Development and Evaluation of an Underwater Advanced Time-Domain Electromagnetic System for Munitions Response Classification

Battelle International Symposium on Bioremediation and Sustainable Environmental Technologies
Tuesday April 16, 2019
Baltimore, Maryland

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Outline

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ESTCP

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The Underwater Munitions Problem

- **Over 400 underwater sites** have been identified by USACE and the U. S. Navy as potentially containing munitions.
- Characterization of underwater munitions is **currently performed through expensive and time consuming process** of manual inspection by Explosive Ordnance Detonation (EOD) experienced divers.
- Current technologies allow for the detection of metallic items in the underwater environment but **few underwater systems are available to apply advanced geophysical classification**.

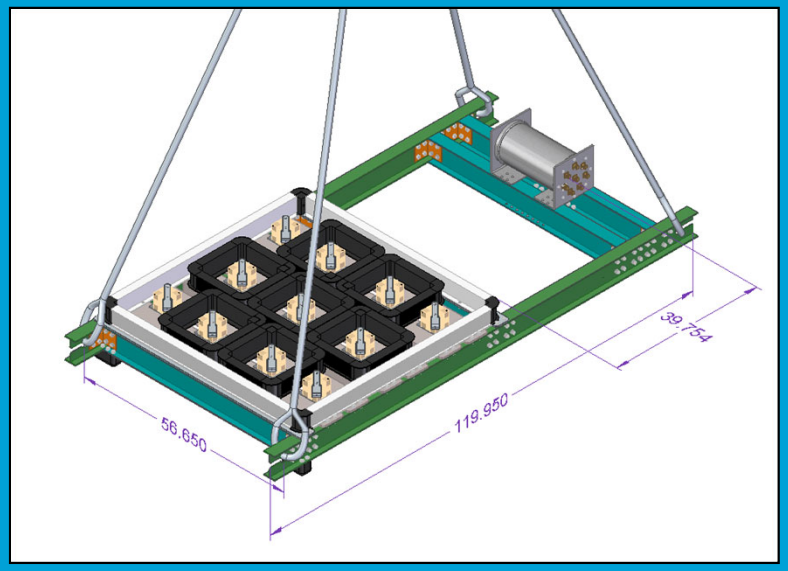
Project Introduction:

Underwater Advanced Time-domain Electromagnetic System

Environmental Security Technology Certification Program (ESTCP) Project MR-201313

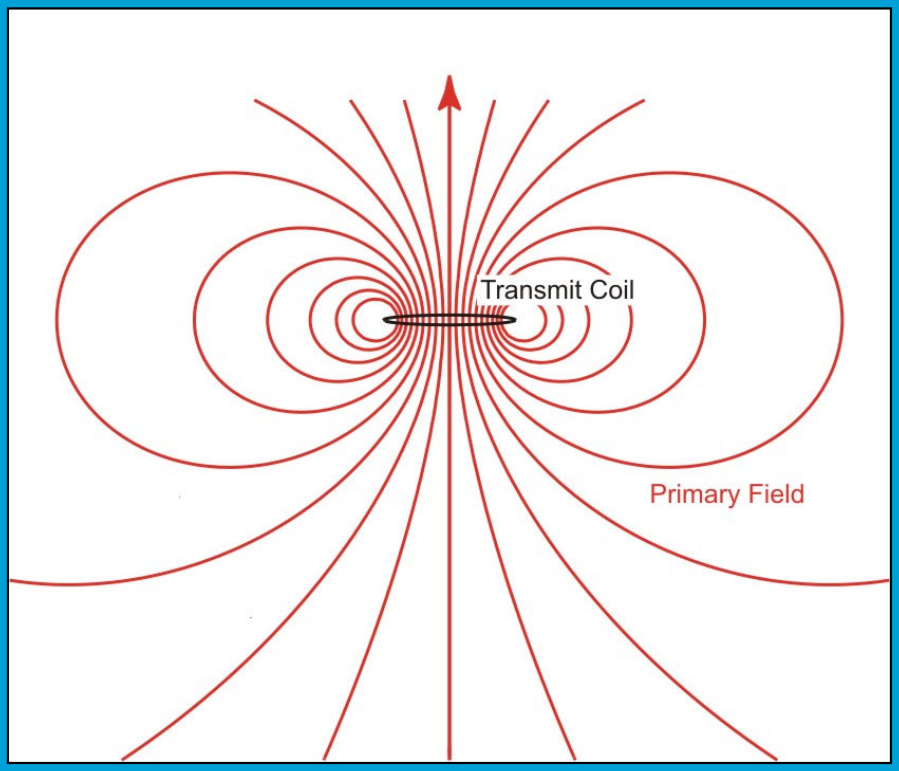
- **Project Performers:** Jacobs, Geometrics, Leidos, Naval Research Lab
- **Objective:** to design and demonstrate an underwater advanced EM system, using existing advanced electromagnetic hardware, capable of munitions classification in saltwater at depths up to approximately 40 feet
- **Results:** it worked; presentation will elaborate.

Emphasis is to design a system that can demonstrate classification effectiveness in marine environment (as opposed to solving longer-term issues such as positioning, deployment methods, system rigor).



Electromagnetic Induction (EMI) Concept
Slide 1 of 3: The Source

- Regulate electrical current in a wire to produce a time-varying magnetic field

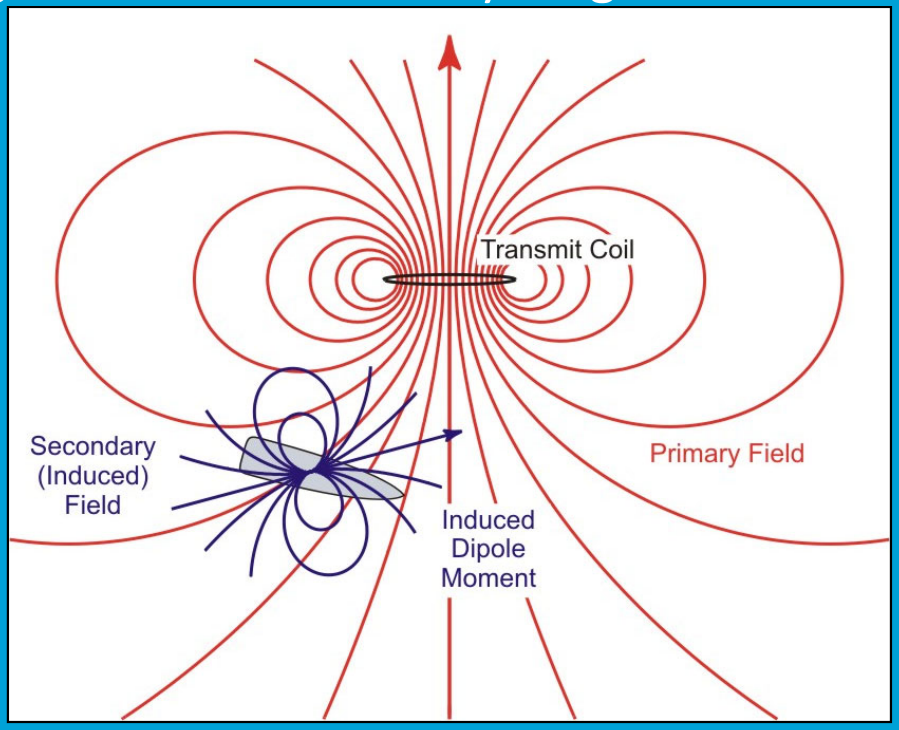


Step 1:

Excitation Pulse

Electromagnetic Induction (EMI) Concept
Slide 2 of 3 : Interaction with Object

- Time-varying magnetic field induces electrical currents in nearby metallic objects, which in turn generates a secondary magnetic field

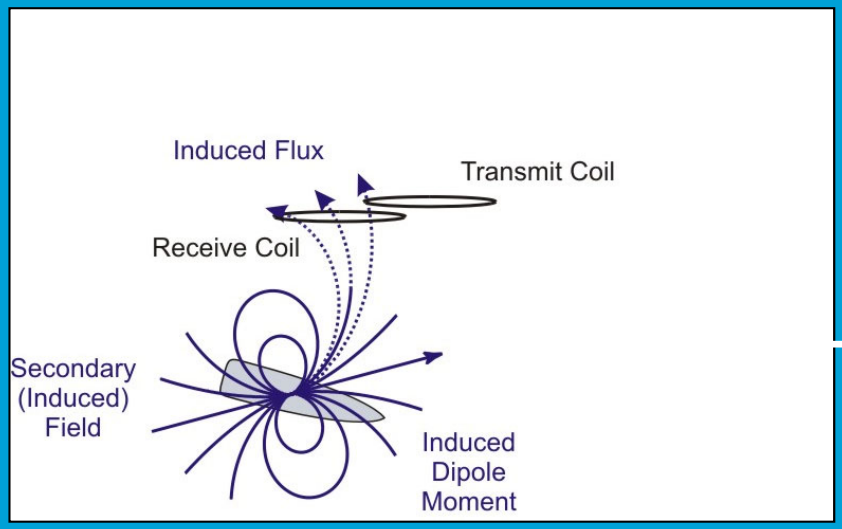


Step 2:

Induced Target Response

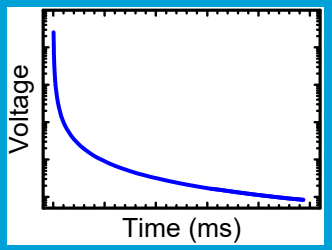
Electromagnetic Induction (EMI) Concept
Slide 3 of 3: Received Signal

- Secondary magnetic field is measured by Receive Coils



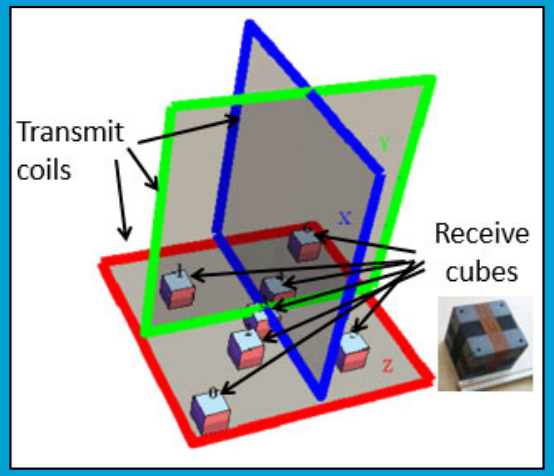
Step 3:

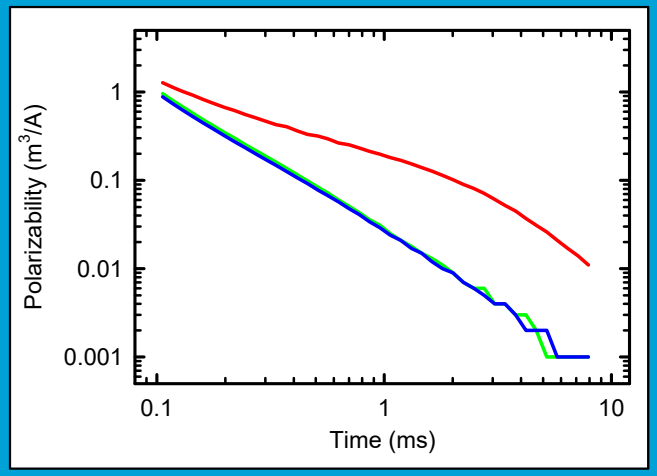
'Listen' to the Induced Field



Advanced Geophysical Classification

- Same EMI principles as previous slides
- Specially-designed sensors illuminate objects from all directions
- Now we can determine intrinsic object features (result independent of object location, depth, or orientation) to classify object as hazardous unexploded ordnance (UXO are rare), or harmless debris (much more common)

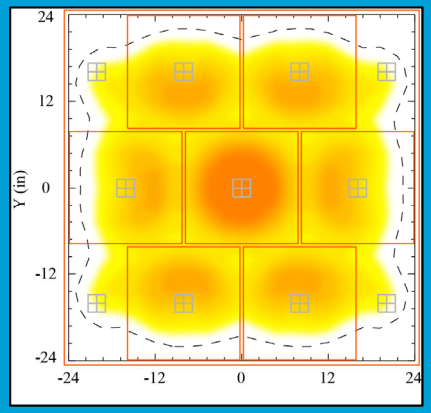


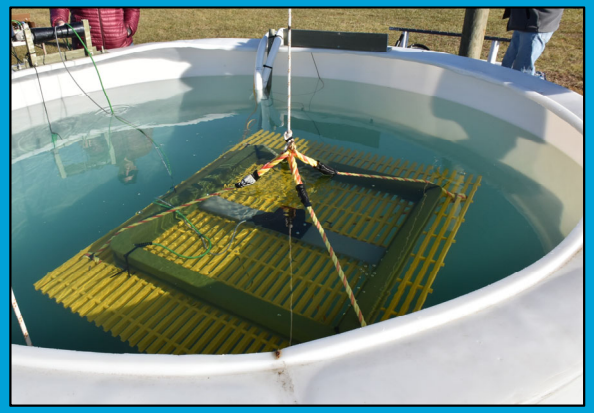


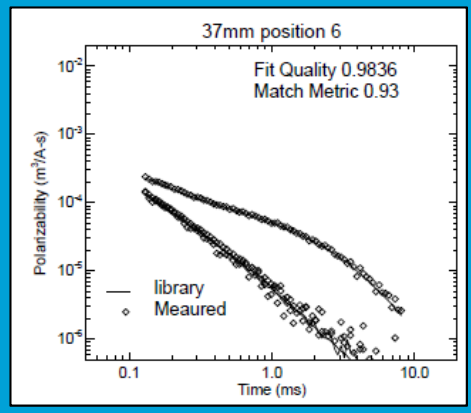
Polarizability Property	Target Property
Decay Rate	Wall Thickness
Relative Magnitude	Shape
Total Magnitude	Size (volume)

Project Timeline

- **Overview of Project Milestones and Demonstration Sites:**
  - 2015-2016 – modeling to assess array design and potential effects of water on data usability
  - February 2016 – initial “dunk” tests at Naval Research Lab’s Blossom Point, Md. facility
  - October 2016 – demonstration in freshwater pond at Naval Surface Warfare Center Panama City, Fla.
  - May 2018 – demonstration in saltwater at USACE’s Field Research Facility, Duck, N.C.

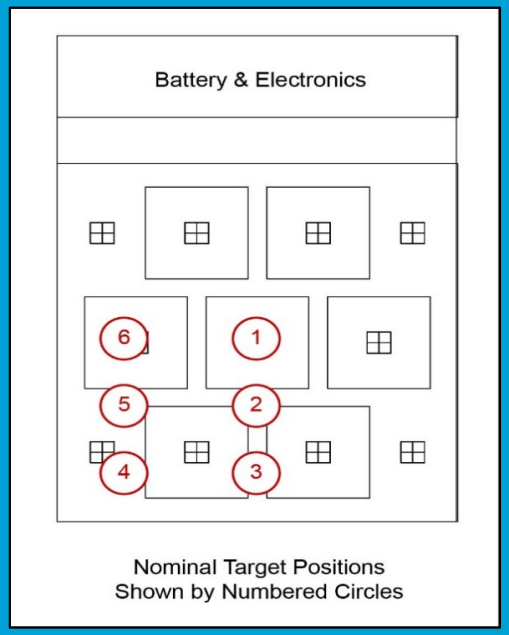


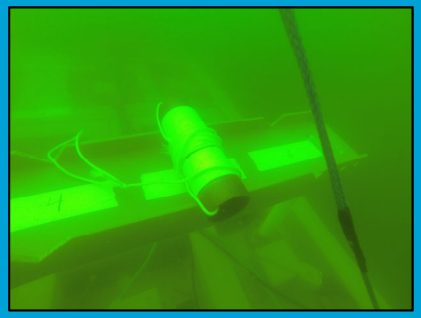




October 2016 Freshwater Demonstration

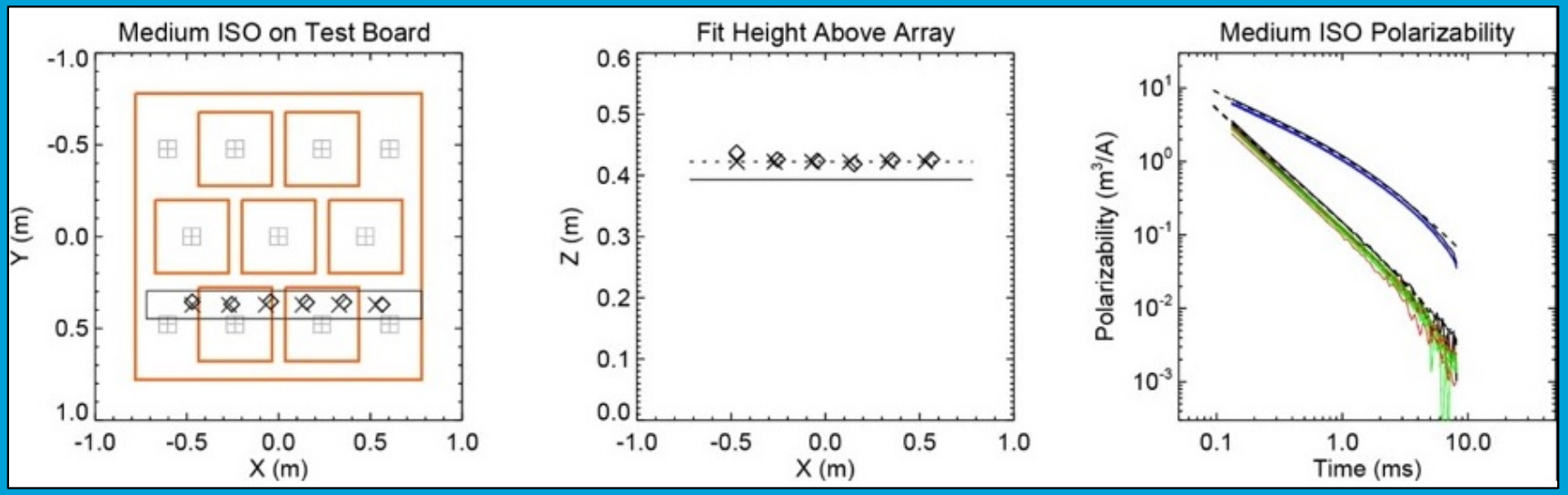
- Naval Surface Warfare Center Panama City, Fla. freshwater pond selected for controlled conditions and site support
- Prior to underwater testing, performed free-air (topside) testing to develop library of Targets of Interest
- Checked the accuracy of inverted target locations and polarizabilities determined by array data collected under controlled conditions
- Underwater data collection plan used six measurements per item (below center) to test various Tx/Rx situations.





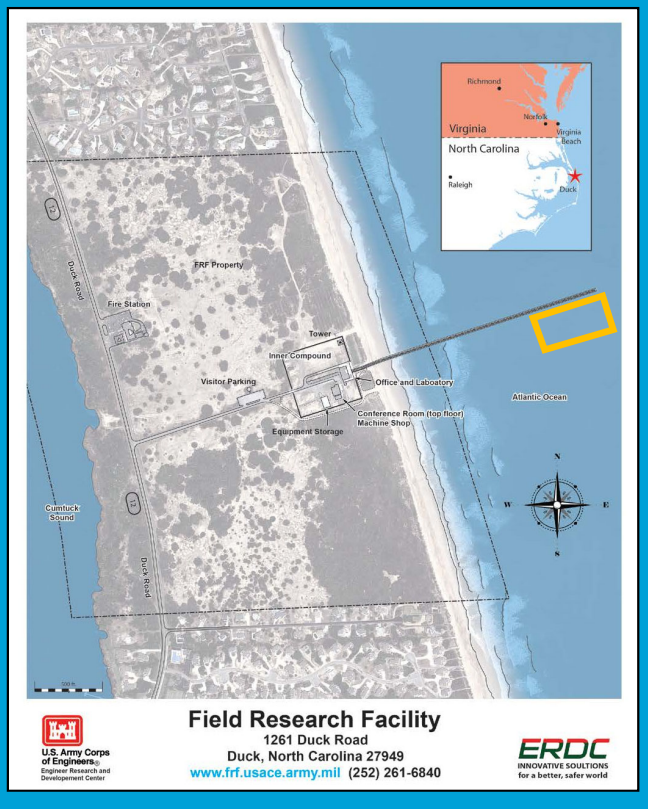
October 2016 Freshwater Demonstration

- Underwater Board Test Results – Medium test item
  - Left: plan view of array with Test Stand (**X**s actual locations)
  - Center: elevation view of array with and Test Stand
  - Polarizability curves (solid) v. library (dashed) – good match between topside and underwater



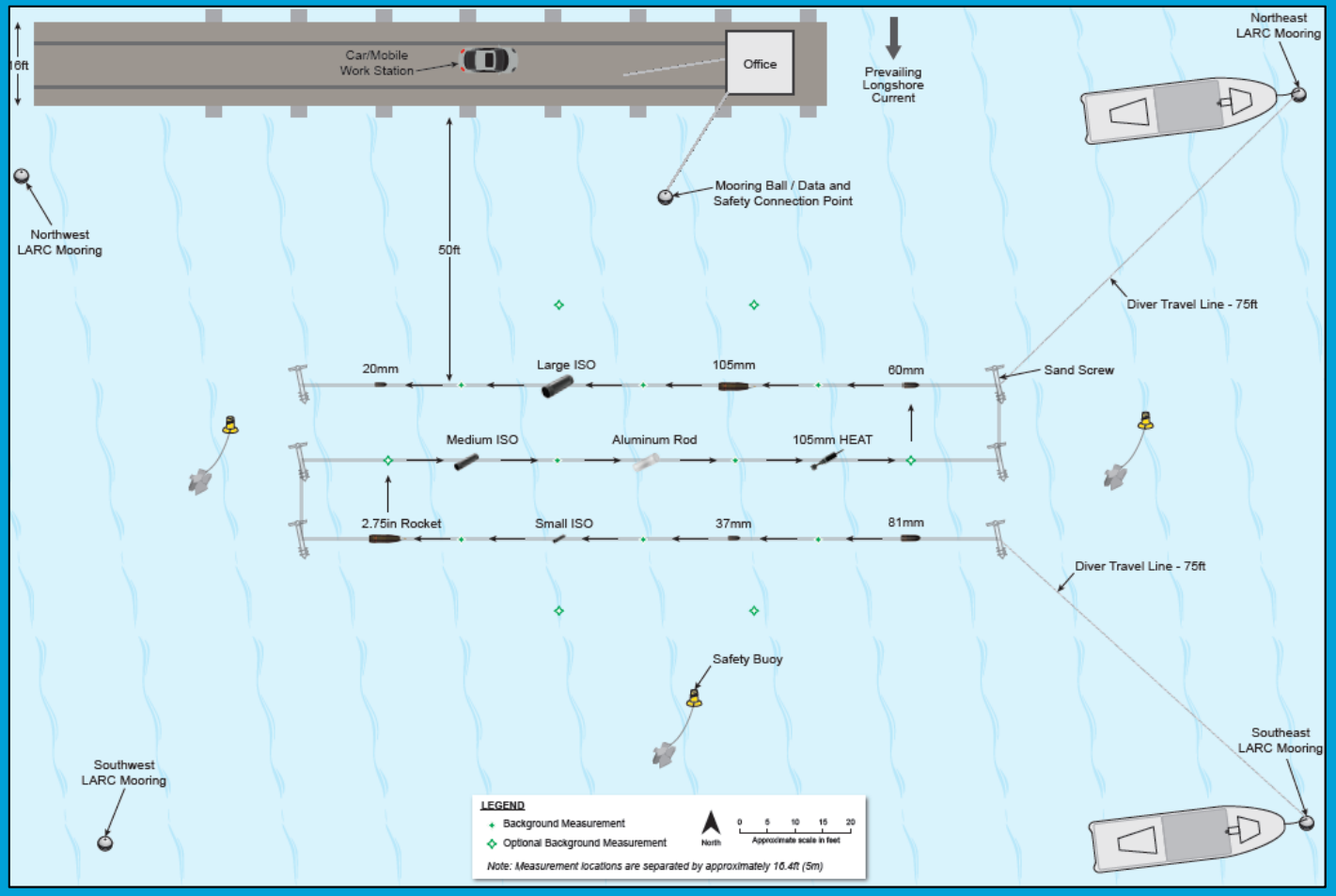
May 2018 Saltwater Demonstration

- USACE Field Research Facility, Duck, N.C. selected for its setting, pier, and support, including two LARCs (Lighter, Amphibious Resupply, Cargo) for Dive Team and Data Team, and environmental data availability (e.g., wave data, conductivity and temperature).



May 2018 Saltwater Demonstration

- Jacobs divers pre-surveyed and constructed the Test Area containing:
  - Small, medium, and large non-UXO test items
  - 105mm projectiles
  - 81mm and 60mm mortar cartridges
  - 2.75in rocket
  - 20mm and 37mm projectiles
  - Aluminum rod
  - Ten background locations for Sensor Function Tests (aluminum sphere)



May 2018 Saltwater Demonstration

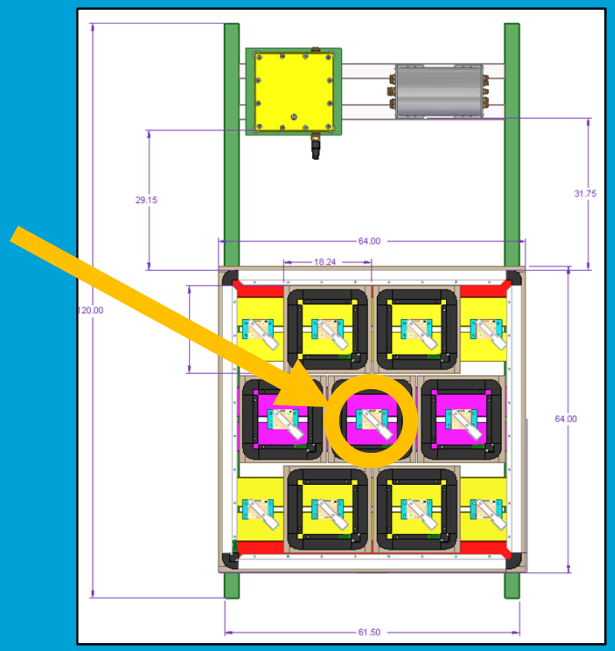
- EM system deployed by crane to divers to swim down to Test Area (~25ft down)
- Dive Team seeded Test Area only after background data collected at proposed seed locations showed no significant preexisting metallic objects

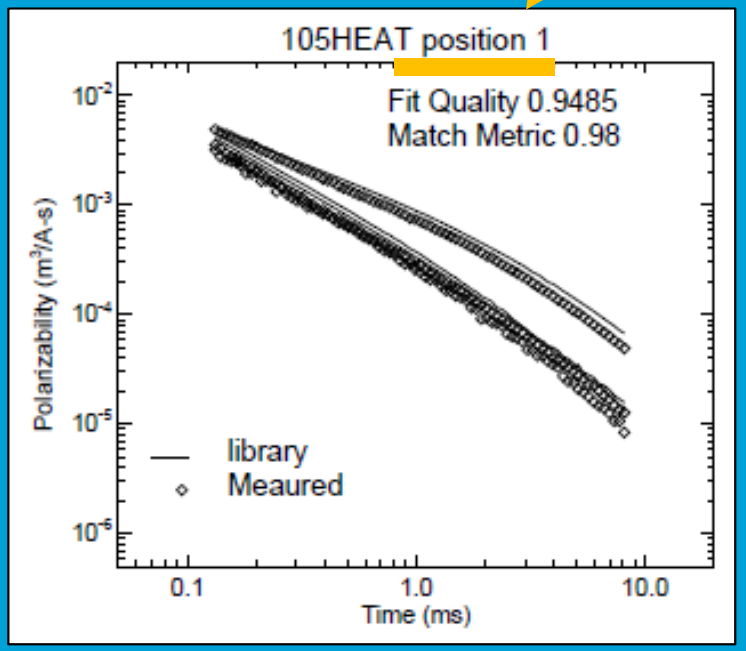
May 2018 Saltwater Demonstration

- EM system maneuvered by Dive Team (two surface-supplied air divers)
- Two-way communications between Dive Team and Data Team
- Data acquisition controlled by and transferred to Data Team on pier

May 2018 Saltwater Demonstration

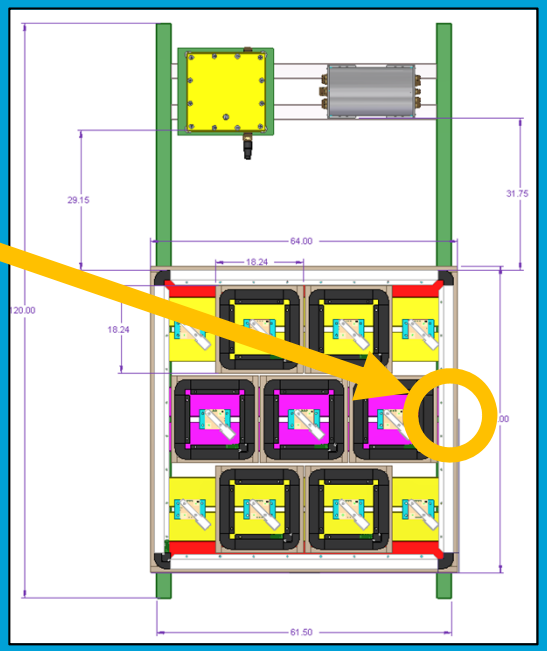
- Classification results indicate EM system works in saltwater
- Stronger fits and matches for larger items near center of EM system

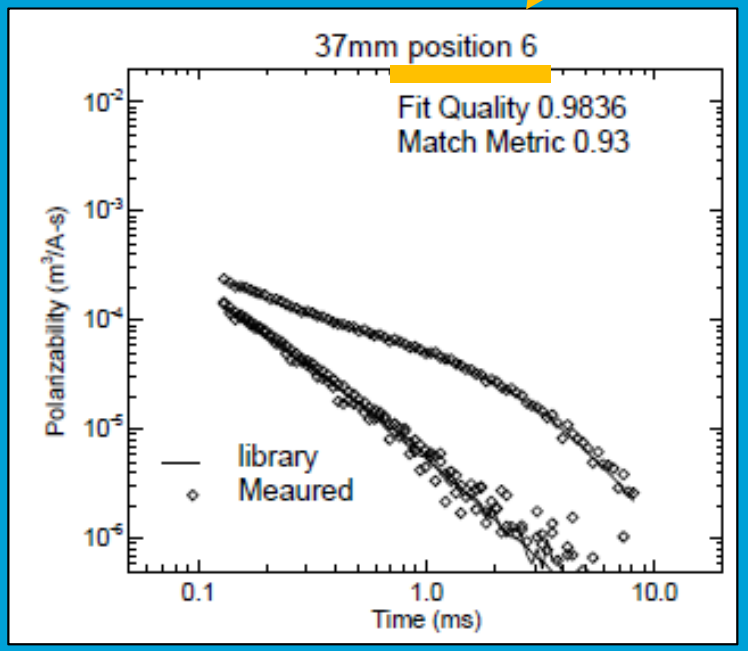




May 2018 Saltwater Demonstration

- Classification results indicate EM system works in saltwater
- Strong fits and matches for smaller items toward exterior





May 2018 Saltwater Demonstration

Performance Objectives Results:

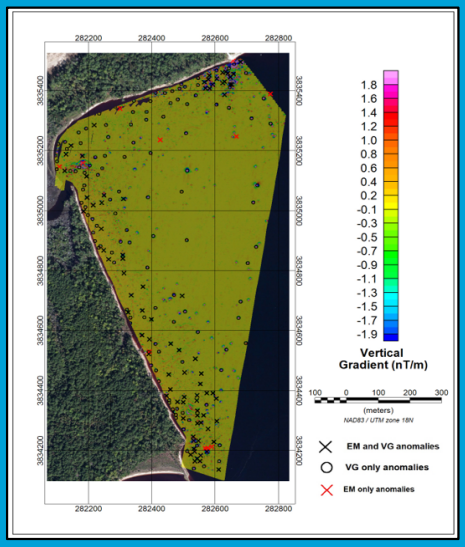
- ✓ Daily sensor response repeatability within 20%
- ✓ Daily classification repeatability of standard item >0.9 fit metric
- ✓ Classification can be achieved within 0.8m of center of array (except 20mm projectile)
- ✓ Target polarizabilities match between saltwater data and freshwater library
- ✓ Sensor response plots are qualitatively similar for topside and underwater data

SNR <30 generally resulted not in meeting Performance Objectives

	Range of Saltwater Demonstration Results			
Test Item	SNR	Fit Coherence	Offset (m)	Library Match
105mm Projectile	616 - 1871	0.985 - 0.999	0.47 - 0.82	0.92 - 0.99
Large ISO	306 - 767	0.988 - 0.998	0.46 - 0.93	0.80 - 0.99
Medium ISO	137 - 483	0.964 - 0.999	0.21 - 0.96	0.69 - 0.98
105mm HEAT	118 - 1308	0.984 - 0.997	0.20 - 1.07	0.57 - 0.99
2.75in Rocket	79 - 1448	0.937 - 0.995	0.12 - 1.04	0.84 - 0.95
60mm Mortar	70 - 282	0.980 - 0.999	0.29 - 0.96	0.87 - 0.95
Aluminum Rod	26 - 193	0.766 - 0.991	0.10 - 2.19	0.06 - 0.99
81mm Mortar	25 - 408	0.945 - 0.996	0.31 - 1.15	0.88 - 0.96
37mm Projectile	18 - 95	0.916 - 0.991	0.20 - 1.25	0.08 - 0.97
20mm Projectile	12 - 24	0.164 - 0.885	0.04 - 8.05	0
Small ISO	9 - 53	0.862 - 0.976	0.28 - 1.40	0 - 0.89

Path Forward

- March 2019: FY20 ESTCP pre-proposal submitted for add'l demonstration to assess effects of sediment type and offsets, and improve deployment methods:
  - Use lighter watercraft (e.g., 27ft scow below)
  - Add positioning methods (e.g., USBL, VEMCO – affordable, commercial off-the-shelf, fine-scale acoustic positioning)
  - Demonstrate at an area with a recent detection survey dataset?
- Current – Sept 2019: adapt raw data for processing in Geosoft



Thank You

Questions?

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Acknowledgements:
Naval Research Laboratory
Naval Surface Warfare Center Panama City, Fla.
USACE Field Research Facility, Duck, N.C.