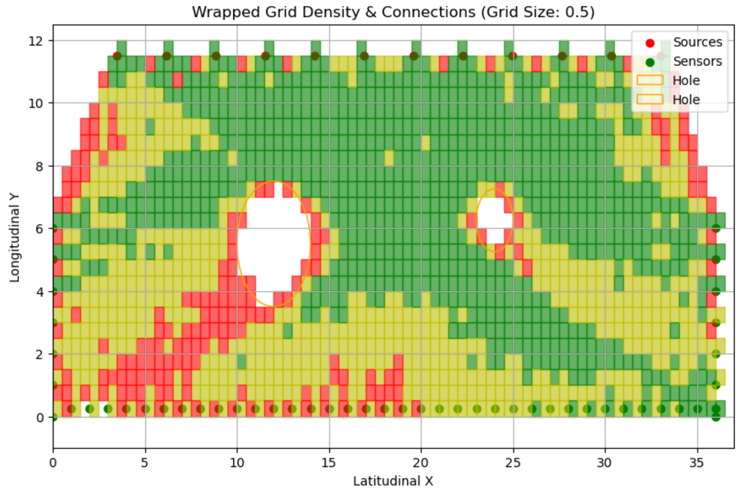
Results for Different Array Configurations

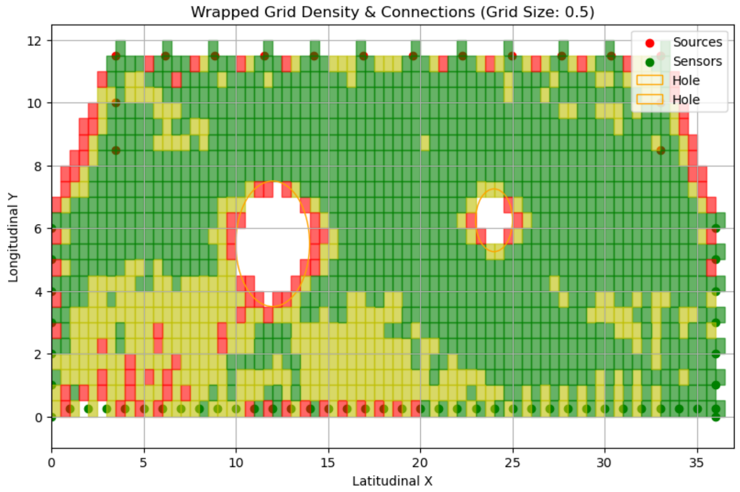








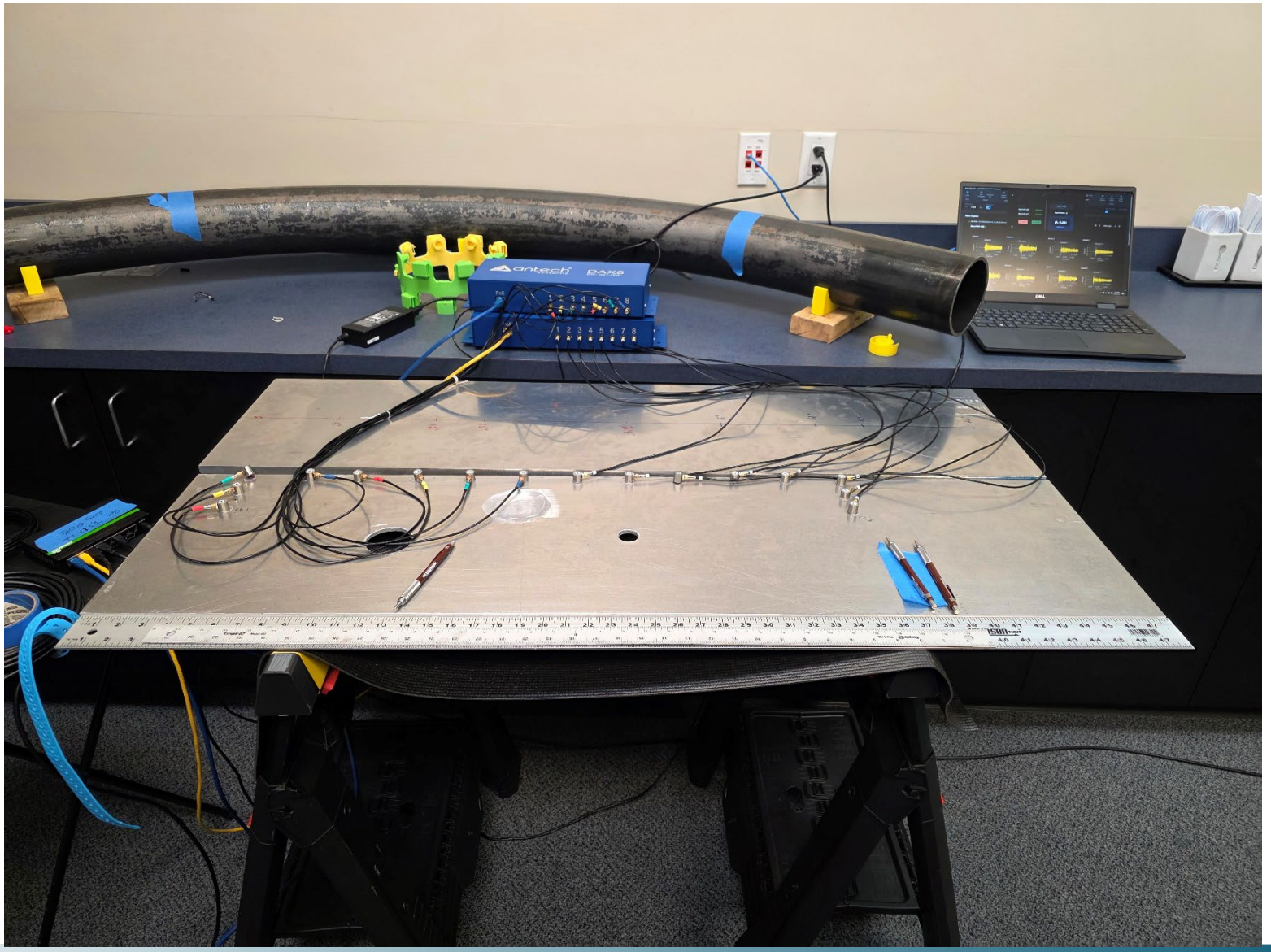




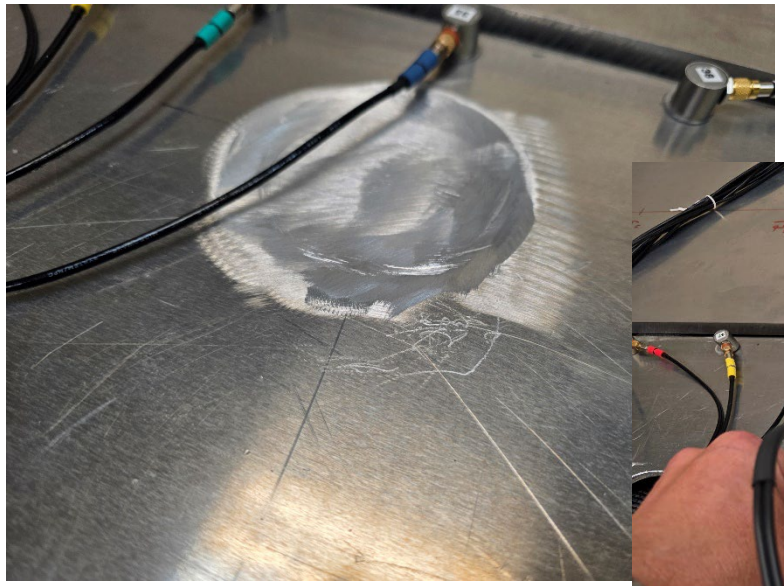
Technical Progress - Testing

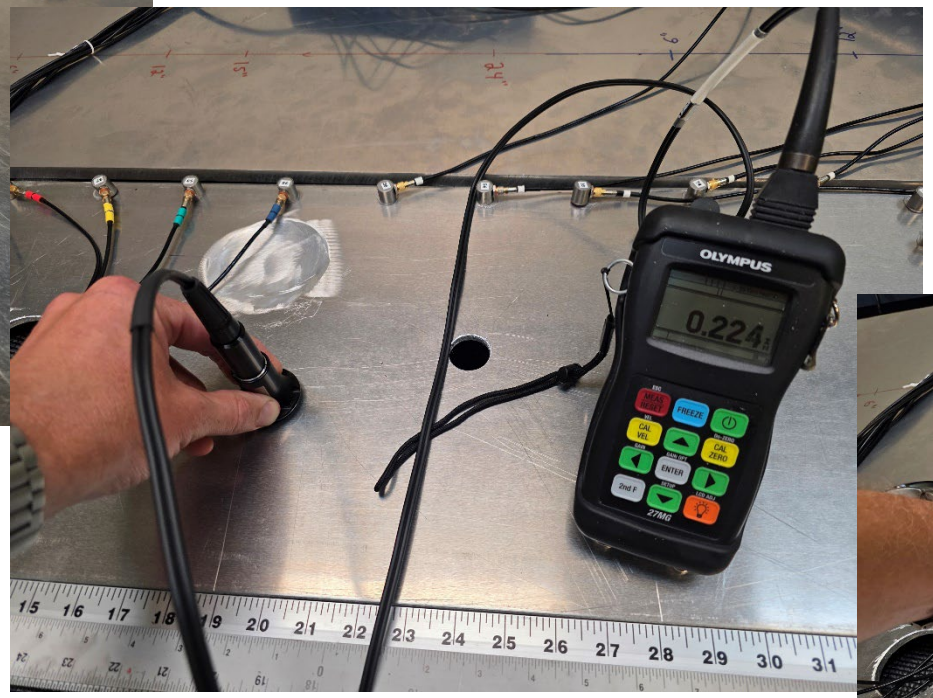
- **Task:** Testing
  - Standard pencil lead breaks (ASTM E 976) were used with 16 quarter inch sensors connected to 2 DAX-8 boards.
  - Tests were conducted on a 1-foot x 4-foot x ¼-inch plate to see the effects of the penetrations on the tomography. Geometries were:
    - No holes in the plate
    - Single 1-inch hole in the plate
    - Two holes, 1-inch and a 2-inch hole in the plate
    - Two holes with a thinned area
  - NNSY access has been set up, and visits scheduled
- Progress – 40% complete.

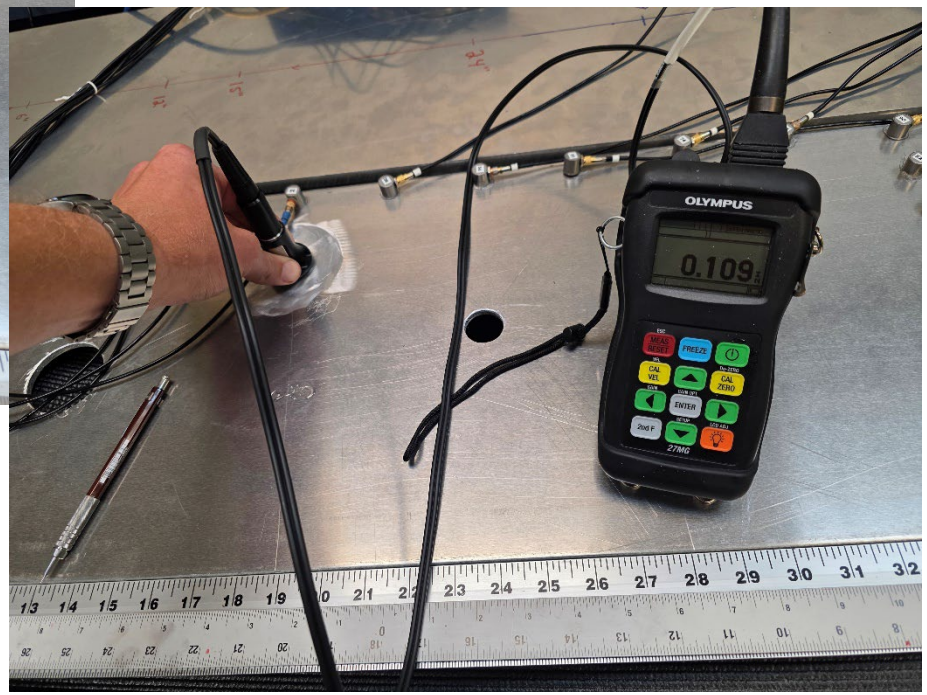
Test Setup



UT Flaw Measurement

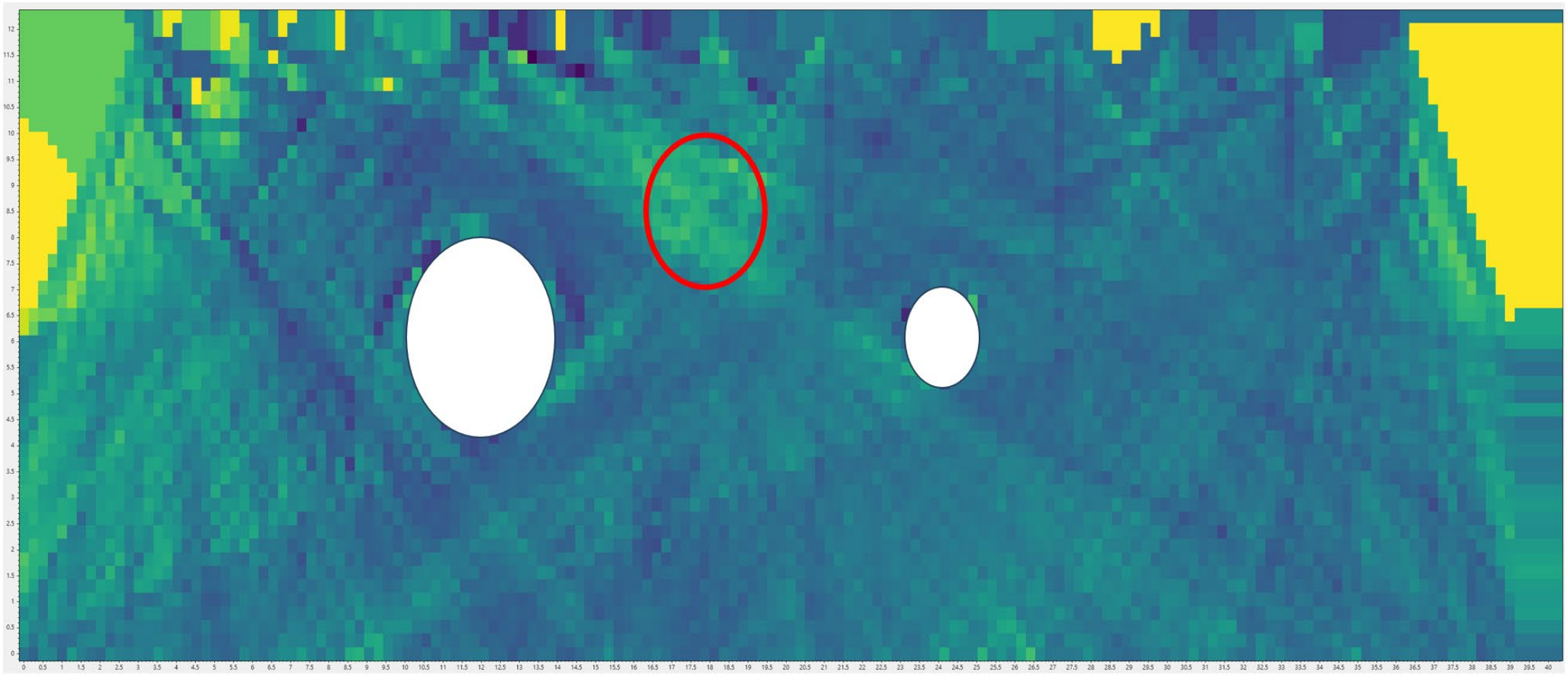






Tomography from Plate

Hole Beams Removed, Flaw highlighted

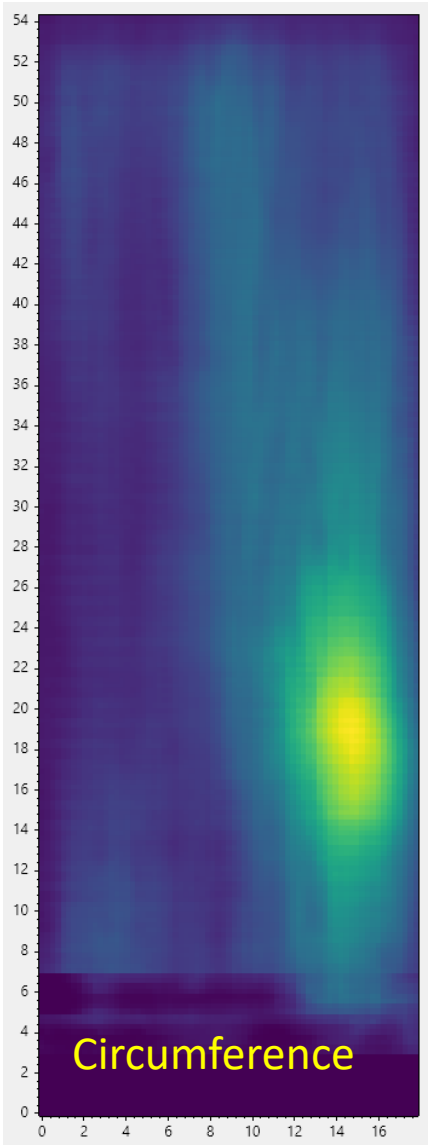


Tomography

- Flaw ground into pipe
- 3x5 inch
- 30% wall loss
- AI enhanced imaging of scan

Pipe

Tomography



Near-Term Plans

- Complete the FEA modelling work
  - Wavelets from simulation data and compare to dispersion curves
- Conduct field tests
- Modify analysis as necessary based on field tests

Questions?

steve.ziola@antechsystems.com

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