



Classification of Underwater UXO from Dynamic EMI Survey Data

MR-21-5066

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In Progress Review Meeting

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Project Team



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GapEOD



Bottom Line Up Front

- Performance, as evaluated, is encouraging
 - Responses to standard objects on a test stand are as predicted
 - In-water testing
 - The modified wing flies straight and level
 - Noise levels are as predicted and manageable, even under way
 - However,
 - The wing is 20+ years old
 - Failure of several systems frustrated completion of the shakedown testing
 - Expectation is that responses in the water will be the same, but unconfirmed
- We believe the technology is sound and should interest and commensurate funding become available, this should be demonstrable

Site Description



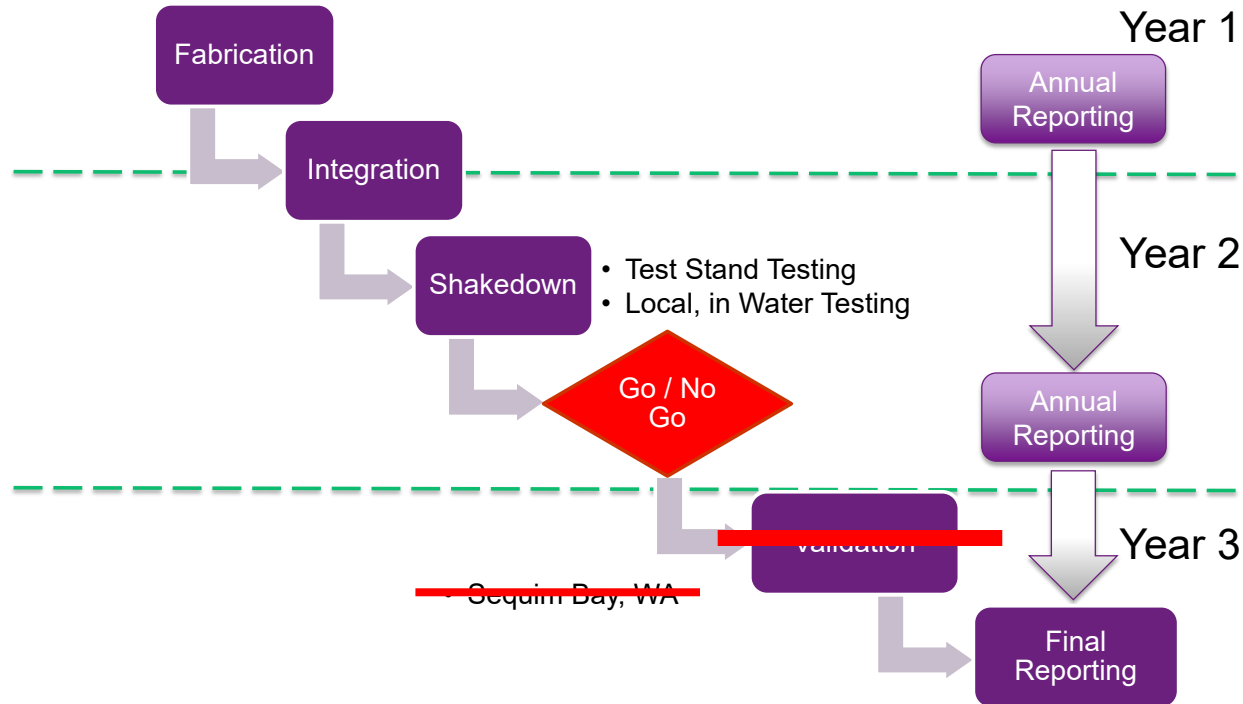
York River, VA

- Location of VIMS
- 2024 test area shown in yellow
 - 5 – 10 meters deep, aligned with bathymetry
- No previous identification of any munitions in test area
- None found during our testing

Technical Approach and Test Design

- Fabrication
 - Design and fabricate key elements required to upgrade the existing EMI array to an UltraTEM Marine system
- Integration
 - Install and interconnect the new elements into the MTA
 - Modifications to the MTA as required
- Shakedown
 - Series of dry land and local testing to confirm system is functional
 - Go / No Go at completion
- ~~Validation~~
 - ~~Demonstration at SERDP / ESTCP Munitions Response Underwater Test Site at Sequim Bay, WA~~
- Reporting
 - Ongoing and final reporting

Technical Approach Workflow



Performance Objectives

Land-based Test Stand

Local, In-Water Testing

Performance Objective	Metric	Data Required	Success Criteria	Performance Objective	Metric	Data Required	Success Criteria
Quantitative Performance Objectives				Quantitative Performance Objectives			
Transmit moment as designed	Stability of operation of transmitter at design levels for extended periods of time	Transmit current waveforms over time	Transmit moments of 700 / 900 A-turns with <1% short term, <10% long term variation	EMI array performance	Ability to collect data of sufficient quality (amplitude and SNR) to conduct classification throughout the design envelope of the array	Same as for land-based	Same as for land-based (York River noise levels 2.3 mV at 0.2 ms)
EMI Array Response – Amplitude	Ability to record physically-meaningful amplitudes from TOI and other objects	EMI data collected with known objects at various locations / depths around array	Consistent results within 10% of model predictions for amplitude (response curves)	Qualitative Performance Objectives			
EMI Response – Classification	Ability to invert data for target location and correctly library match results	Inverted results for data collected for known objects at various locations / depths around array	Inversions match models / library within perimeter of array and to predicted effective range	Platform stability in flight	The array flies through the water at the programmed altitude / depth while holding attitude	Observations and interviews with vessel crew	Ability to hold altitude and pitch / roll
				Vessel crew performance	Monitor crew satisfaction / fatigue reports for operational issues which require modification	Observations and interviews with vessel crew	Is workload reasonable for sustained operations (hours/days)
Platform and environmental noise	Environmental noise levels are low enough to successfully classify targets	Repeated measurements	Noise levels ≤ 0.7 mV at 0.2 ms (MR-201610 at BP levels)	Data collection / analysis performance	Does data collection / processing workflow allow for timely analysis and feedback	Observations and interviews with field team	Is workload reasonable for sustained operations (hours/days)

Performance Assessment / Results

- The UltraTEM Marine MTA, as compared to the MR-201610 MTA
 - 5.3x more A·turns
 - Noise level 40% lower
 - Combined these indicate an 80% improvement in effective range
 - At a fixed range the new system should be effective against targets which are almost 60% smaller
- Initial results from dry-land testing the system indicate performance is as designed.
- In-water shakedown testing indicate the same, as far as it got

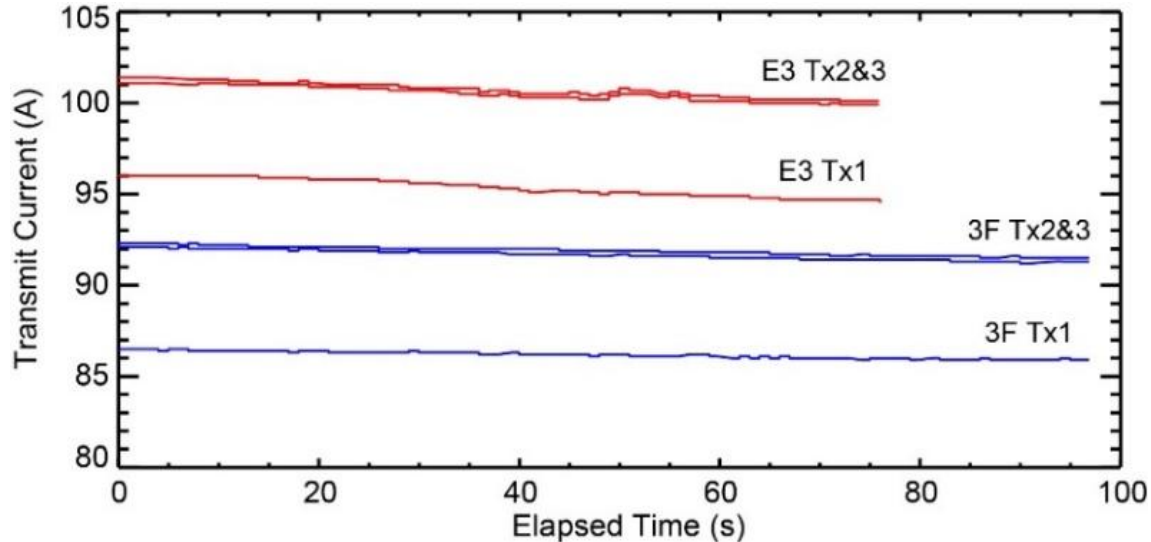
High-Powered UltraTEM Marine

- The high-power UltraTEM Marine system was delivered to NRL in late November, 2023.
 - Large 4.59 m x 1.03 m transmit loop
 - The outer transmitter loop has seven turns
 - Enclosing a pair of 2.25 m x 0.93 m transmit loops
 - The inner loops each have nine turns
 - Six 3-axis receivers.
 - The receivers each have a pair of 15 cm square loops for each axis and an electronic gain of 2322.20.
 - The wound transmitter loops match the design (*i.e.*, resistance and inductance)

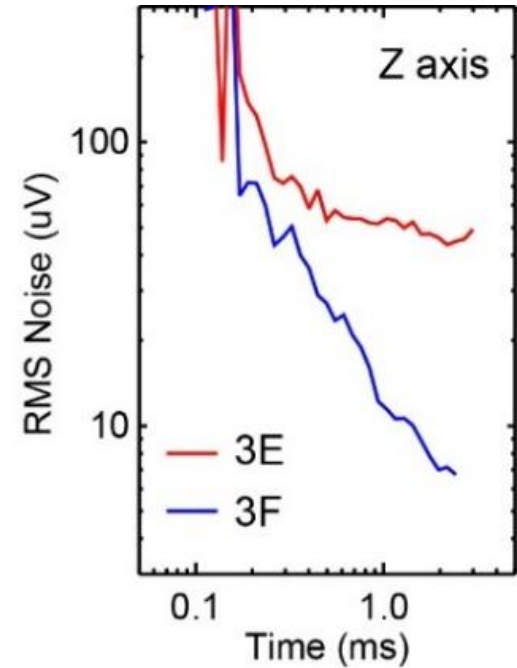
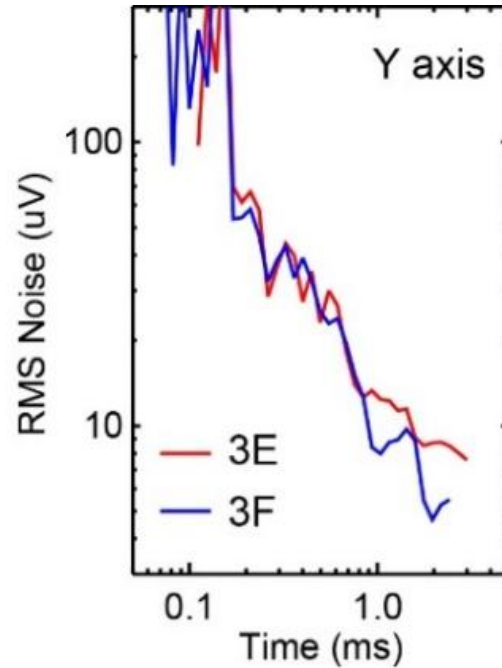
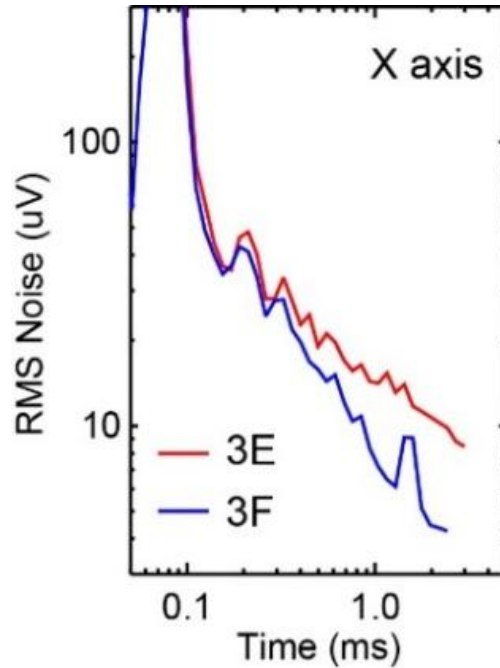


Land-Based Testing

- The goal is to field a system capable of generating 700/900 A·turns in the transmitter coils. This allows for classification with a workable standoff.
- In the two available “dynamic” modes, 3E (75 Hz) and 3F (90 Hz), the system generates 90 – 100 A, as designed.
- 90 Hz operation is limited to charging time and details of cable length.
- 75 Hz operation is a viable option in 60-Hz free areas



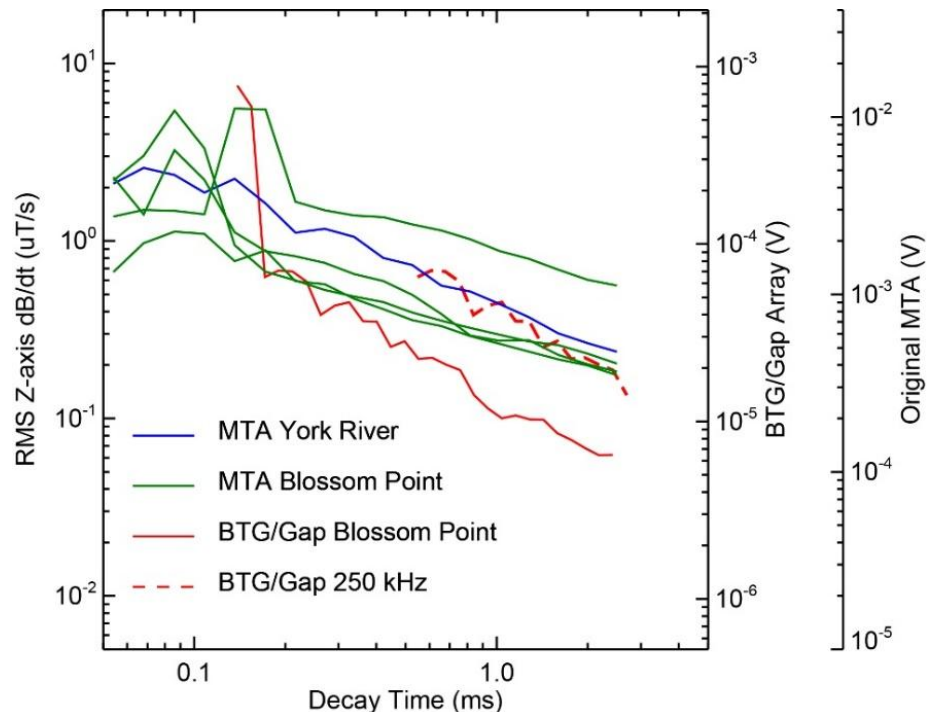
Noise Levels, No Metallic Source



Comparison of Noise Levels

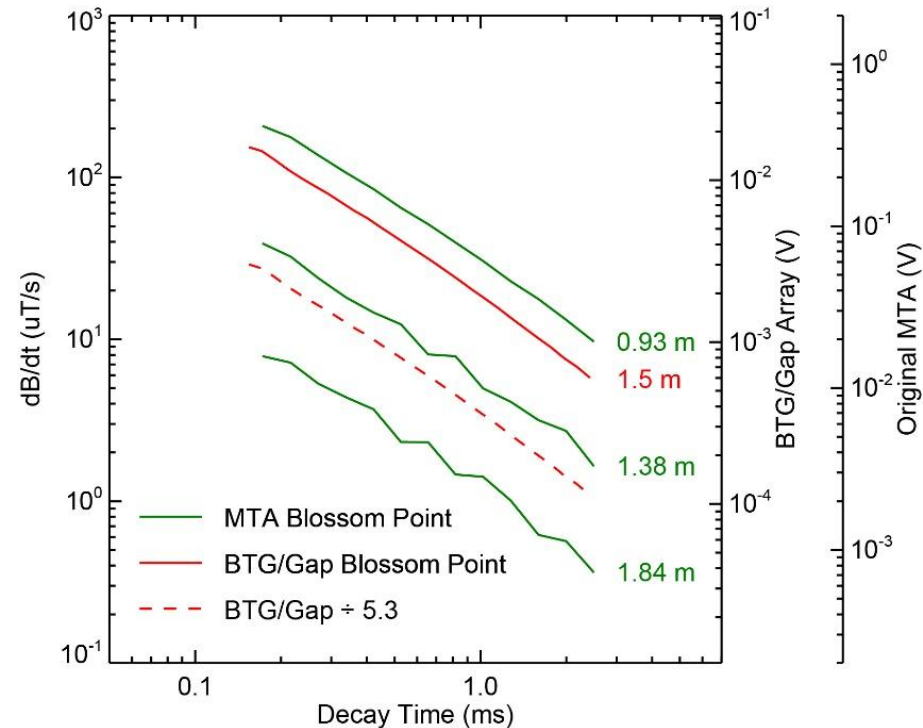
- When put on a common scale, the EODTx100M system exhibits ~40% lower noise as designed.
- If recomputed to match acquisition parameters, the noise levels of the systems are basically the same, as expected.

System	Sampling	Stacking	Gating
BTG/Gap	800 kHz	6	10%
MTA cDAQ	250 kHz	3	20%



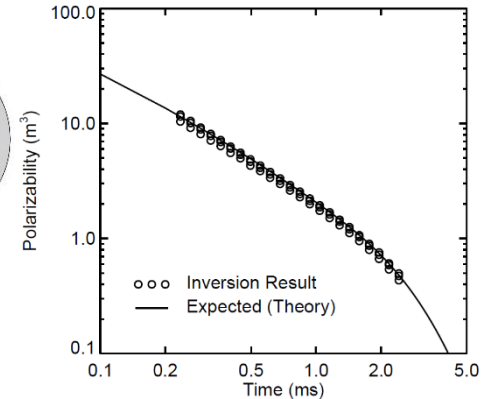
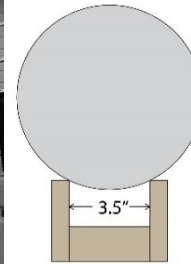
Response to a 12-in Dia. Sphere

- Data were collected with the ball rolling along on a rail below the array, midway between adjacent receivers. The ball was about 1.5 m below the array.
- Signals divided by the ratio of the total transmit currents (5.3x), results match, as expected.

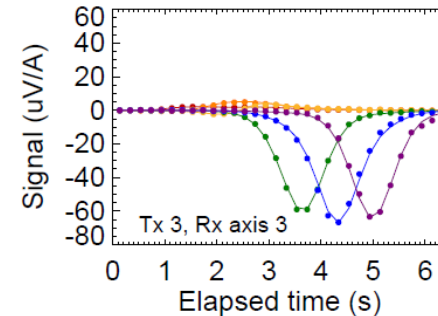
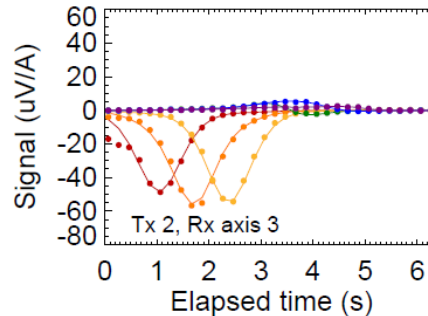
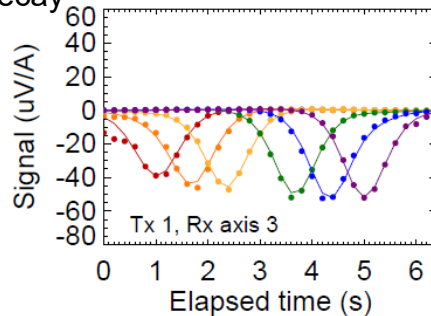


Response to 8-in Dia. Sphere

- 8-in diameter, 0.118" thick steel ball, 58cm
- All receivers giving responses per model
- The ball was rolling at a speed of 0.92 m/s
- The fit coherence was 0.980



1.59 ms Decay

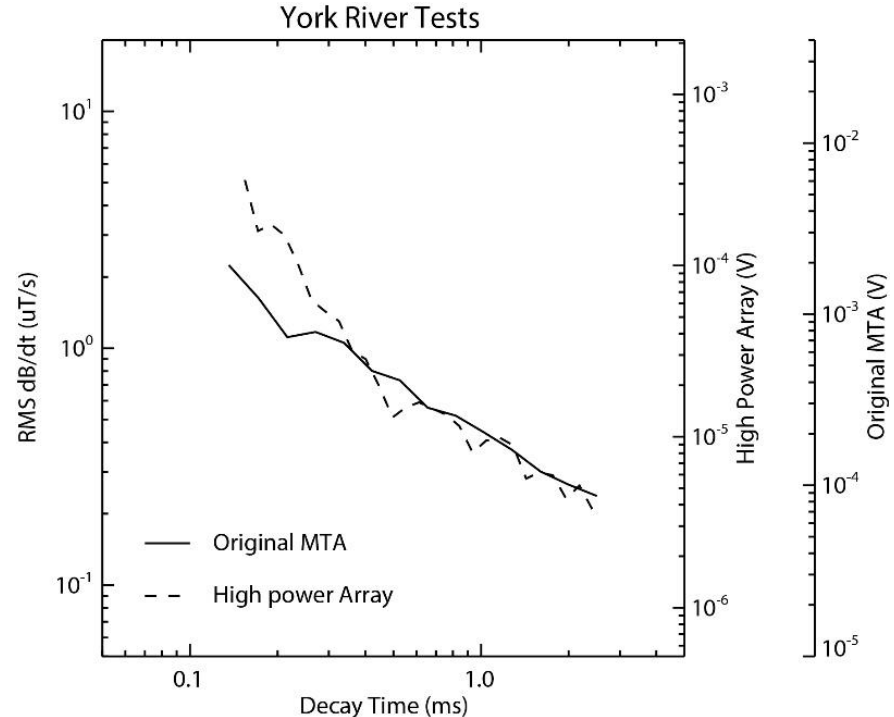


In-Water Testing – October, 2024

- Noise floor measurements
- The values are comparable
- Caution with reading too much into these one-time measurements made 5 years apart
- They are comparable, which is encouraging

Issue: EMI transmitters would often shut down when submerged. Suspect problem is with one of 4 connectors on custom TW power cable

Shakedown cut short due to inclement weather and target strip compromise



In-Water Testing – November, 2024

- One more try to wrap up shakedown:
 - Even with significant bracing, EMI transmitters would often shut down when submerged.
 - GapEOD provided standard bracing in July, 2025
 - The data aggregation / time stamping unit failed
 - One of the wing actuators failed. System will not recycle without both actuators functional
 - One installed T-cube was not responding correctly. Spare also not responding correctly
 - Unresolved issues with how data from BTField is written exported from database to HDF5 and ASCII files continued



Performance Objectives

Land-based Test Stand					Local, In-Water Testing				
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Cost Assessment

- **Cost Drivers**
 - # hectares / day surveyed
 - Data Analysis Time
 - Complexity / Higher Burden?
- **Cost Benefit**
 - Reduction of non-hazardous items to be reacquired and remediated leads directly to cost savings
 - Requires stakeholder buy-in to trust AGC-based decisions

Cost Element	Data Tracked	Cost
Data Collection Costs		
Pre/Post Survey Activities	Spares and repairs (/week)	\$9,000
	Mobilization and preparation	\$44,387
	Emplace IVS	\$4,400
	Initial IVS Survey	\$1,525
Survey Costs	Cost per survey day Cost per hectare Production Rate (ha/day)	\$8,570 / day \$413 / ha 20.7 ha/day
Processing Costs		\$1,485 / day \$72 / ha

Issue / Lessons Learned

- In-water system response to metallic targets to be verified.
- Issue with EMI transmitter shut down needs resolution.
- The receiver cube and file format issues are resolvable.
- 10-year-old equipment rapidly became 20-year-old equipment, with all of the issues that brings along
- The team believes the system is within arms reach of successful prove out, but the project is out of time and money.

Scale-up

- The concept is sound and the AGC technology will perform as designed
- The available version of the MTA wing is 20+ years old, based on many obsolete or aging-out components.
- Recommend taking the results of this effort as a guide to designing a modern version and implementing that for demonstration and full-scale remediation work.

Technology Transfer

- Our primary channel for technology transfer has been planned to be live demonstration and the results/products therein.
 - ~~Demonstrations~~
 - ~~Demonstration at Sequim Bay, WA~~
 - ~~Follow-on ESTCP Live Site demonstrations, as available~~
 - For each, attendance and briefing of relevant stakeholders, as feasible
 - Dissemination of NRL reports to relevant stakeholders
 - Presentation at relevant community conferences / workshops



Backup Slides

MR-21-5066: Classification of Underwater UXO from Dynamic EMI Survey Data

Performers:

- *NRL, Nova Research, BTG, GapEOD*

Technology Focus

- *Demonstrate that when outfitted with a high-power transmitter and modern EMI sensors, the MTA wing can reliably detect and classify underwater targets.*

Demonstration Site

- *Test Site in the York River, VA, near VIMS*

Demonstration Objectives

- *Design goal for system is the reliable detection and classification of a 105mm projectile at a standoff of >2 meters, allowing for routine operation of the array.*

Project Progress and Results

- *UltraTEM Marine performance (SNR, Tx current), as evaluated, are as designed*
- *Two major issues would require attention to continue*

Implementation

- *Two rounds of in-water shakedown testing undertaken. To continue, additional time and funding required..*



Plain Language Summary

- Technology which can effectively detect and classify targets at underwater munitions response sites is not widely available currently, while the DoD's liability of underwater munitions contamination is significant.
- The Marine Towed Array (MTA) is unique platform which is towed ~1m above the bottom behind a small surface vessel.
- A high-powered Electromagnetic Induction (EMI) system was developed from the UltraTEM Marine family to bring dynamic UXO detection and classification to the underwater regime using the MTA.
- The MTA is designed to “bottom-follow” using its control surfaces rather than relying on the vessel tow, providing superior altitude control and therefore classification-grade EMI data necessary for Advanced Geophysical Classification.

Impact to the DoD Mission

- A second shakedown cruise was completed, with two open issues
- Nothing so far indicates that the MTA specifically, or AGC in general cannot be very successful in the underwater world



Publications

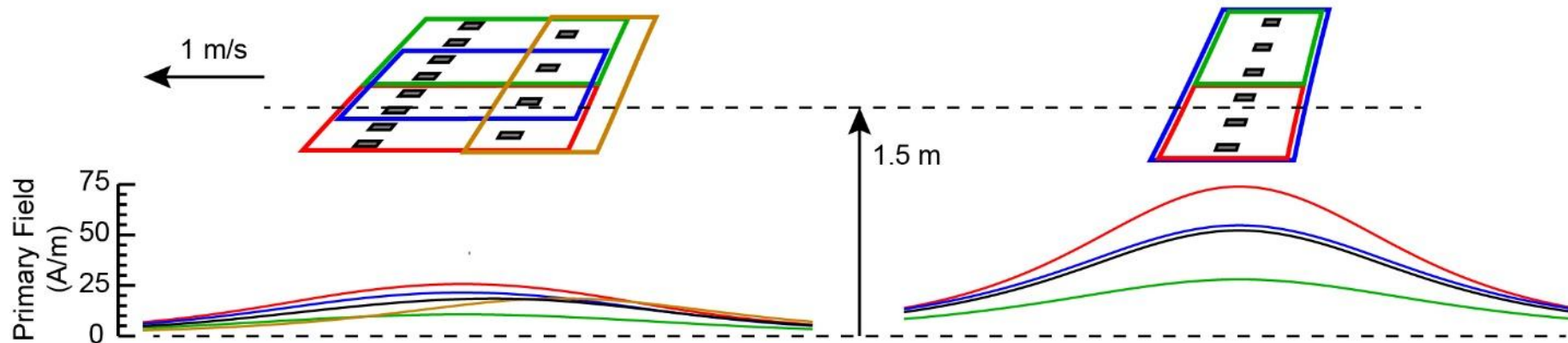
- “Classification of Underwater UXO from Dynamic EMI Survey Data, ESTCP MR-21-5066, DRAFT Final Report,” Bell, T.H., Massey, G.M., Billings, S.F., Harbaugh, G.R., Steinhurst, D.A., Wahl, K.J., July, 2025
- “Classification of Underwater UXO from Dynamic EMI Survey Data, Interim Report on EMI Transmitter Prototype Validation, v1, ESTCP Project MR-21-5066,” Steinhurst, D.A., Harbaugh, G.R., Bell, T.H., Billings, S.F., Mulvaney, S.P., July, 2022.
- “Classification of Underwater UXO from Dynamic EMI Survey Data Interim Report on EMI Array Design, ESTCP Project MR-21-5066, Steinhurst, D.A., Harbaugh, G.R., Bell, T.H., Billings, S.F., Mulvaney, S.P., March, 2022.
- “Underwater EMI Sensor Platform for Metallic Item Detection, Classification of Underwater UXO from Dynamic EMI Survey Data - ESTCP Project MR-21-5066,” Steinhurst, D.A., Harbaugh, G.R., Bell, T.H., S.F. Billings, Wahl, 2024 DoD Energy and Environment Innovation Symposium on 12/04/2024.
- “Classification of Underwater UXO from Dynamic EMI Survey Data - ESTCP Project MR-21-5066,” Steinhurst, D.A., Harbaugh, G.R., Bell, T.H., S.F. Billings, Wahl, , Presented at the 2023 DoD Energy and Environment Innovation Symposium on 11/29/2023, NRL IR-6170-23-6-U, dated 11/13/2023.
- “Classification of Underwater UXO from Dynamic EMI Survey Data - ESTCP Project MR-21-5066,” Steinhurst, D.A., Harbaugh, G.R., Bell, T.H., S.F. Billings, PA Whitener, K.E., Presented at the 2022 SERDP/ESTCP/OE-Innovation Symposium on 11/29/2022, NRL IR-6177-22-29-U, dated 11/21/2022.
- “Classification of Underwater UXO from Dynamic EMI Survey Data, MR-21-5066,” Daniel A. Steinhurst; Glenn R. Harbaugh; Thomas H. Bell; Stephen Billings; and Shawn P. Mulvaney, presented at the SERDP and ESTCP Symposium 2021, November 29 – December 3, 2021, a virtual event.

Compare UltraTEMA-4 vs Existing Array

“Why does the design of this project target such a significantly higher MMF?”

UltraTEM Marine

Marine Towed Array



- Peak primary field strength: MTA 2.8x that of the UltraTEM Marine
- FWHM extents of the transmit fields along track: UltraTEMA-4 2.3x that for the MTA