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Approaches to Ultrasonic Inspection of Marine Structures

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Engineering and Sensing for Structural Integrity

Outline

- Introduction to U.S. Navy SBIR project
- Guided Wave Ultrasound
  - Fundamentals, Benefits & Applications
- Phased Array Ultrasound
  - Principles, Advantages & Limitations
- The way forward
- Summary

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Introduction

- SBIR Topic: Improved Approaches to Nondestructively Test Marine Aluminum Structures
- Topic # N06-132
- Contract # N00024-08-C-4166
- Status: Currently in 12 month Phase II with option to enter a second 12 month Phase II starting December 2009

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Guided Wave UT

- Waves whose propagation characteristics depend on structural boundaries such as those in plates, tubes, rods, and embedded layers.
- The ultrasonic energy fills the entire thickness of the structure.
- Can inspect structures from a distance as well.

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Guided Waves

- Commercial guided wave (GW) technology has been around for about a decade
- Research on GW dates back over 50 years
- GW are used as a rapid screening technology (1/10th the time and cost of conventional UT and other NDT techniques)
- R&D is closing the gap between guided wave and conventional NDT characterization/sizing capabilities

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Guided Waves

- Guided waves are a cost effective method for screening large areas for corrosion, wall loss and defects
  - GW may be used to monitor ship hulls for damage, sizing damage, and remote detection of corrosion and hull thinning.
  - Weld inspection in thin plate – ¼” or 6 mm and less
  - Cost-effective screening of on-board piping and tubing

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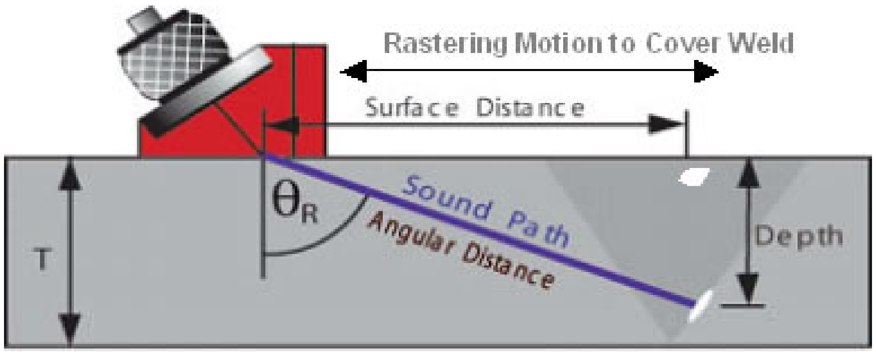
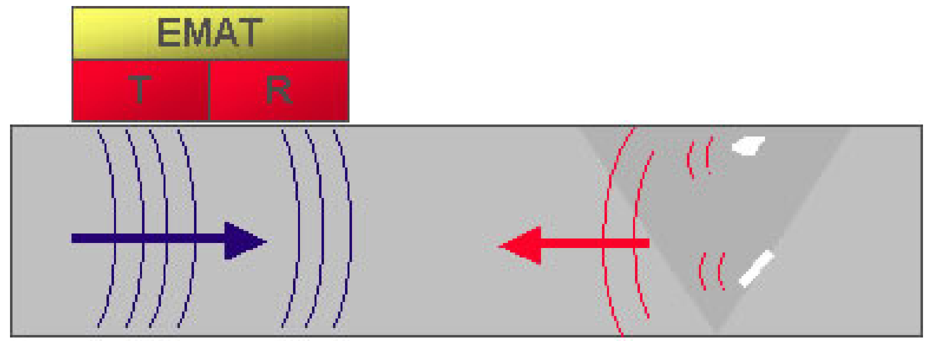
Conventional UT vs. EMAT



θ_R = Angle of Refraction
T = Material Thickness
Surface Distance = $\sin\theta_R$ x Sound Path
Depth (1^{st} Leg) = $\cos\theta_R$ x Sound Path

Shear Vertical Wave



- Shear horizontal wave at 90°
- Full thickness penetration
- No need for rastering motion
- Normalization of the signal
- Capable of penetrating dendritic structures

Shear Horizontal Wave

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Long Range Ultrasonic Testing using EMAT

- Advantages
  - No couplant required (vis-à-vis Conventional UT)
  - Insensitive to surface conditions
  - Ease in probe deployment
  - Unique wave modes
  - High scan speeds
  - High temperature (adaptable)
  - Very high resolution for thinner gages
  - Easy automated inspection

Ship Hull Corrosion

- Ship hulls may be screened rapidly to detect areas with measurable corrosion at 1/10 the time cost.
- An entire hull plate, or a larger area, may be inspected using a single scan line.
- Conventional UT thickness measurements require point-by-point scanning.
- GW UT launches wave up and down the hull from a single sensor position
- Submerged hulls may be inspected from the above the water line.

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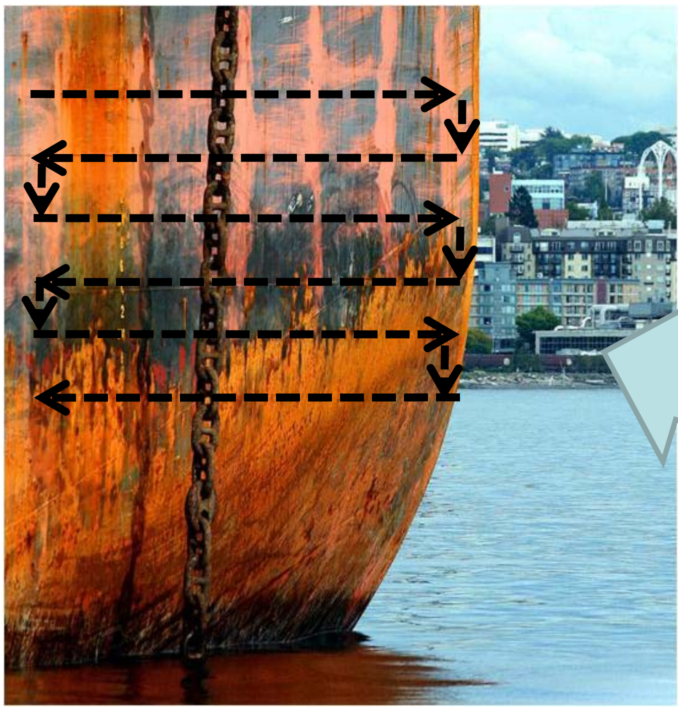
Ship Hull Corrosion

- Conventional UT scanning is point-by-point , 2-D scanning path
- 100 % access to ship hull is required for complete inspection coverage

Conventional UT scanning is point-by-point , 2-D scanning path



A scanning robot is installed on ship and physically and used to scan hull point by point.   Scanner does not operate underwater.

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Ship Hull Corrosion

- Guided wave UT requires scanning in only 1-dimension
- Multiple plates may be inspected from a single sensor location
- Submerged hulls may be inspected from above the water line

Scanning direction

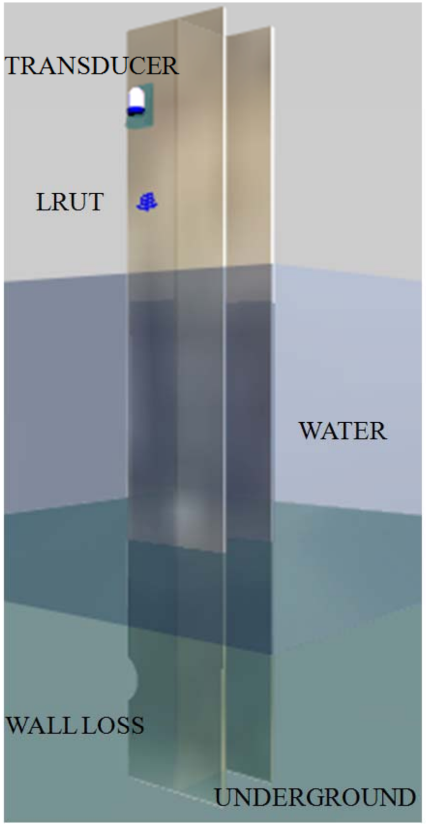
Corrosion is remotely detected

Wave propagation direction

Ship Hull Corrosion

- Technology is being adapted from underwater bridge pile inspection

H-PILE



Long range ultrasound (LRUT)

- Travels tens of feet in rail, pipelines, H-pile flange, and webs.
- Shear horizontal waves (SH-waves) are an unique family of waves that are insensitive to water and pile surface coatings.
- SH-waves waves are reflected back from underwater wall loss

Pipeline and Tubing Inspection

- Pipelines may be screened from a single sensor position
  - Up to 500 feet of above ground piping may be inspected from a single sensor position
  - 30 – 90 feet of buried pipe may be inspected from a single sensor position.

Pipeline and Tubing Inspection

- Complex piping systems
  - 90 elbows
  - 180 elbows
  - Multiple elbows
  - Multiple welds

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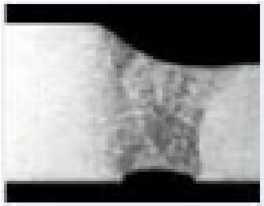
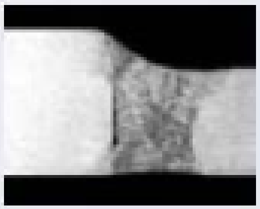
Sample weld defects detected by EMATs



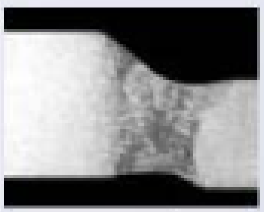
Lack of Penetration

Minimum 10% depth by 0.2" length



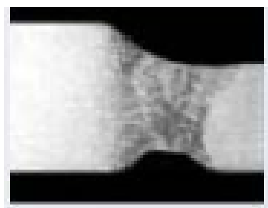
Lack of Fusion

Minimum 10% depth by 0.2" length



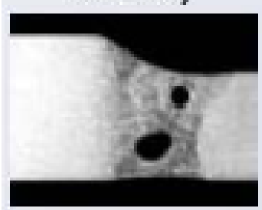
Mismatch

Minimum 10% depth by 0.2" length



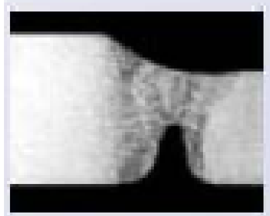
Concavity

Minimum 10% depth by 0.2" length



Porosity

Minimum 0.012" diameter by 10% through thickness



Pinhole

Minimum 0.012" diameter by 10% through thickness

Weld Inspection Standards

- ABS Guide for Nondestructive Inspection of Hull Welds 2002
- MILSTD - 2035A Nondestructive Testing Acceptance Criteria.
- These documents were used as guidelines for minimum inspection sensitivity.
- Specimens were designed and tested to evaluate performance
- Calibration reflector holes to be 1.2 mm (0.047 (3/64) in.) diameter x 38 mm (1.5 in.) deep
- Standards were written for steel welds in thick plate

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Weld Inspection Standards

- Current available standards are for steel structures (> ¼” thick)
- No standards available for thin marine aluminum structures
- Visual inspection
- Need inspection standards and tolerance for thin Aluminum structures

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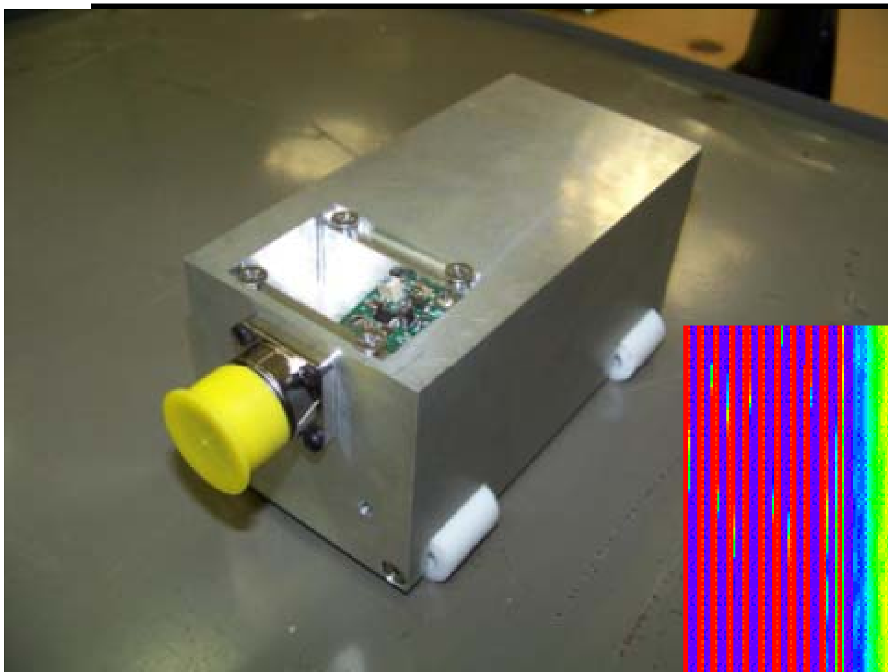
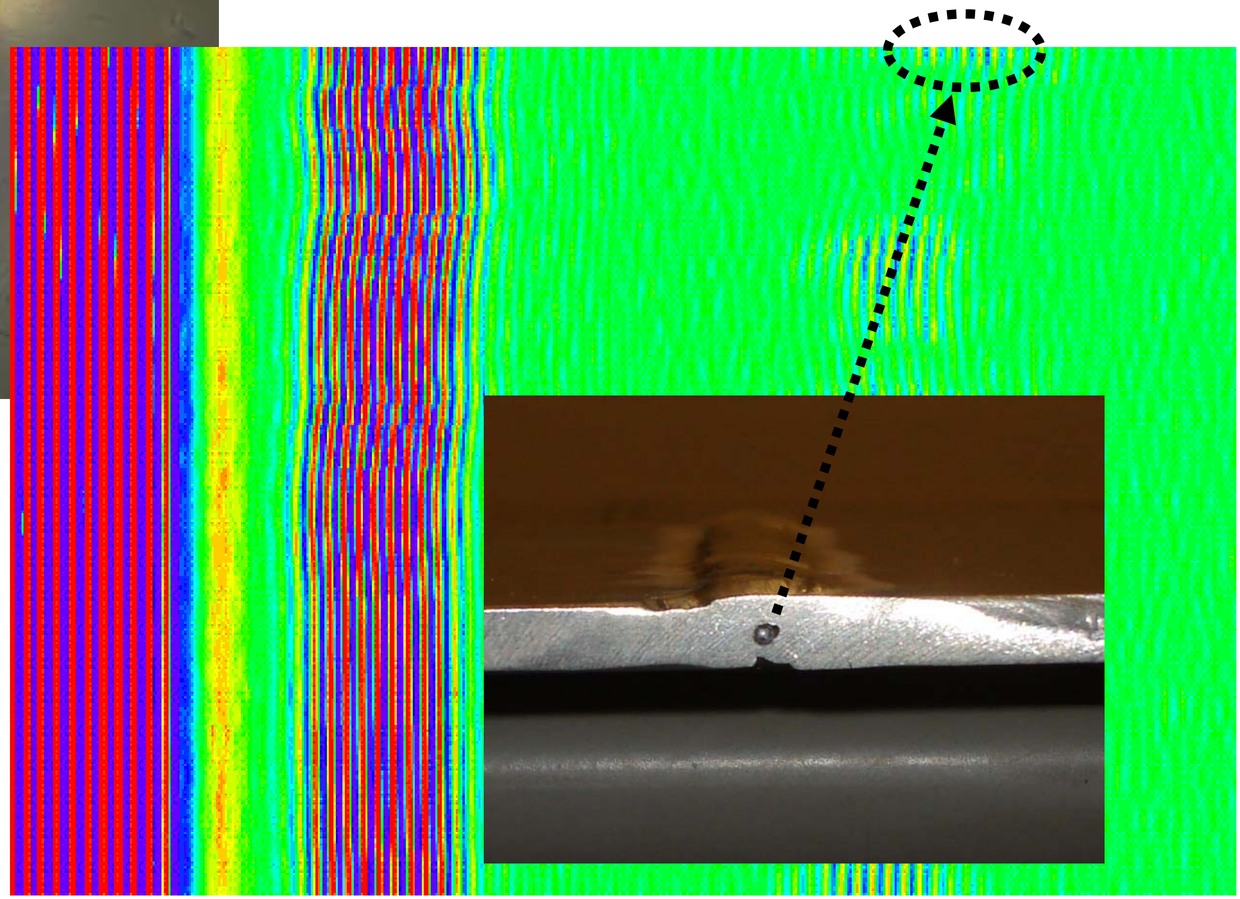
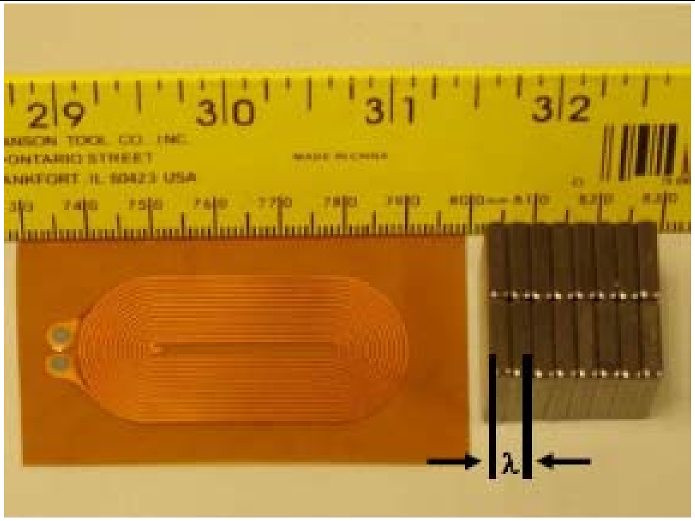
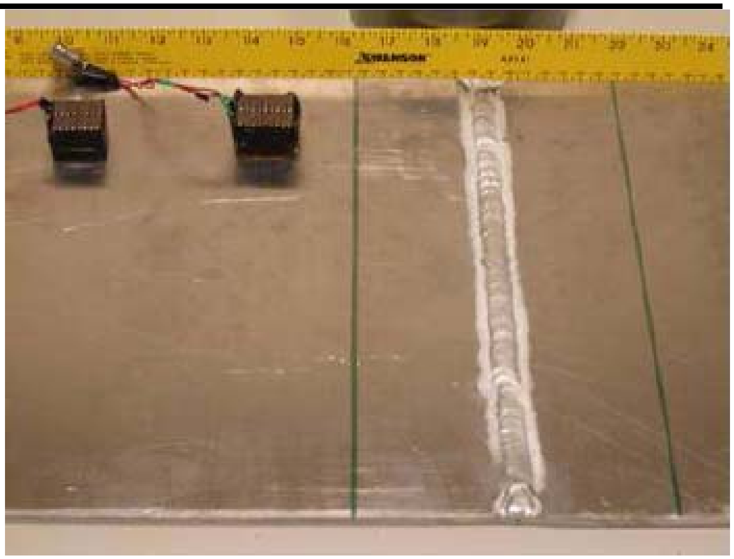
Guided Wave UT Scanner and Display

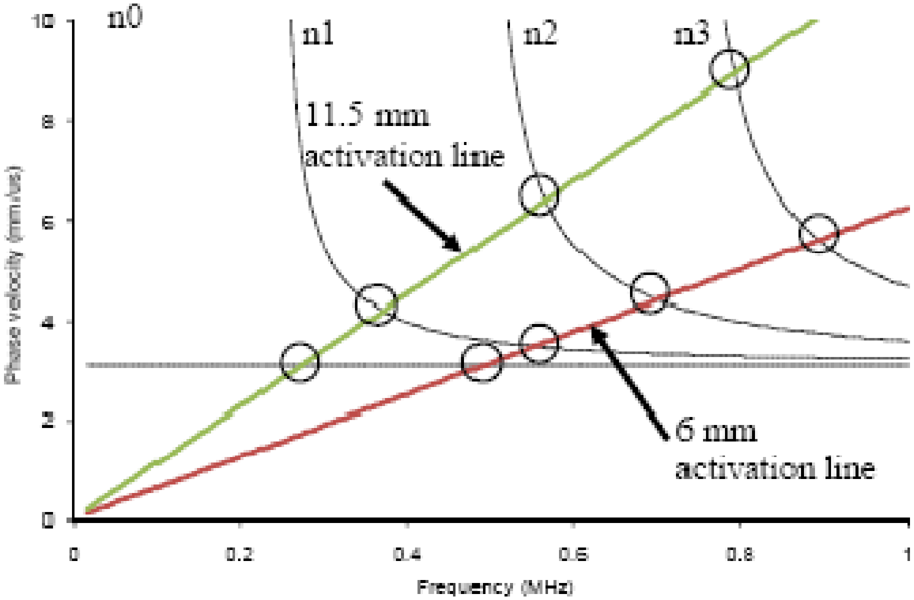




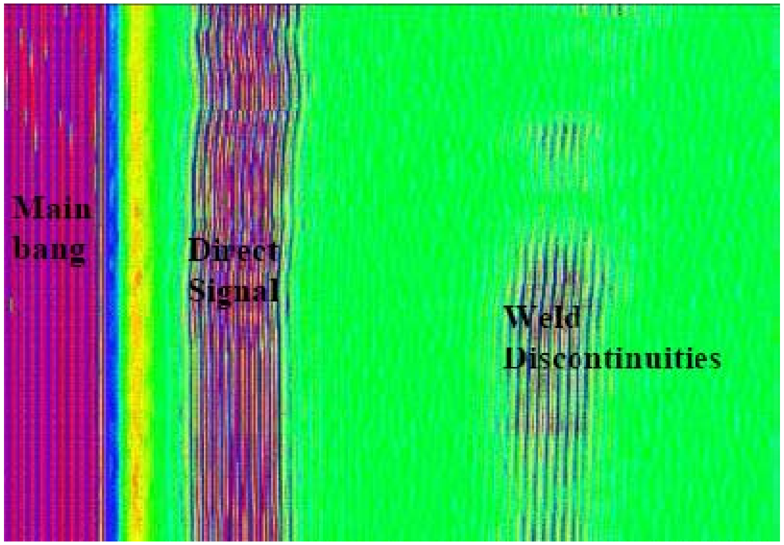
SH EMAT Inspection of Butt Welds



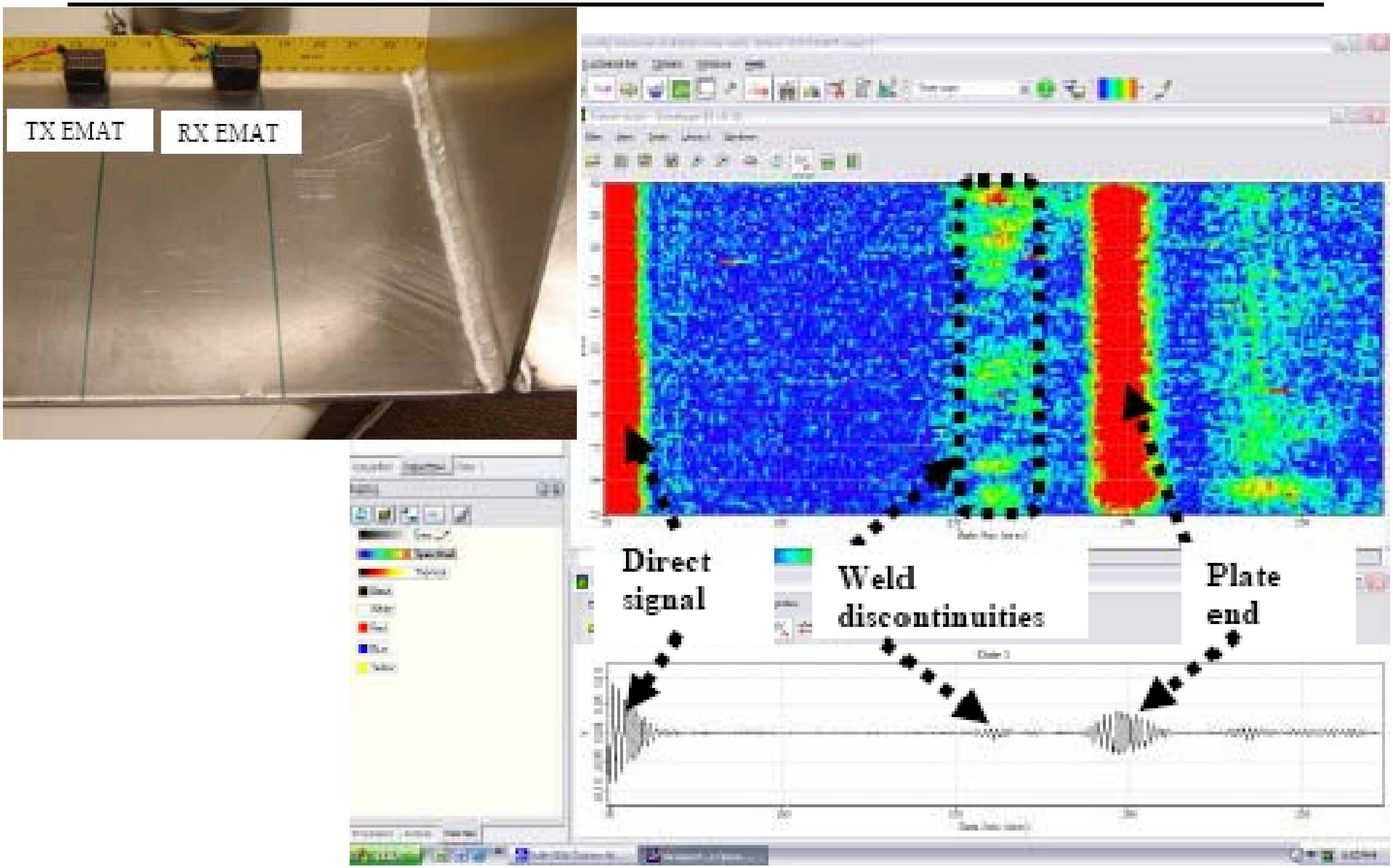




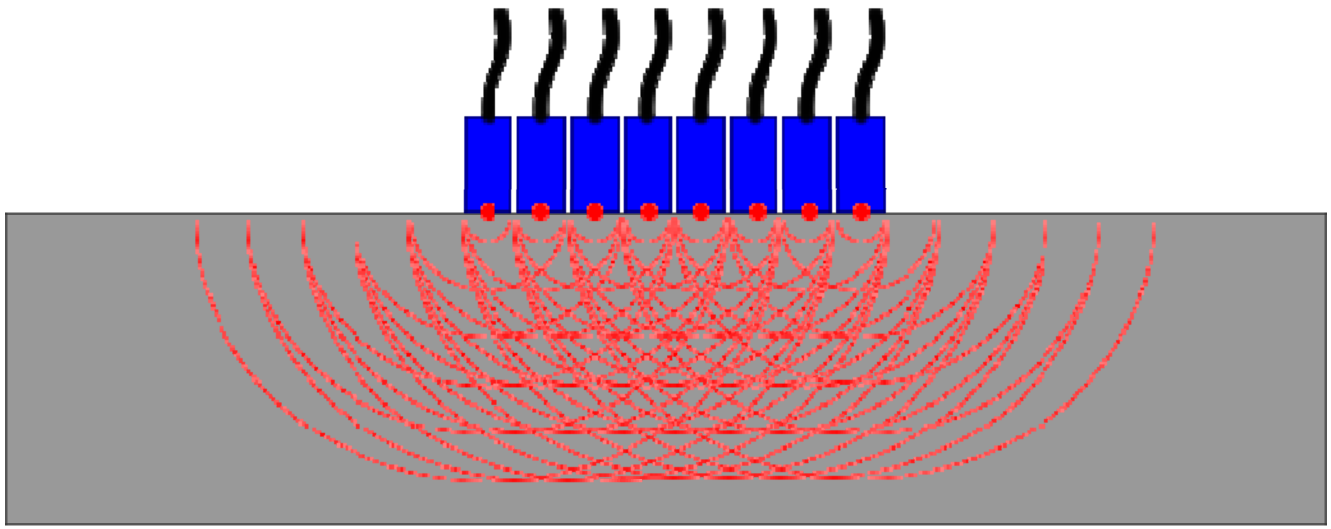
n0 mode; 6 mm wavelength, 0.52 MHz



SH EMAT Inspection of Flange Welds



Phased Array UT Schematic



Major benefits of PAUT

- Faster – linear array PAUT is an order of magnitude faster than conventional UT
- Flexibility – same single array can inspect different components with different inspection patterns
- Complex test material shapes
- Small array size – ideal for inspections with space limitations
- Mechanical reliability – less moving parts of the probe
- Detection of defects of various orientations

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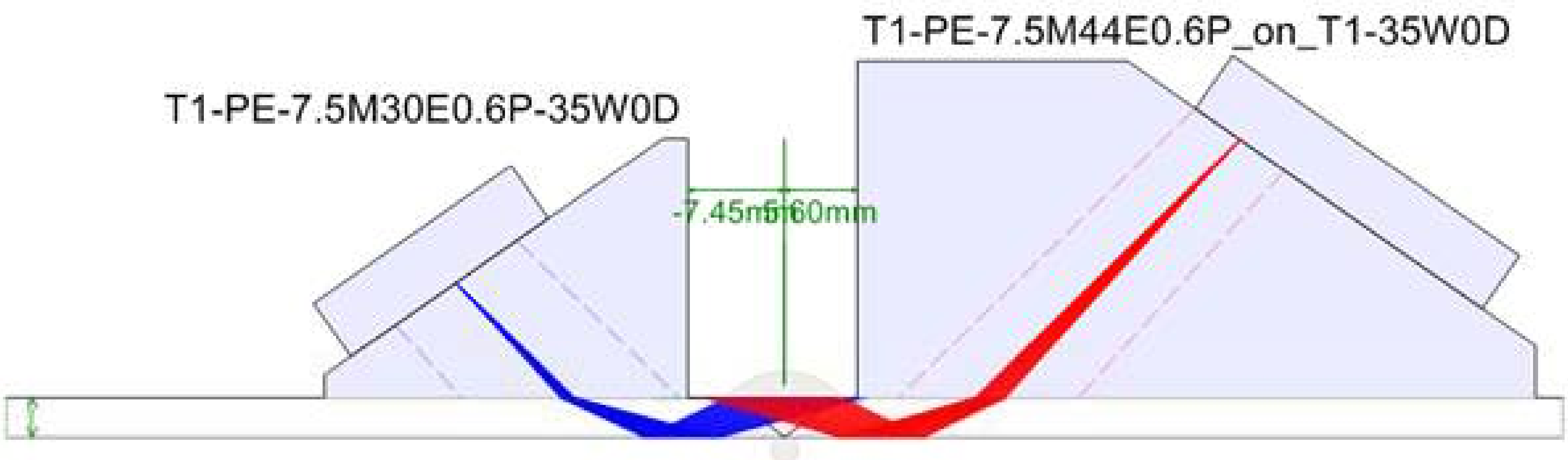
Limitations of PAUT

- For thin structures, PAUT is not very effective as there are blind spots



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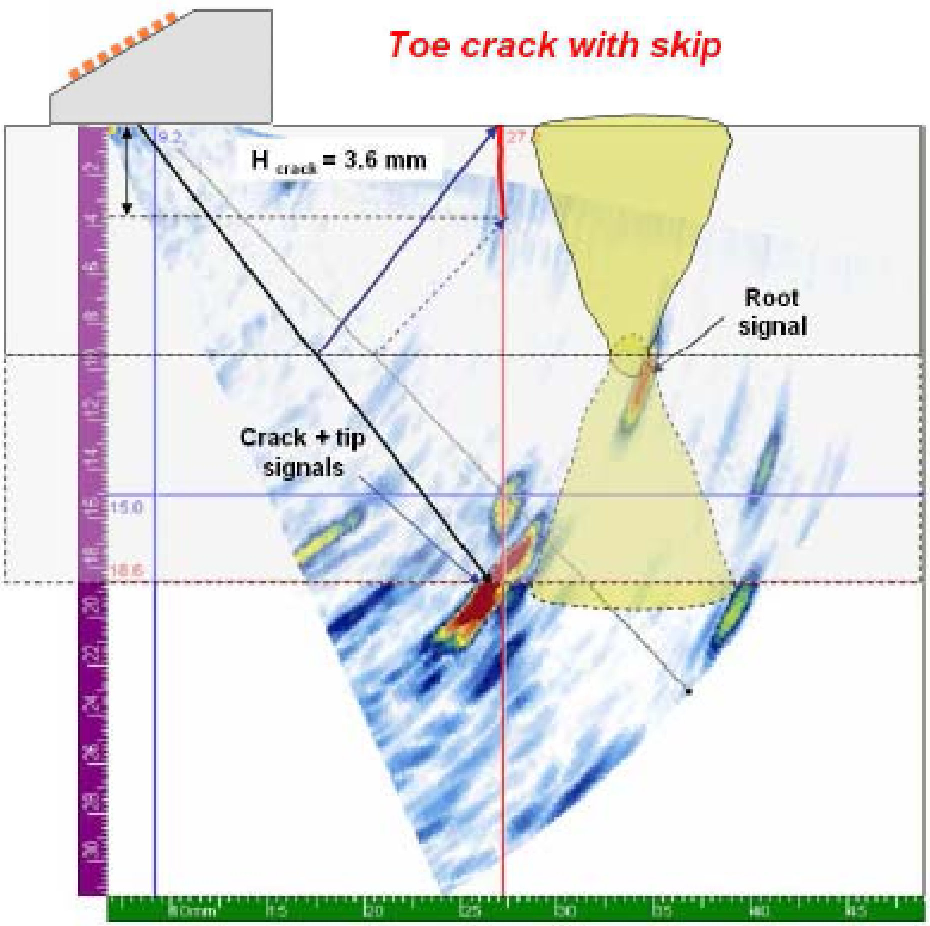
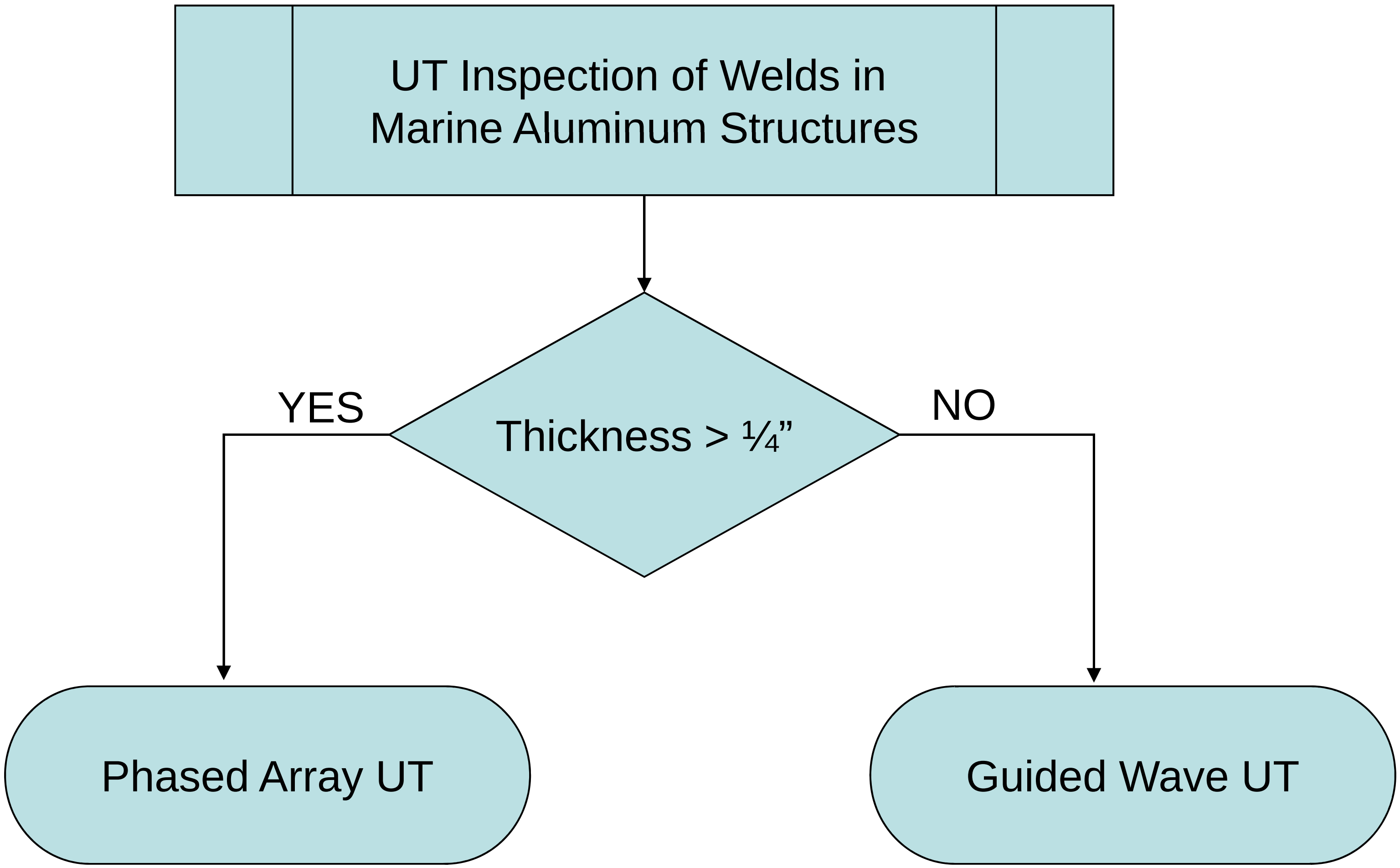
Limitations of PAUT



- Difficult to interpret signals; Harder to size the defect; Skilled operator required

The Way Forward



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Summary

- UT technique is here to stay
- However, there are applications where conventional UT is not applicable
- Guided Wave UT provides a viable and efficient alternative
  - Rapid
  - Non-contact
  - Thin structures (<0.25”)

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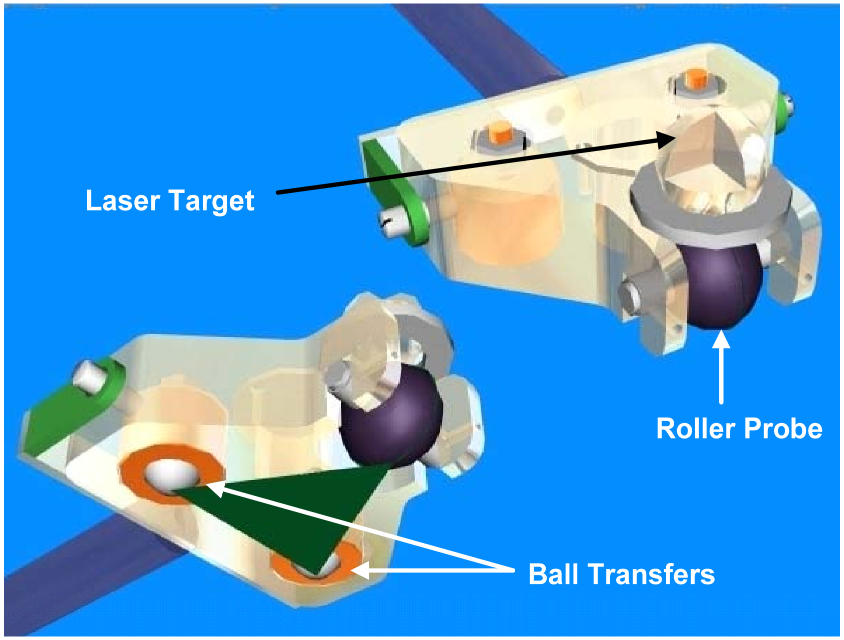
End-User Collaboration

- Looking for shipyard operators for field testing and feedback
- Need input on defect tolerances
- Apply our guided wave UT for any possible application
  - Weld inspection
  - Corrosion in ship hull
  - Tubing and pipe defects, corrosion
- Provide UT solutions (Conventional, PAUT and GWUT)

STACMOUSE

Submarine Wall Thickness and Circularity Measurement

- Integrated system for simultaneous submarine pressure hull thickness and circularity measurement
- *Laser tracker* technology for *circularity measurement*
- *Ultrasonic* testing instrumentation for *thickness measurement*
- Looking for feed back from submarine community



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STACMOUSE

- *Wireless communication* between the sensing systems and data acquisition hardware is also provided.
- STACMouse provides explicit geometric characterization data for analytical models and tracks corrosion wastage and other ultrasonic indications of the pressure-hull condition
- Laser tracker provides 3D coordinates with an accuracy of ±25.4 μm (0.001”) over a 70 m (230 foot) range
- UT software provides a complete data acquisition, interpretation and display capability