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Dynamic Classification with the Marine Towed Array

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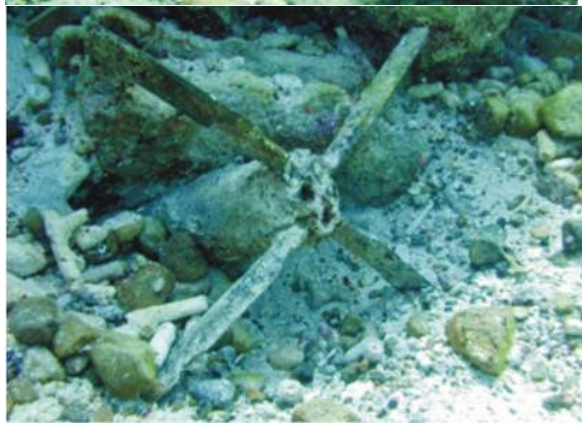
Outline

- Background
- Marine Towed Array
- Array design and testing
- Modeling results
- Fabrication and Installation
- Testing
- Conclusions

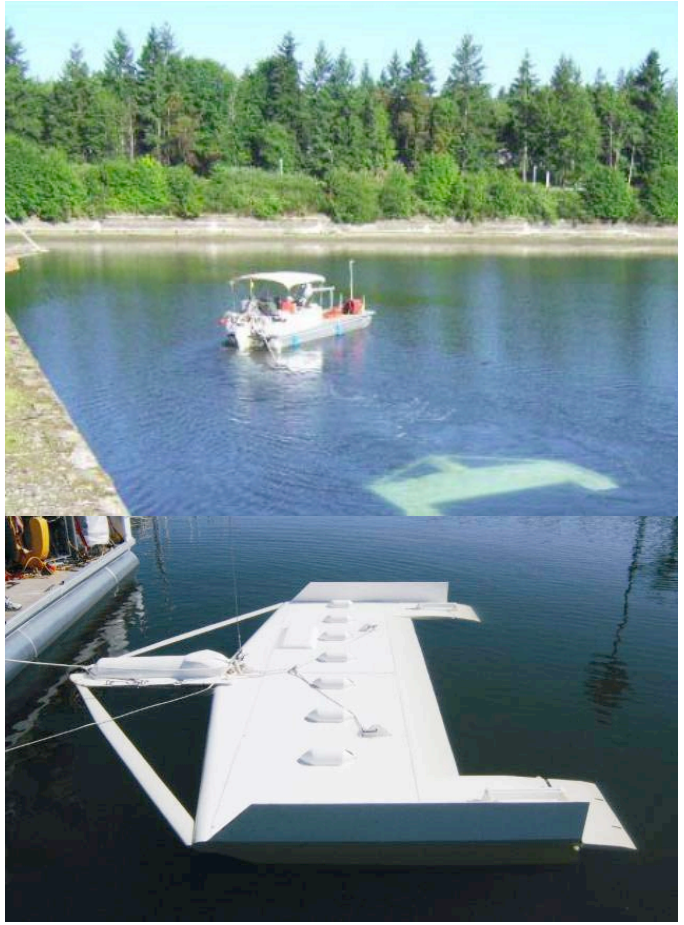
Background

- UXO – Land and underwater
- Adaptation of land-based UXO technology
- Systematic detection and classification limited
- Acoustic systems evolving for underwater UXO work



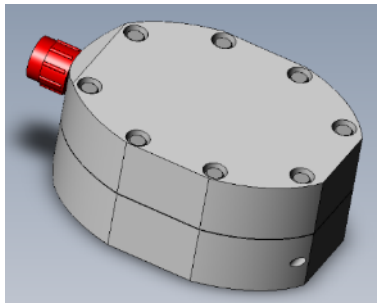
Marine Towed Array

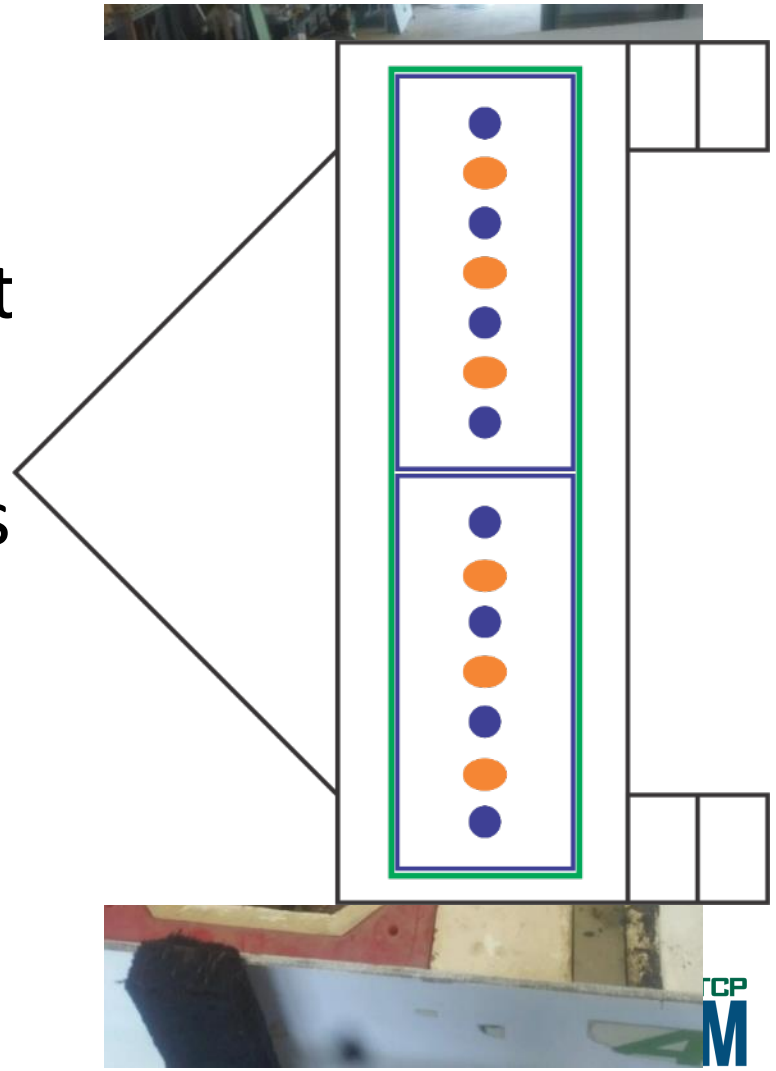
- Towed “Flying Wing” design
  - Development funded by SERDP/ESTCP
  - Dual-mode sensor array
    - Total-field magnetometers
    - EMI sensor array
- Successfully demonstrated under a range of conditions



Advanced EMI Array

- Remove existing transmitter and receiver loops
- Install 6 triaxial receiver cubes in a water-tight enclosures adapted from SERDP MR-1714
- Pressure vessel and cabling for the electronics provided by VIMS
- Advanced EMI electronics





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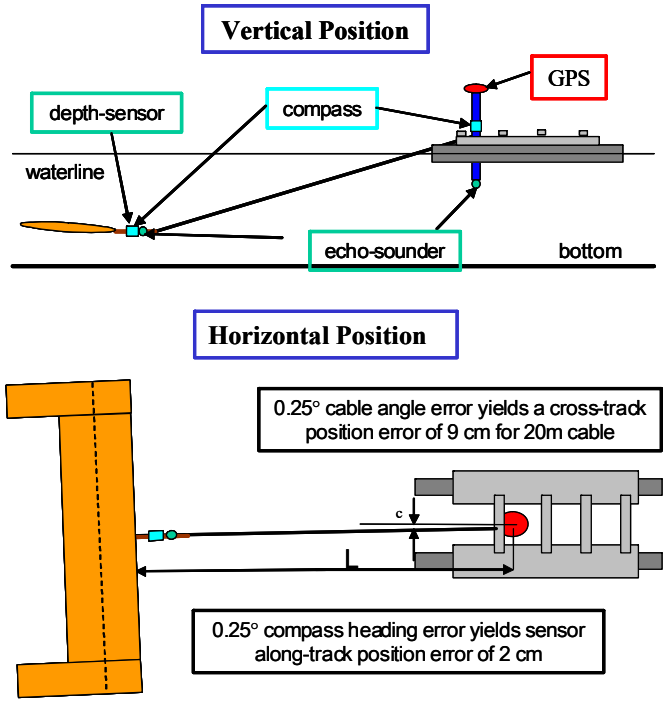
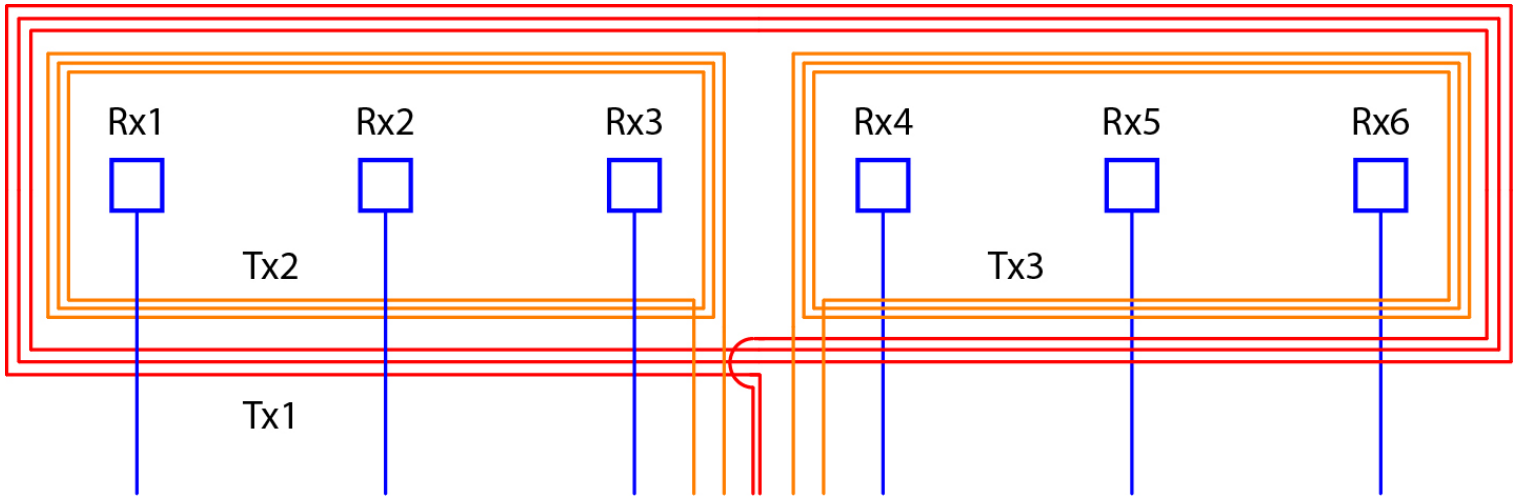
Magnetometer DAQ and Position Systems

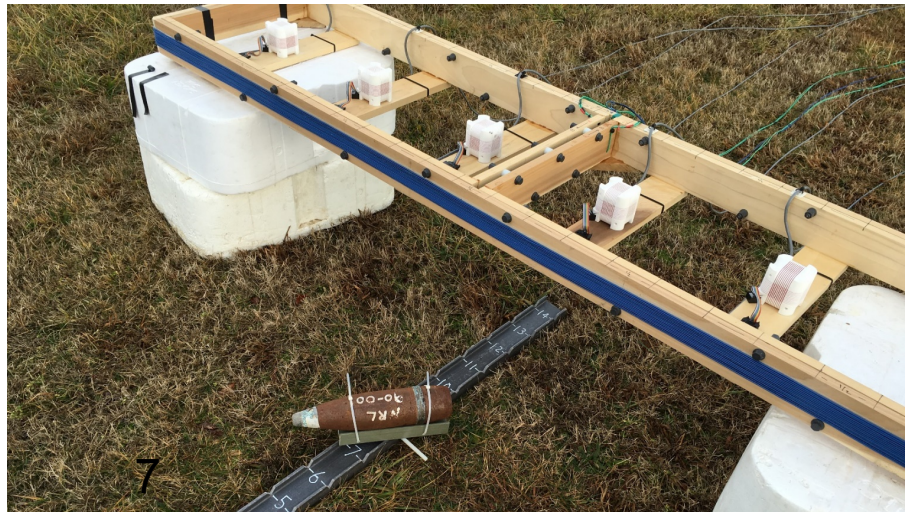
- No significant changes planned
  - DAQ – MagLog
  - GPS – dual-antenna configuration
  - IMU – tactical grade, on the wing
  - Tow cable angle measurement
  - Depth sounder, etc.



mini Marine Towed Array Design

- ½ scale, 3 Tx loops
- 6 triaxial Rx cubes
- Existing AGC electronics with channels added





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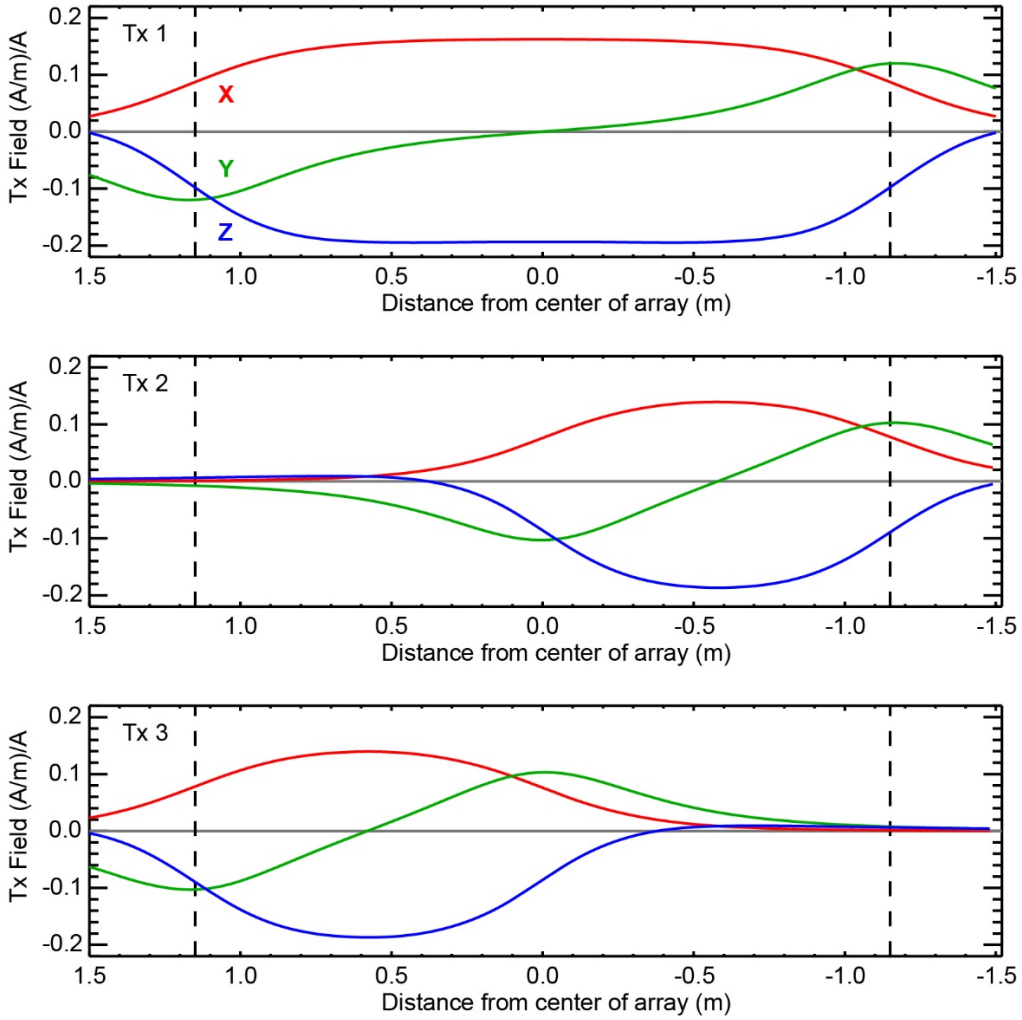
Primary Field Excitation

To collect AGC-class data, the target must be excited by primary fields in three orthogonal directions



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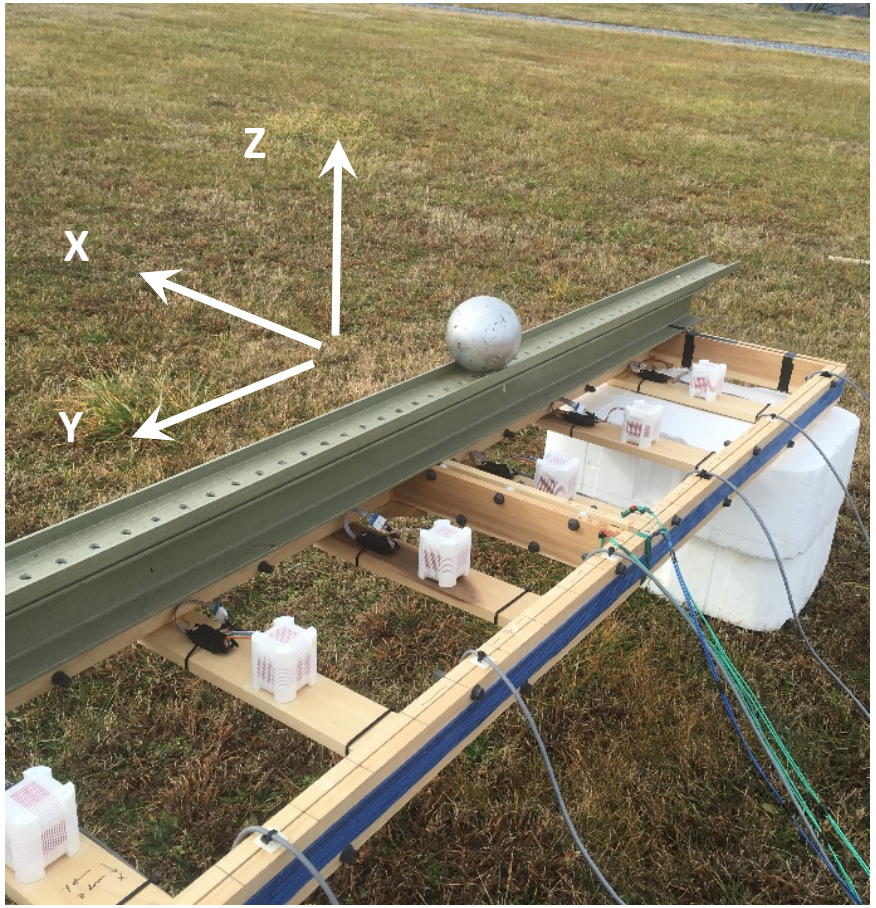
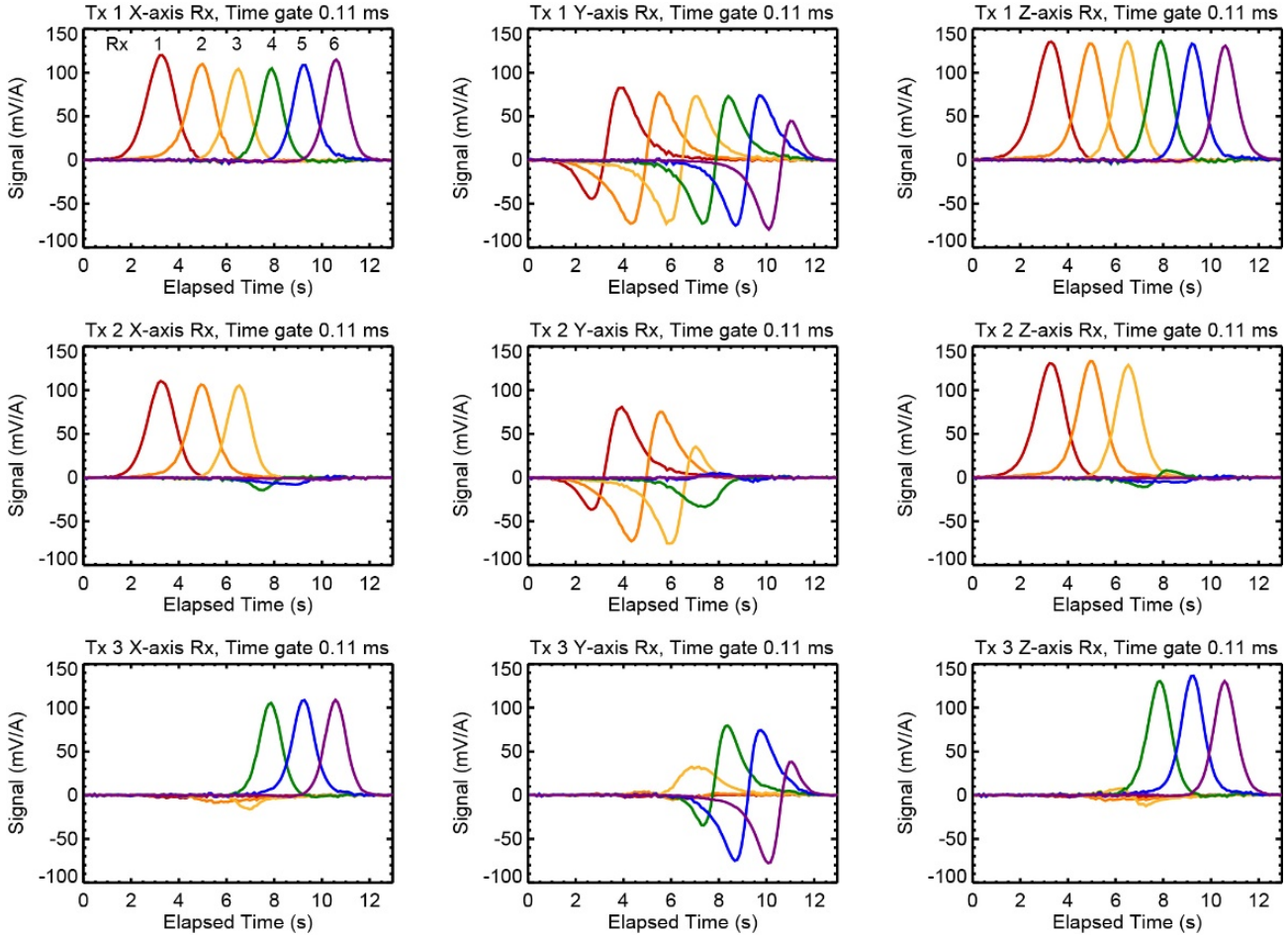
“Dynamic Data” Roll Test





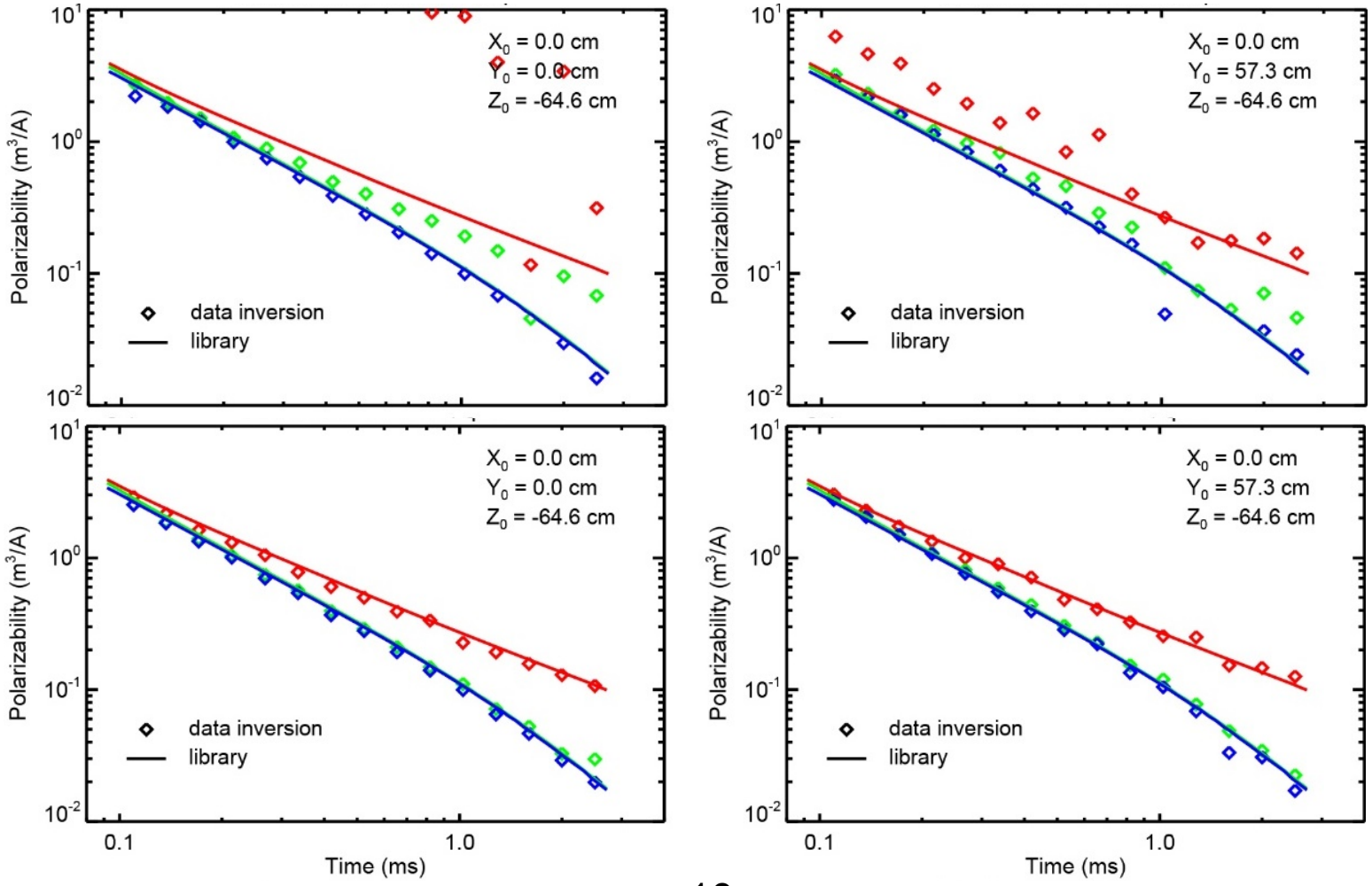
Classification Performance

Target under center of array

Target under center of inner loop (Tx2)

Outer Loop Only

Inner Loops Only



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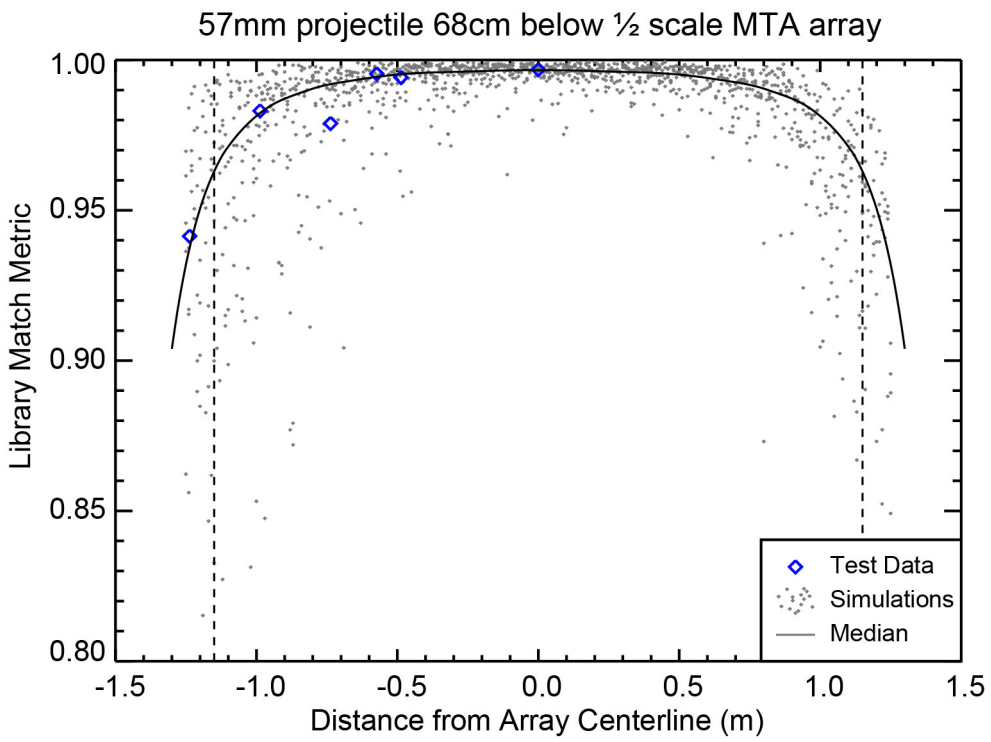
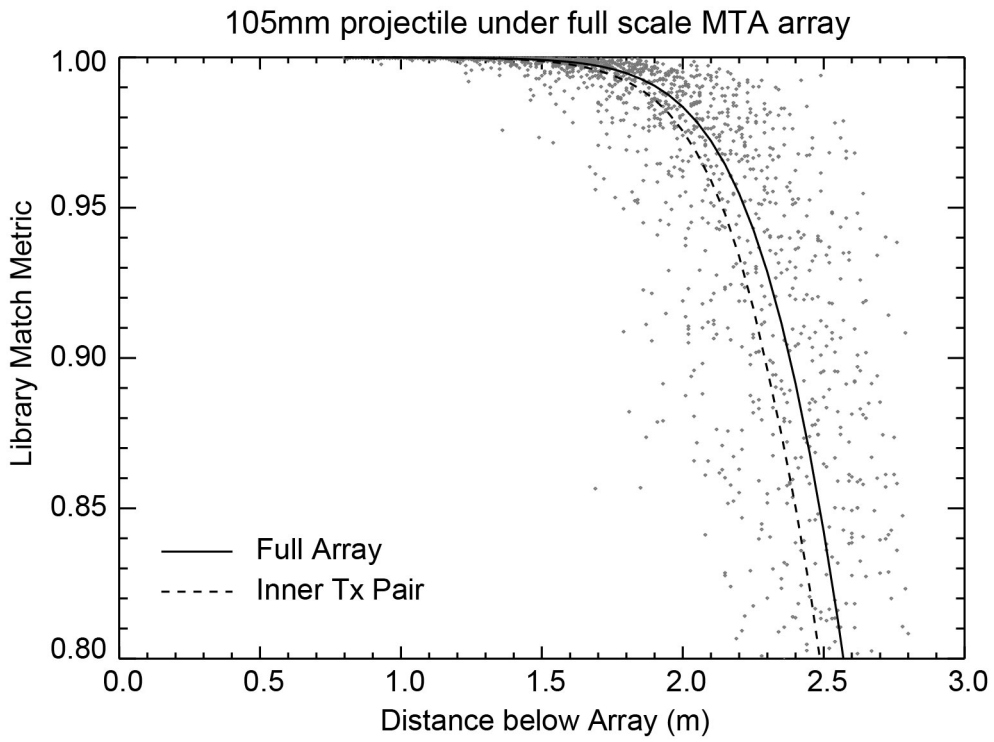
Modeling Results

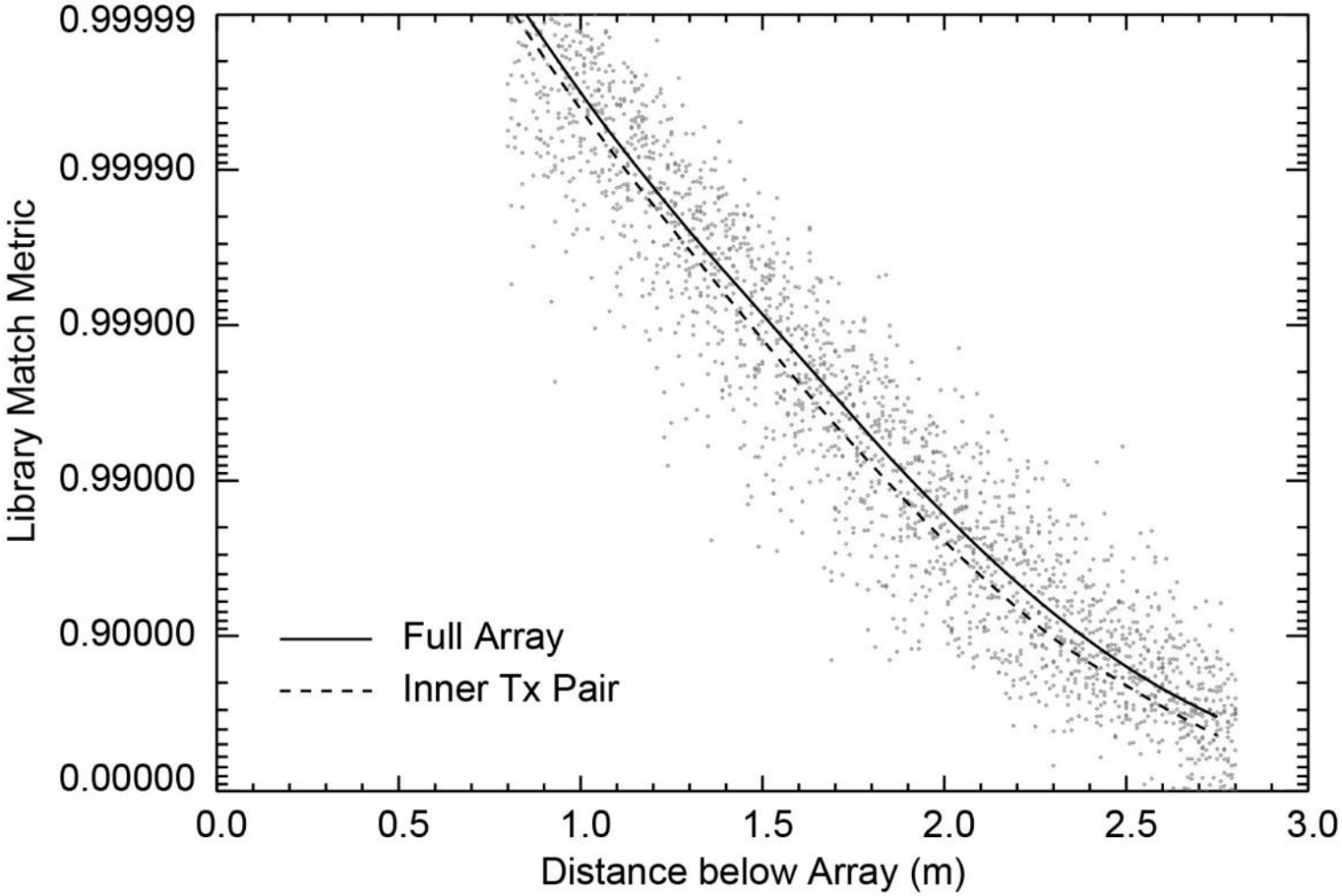
Model developed from results to give predictive capability





Model Performance of Full Array

Simulation results for the full array, 480 A-turns, 105mm Projectile



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Test Flight at VIMS – January, 2019

- All mechanical repairs completed
- New tow point for tow vessel
  - Improved integration of optical encoder to measure tow cable angle
- Successful flight
  - No CoG / CoB issues
  - Autopilot functioned as expected
    - Depth mode
    - Altitude mode

Fabrication of Full-Sized EMI coils

- Applied lessons learned from:
  - SERDP MR-2409
  - SERDP MR-2500
  - ESTCP MR-201313

- Insulation buffer around transmitter coils necessary for use in conductive media

Full-Sized EMI Coils

- Main Loop
  - 4.63 m x 1.07 m
- Inner Loops
  - 2.26 m x 0.97 m

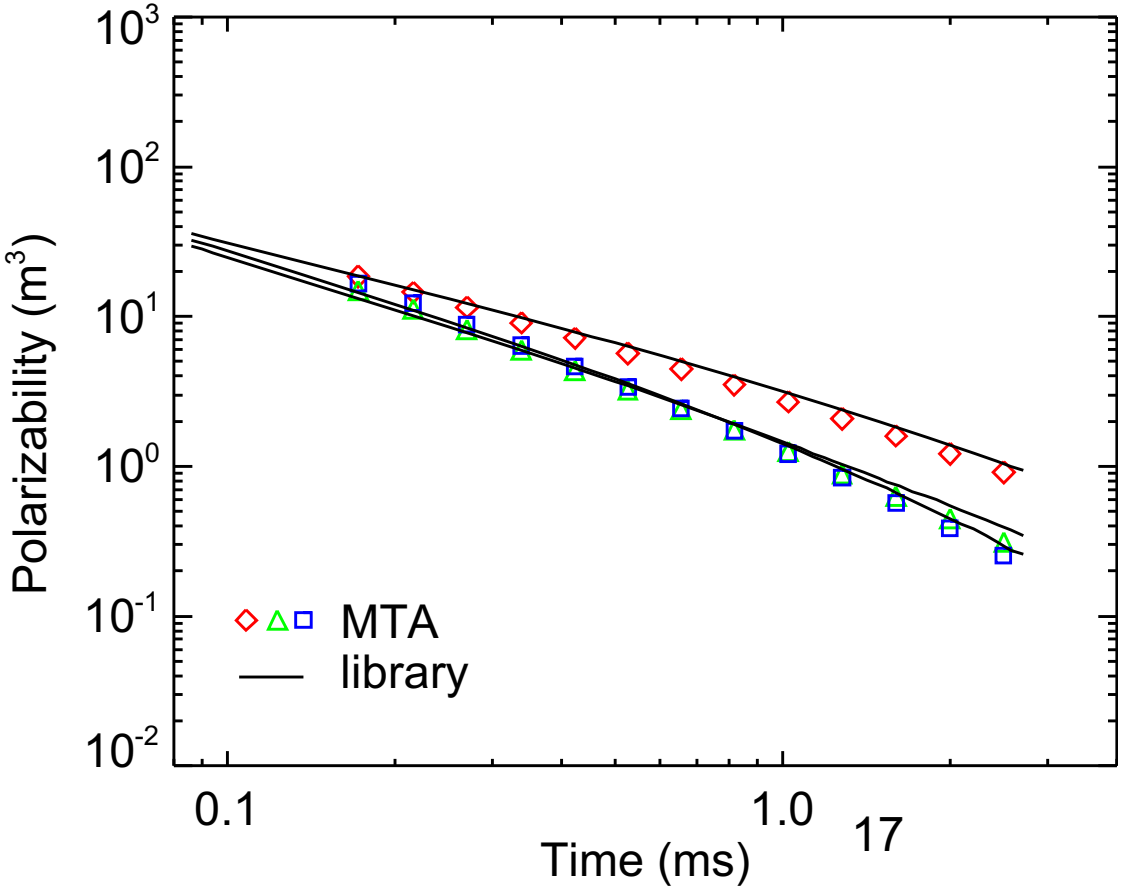
- 20 turns of 14 AWG copper wire, carefully wound

Testing the EMI Array on Land

- Testing of complete EMI system
  - Transmitter
  - Full-sized transmitter loops
  - Receivers cubes installed in waterproof housings
  - All underwater cabling connected
- Test program similar to miniMTA checkout

Testing the EMI Array on Land

105mm projectile sequentially positioned underneath array to simulate a dynamic data collection



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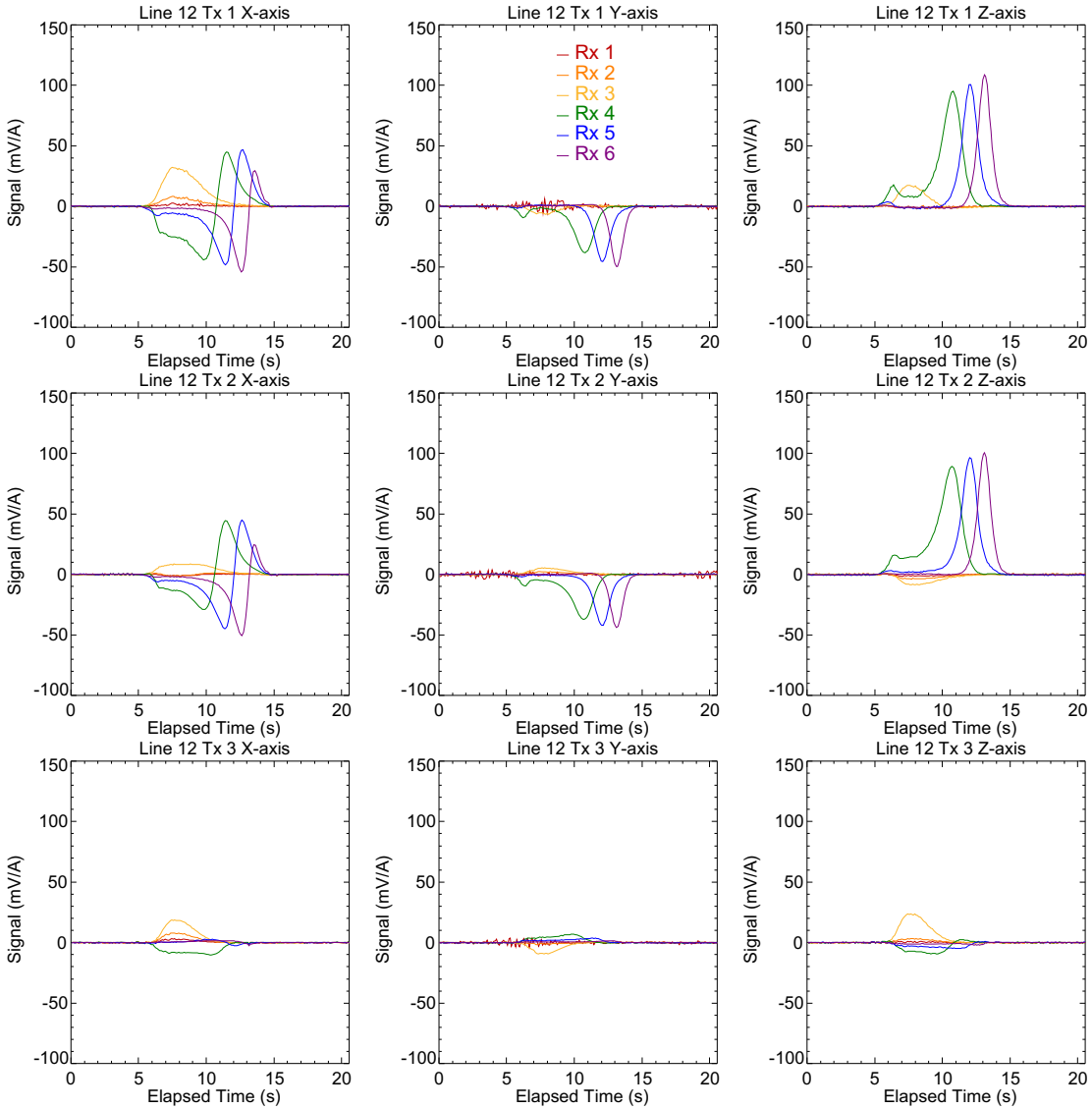
Testing the EMI Array on Land

12-in diameter steel sphere (hollow)

Rolled down inclined ramp to energize the receivers on one side of array sequentially



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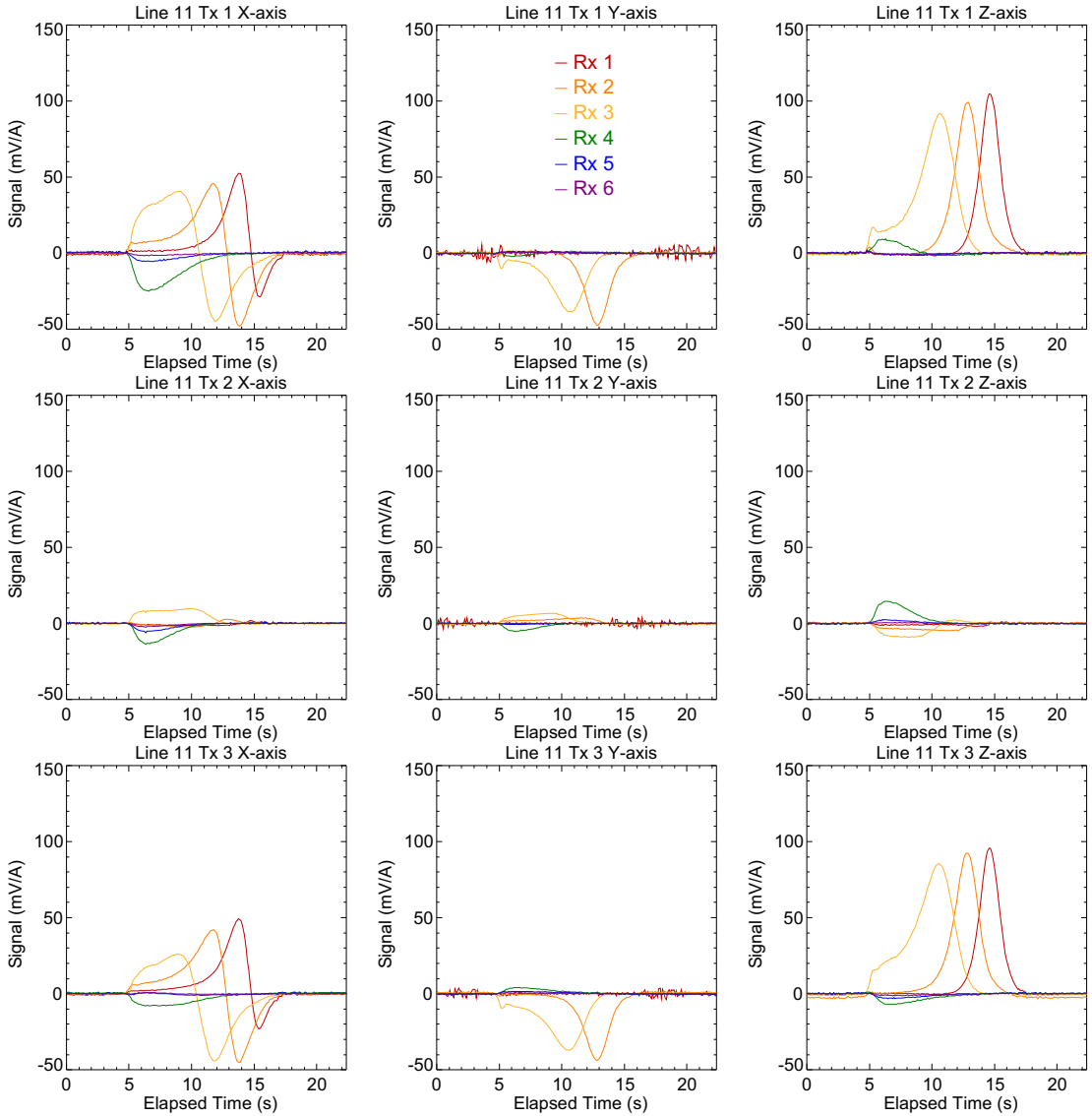
Testing the EMI Array on Land

And then the other side…



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Testing the EMI Array on Land

- Array is functional, but with some caveats
  - Transmit current is lower than planned 20A
  - Resistance of coils plays a large role

$$Transmit\ Current = \frac{Applied\ Voltage - \delta V}{R_0 + n\rho L}.$$

    - δV = 4 Volts for the IGBT switches in our transmitter
  - Transmitter modified to accept +/- 24 Volts
    - Up from +/- 12 Volt design limits
  - Receivers saturate at early time

Testing the MTA at VIMS

- Testing on the York River, VA, near VIMS
- Tow vehicle was the *R/V Tidewater*

- Average water depth of 6.7 m
- Weakly stratified water column with average conductivity of 3.45 S/m

Test Items

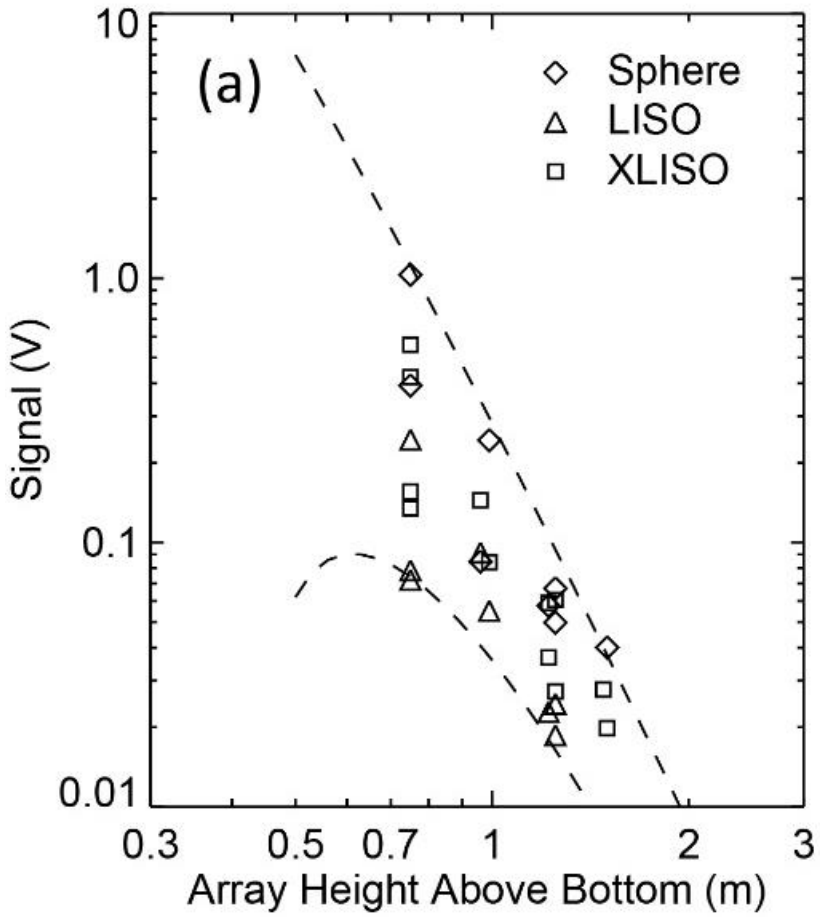
- Six surrogates deployed in a line
- 10 m intervals
- Two 12-in diameter steel balls
    - Hollow, 1/8” wall thickness
- Two Large ISOs (LISO)
    - 4” diameter x 12” long
    - 105mm projectile
- Two Extra-Large ISOs (XLISO)
    - 6” diameter x 24” long
    - 155mm projectile

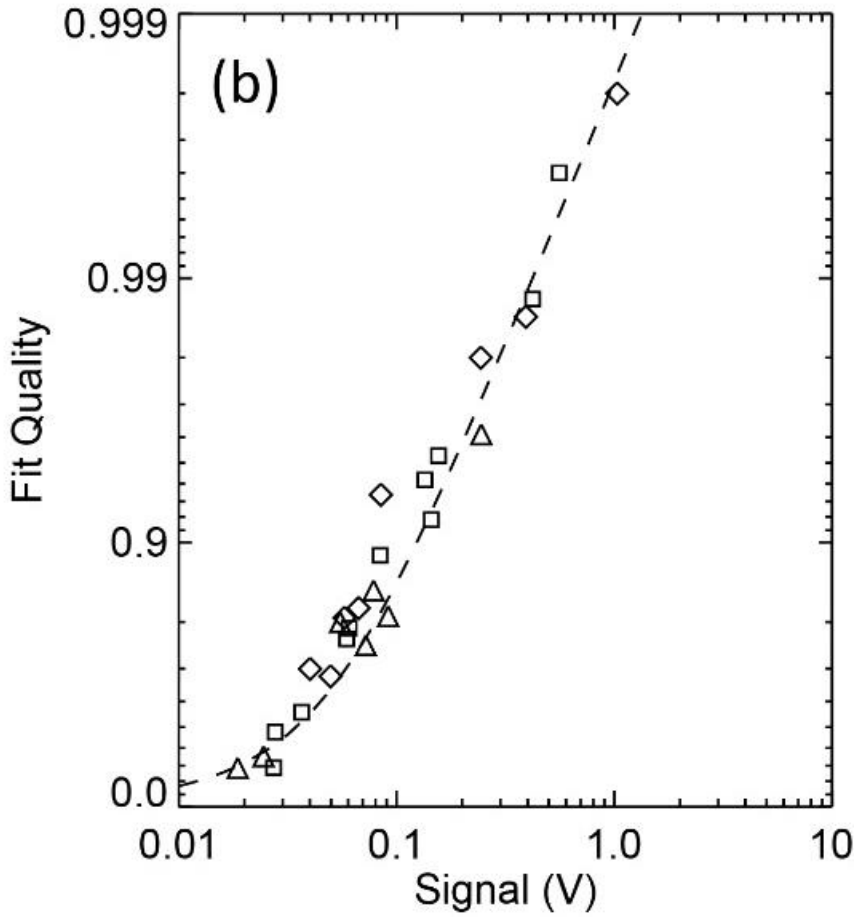
Testing the MTA

Array performed as expected based on final land testing

$$Fit\ Quality = S/\sqrt{S^2 + N^2}$$

where *S* is the signal and *N* is the noise

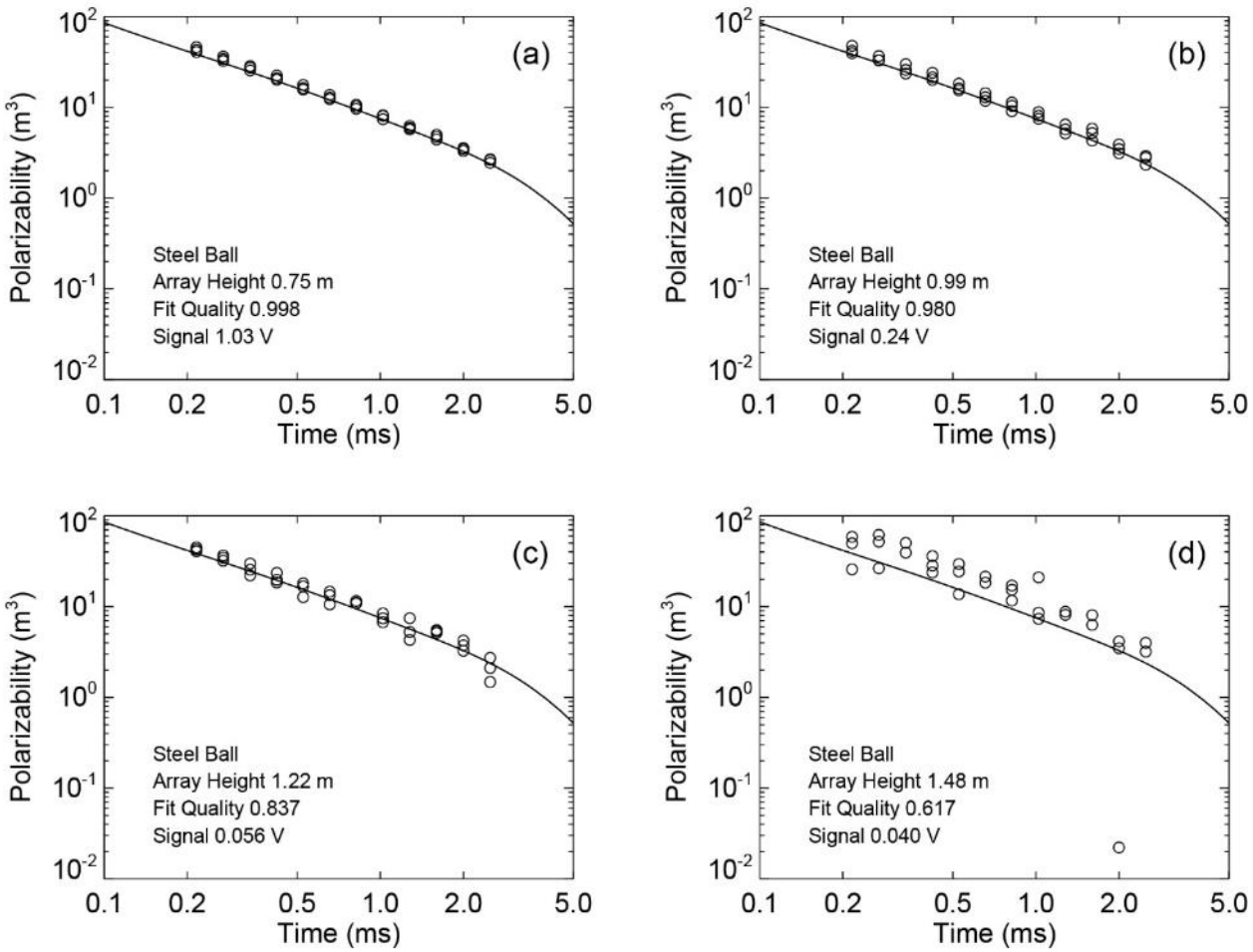




Inversion Results vs Array Height

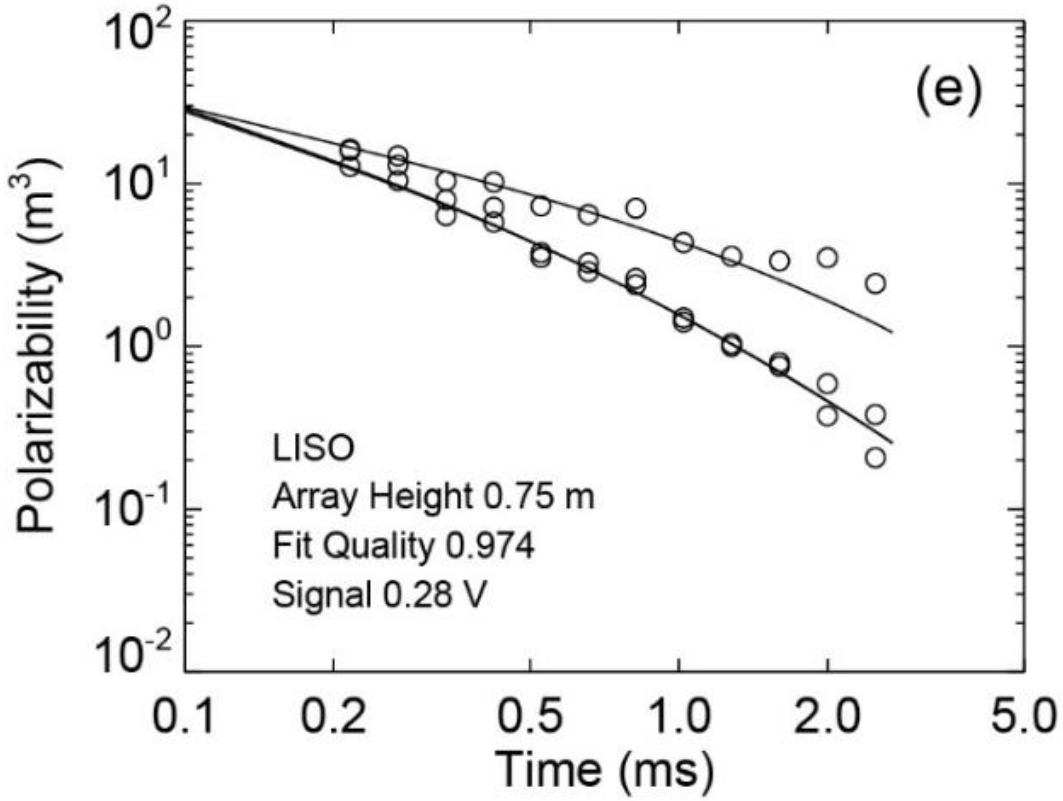
12-in Steel Sphere (hollow)

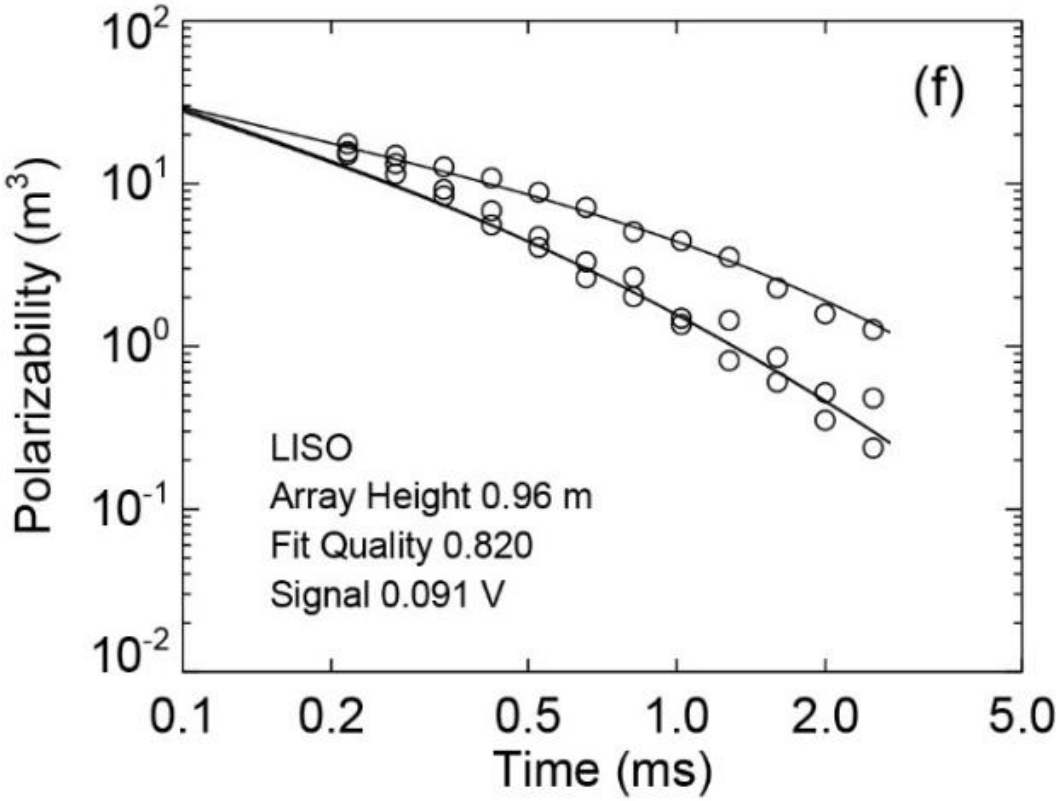
- Inversion results yield good results with fit qualities greater than ~0.75.
- Deviations between actual and modeled results are <15% for fit qualities >0.8.



Inversion Results vs Array Height

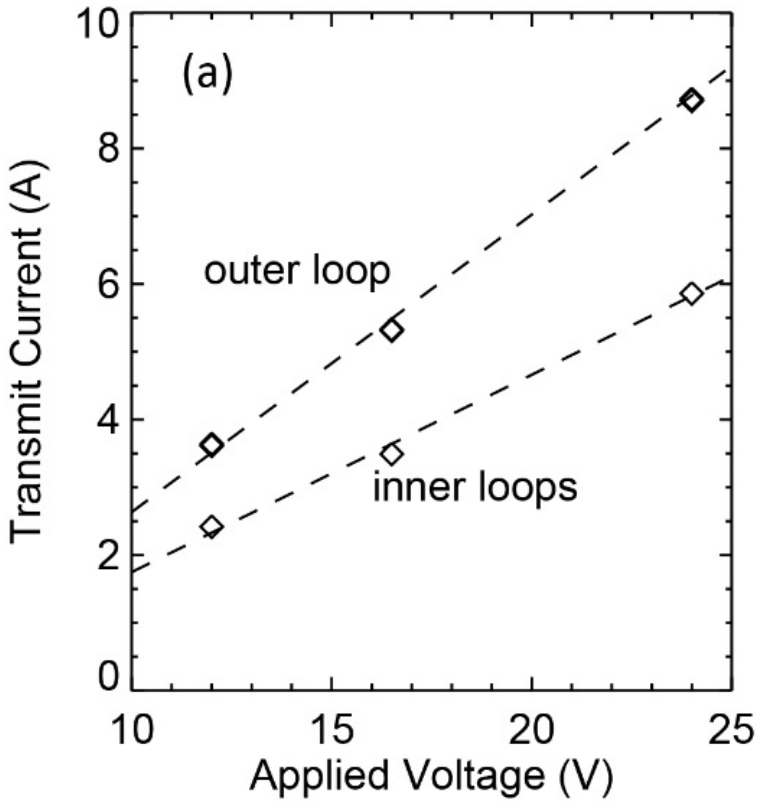
- Large ISO (105mm surrogate)

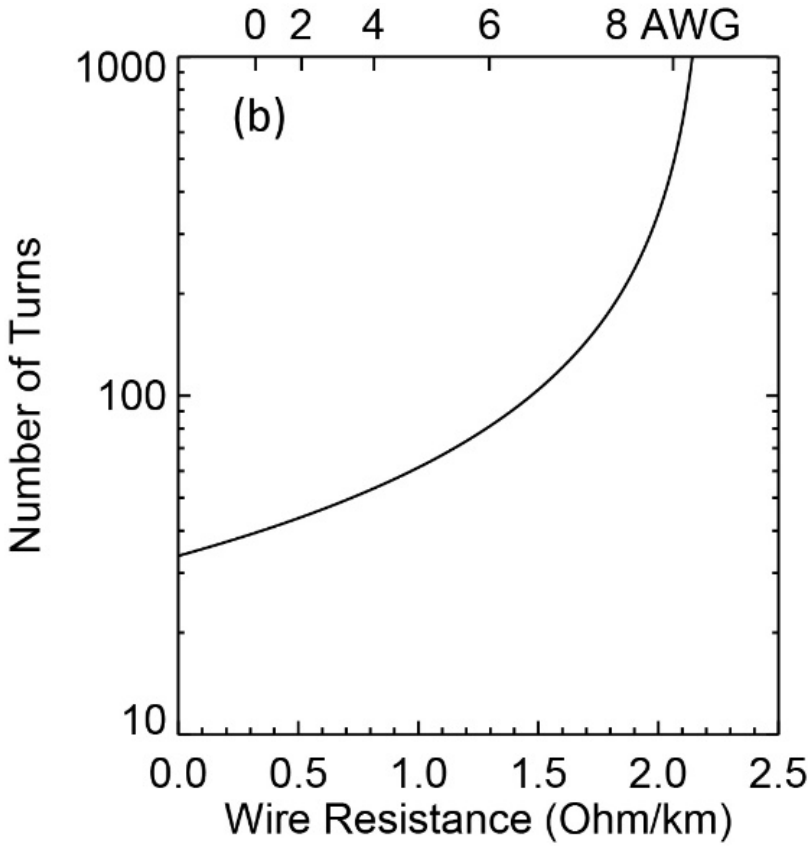




Transmitter & Tx Loops Performance

- Transmit Current vs applied voltage
- Turns required to achieve necessary current vs AWG





Summary of Results

- Array performs as well in salt water as it does on land
- Transmit currents are lower than planned
- Real-world noise levels are 2-3x larger than anticipated
- To improve SNR to levels required to meet design goals would require ~800 A·turns versus design 480 A·turns
- This could be achieved by either:
    - New transmitter loops with heavier gauge wire (80 turns, 6 AWG)
    - New transmitter capable of using +/- 48 Volts

Conclusions

- As currently implemented, the MTA EMI array is not a viable survey instrument.
- It does perform as expected from land testing
- No insurmountable “show-stoppers” seen for implementing a functional version.

- The MTA magnetometer array is a valuable tool in the DoD arsenal for classification of underwater UXO.

Acknowledgements

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