Underwater UXO targets detection, mapping and classification from onepass dynamic data sets

Project Number MR23-9000

Principal Investigator: Fridon Shubitidze

PI's Organization: Dartmouth College

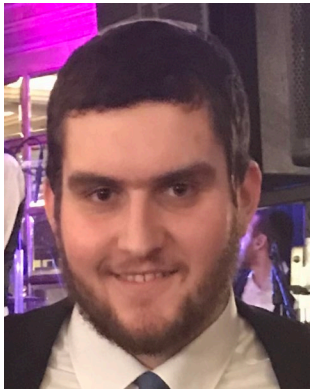
In Progress Review Meeting

01/14/2026

Project Team

Dr. Fridon Shubitidze
Thayer School of Engineering, Dartmouth College

Grad Student



Mr. Maximilian Orman-Kollmar

- Military Installation Contact: SERDP-ESTC

Overview:

- The project's objectives:
  - Determine feasibility of using one-pass dynamic UW EMI sensors data sets for targets detection and classification
  - Understand and mitigate the sensor motion/orientation effects.
  - Process UW dynamic data sets.
  - Assess classification performance.

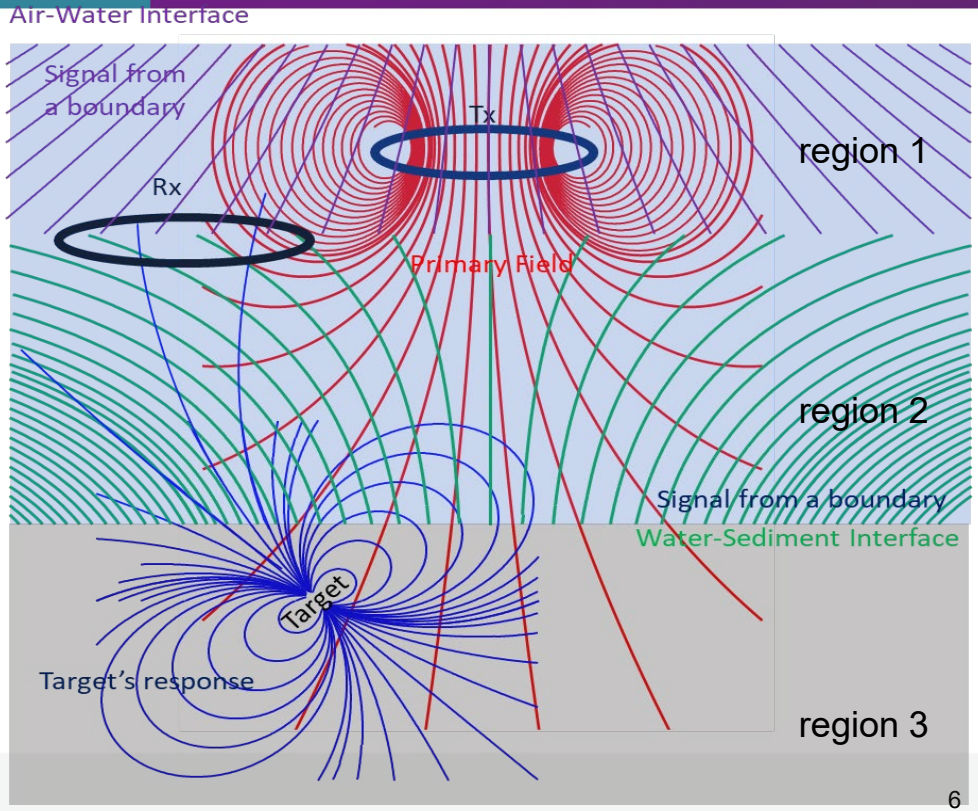
Bottom Line Up Front

- **Goal:** Evaluate the applicability of UW EMI systems and data processing algorithms for detecting, locating, and classifying UW targets using single-pass EMI data set.
- **Technologies tested**
  - Advanced EMI signal-processing algorithms applied to raw ULTRATEMA datasets collected at a U.S. Navy site.
  - Innovative noise-filtering techniques were tested for background noise and unexpected, non-physical signal spikes removal.
  - Forward and inverse EMI modeling frameworks were employed for data inversion and target classification.
- **Results:**
  - Data spikes and background noise were successfully removed, resulting in improved target detection performance.
  - Robust target-classification features were extracted, and detected anomalies were classified.
- **Challenges:**
  - Variability in UW geolocation accuracy, combined with EMI sensor signal spikes, has the potential to degrade data quality and pose significant challenges for targets classification.
- **Support needed**
  - Ground-truth data are required to fully assess and validate the classification performance of the developed algorithms.

Site Description

- The data for this demonstration were collected at a U.S. Navy site using the ULTRATEMA sensor.
- The demonstration area was divided into three sections, with each section further subdivided into shallow and deep zones.
- For this deployment, the ULTRATEMA system used a slightly modified transmitter configuration, operating with three Tx coils instead of the four used in earlier demos.
- The data were delivered as ascii files with multiple formats.

EMI sensing in underwater environment



- The total field in Region 2 is the sum of the fields produced by the transmitter coil (response from water), reflected fields from boundaries, and fields from a target.
- The fields in Region 1 are the transmitted fields.
- The total field in Region 3 is the sum of the transmitted fields and the response from a target.
- During dynamic data collection mode, the Rx coils move within a time-varying magnetic field, resulting in additional motion-induced signals.

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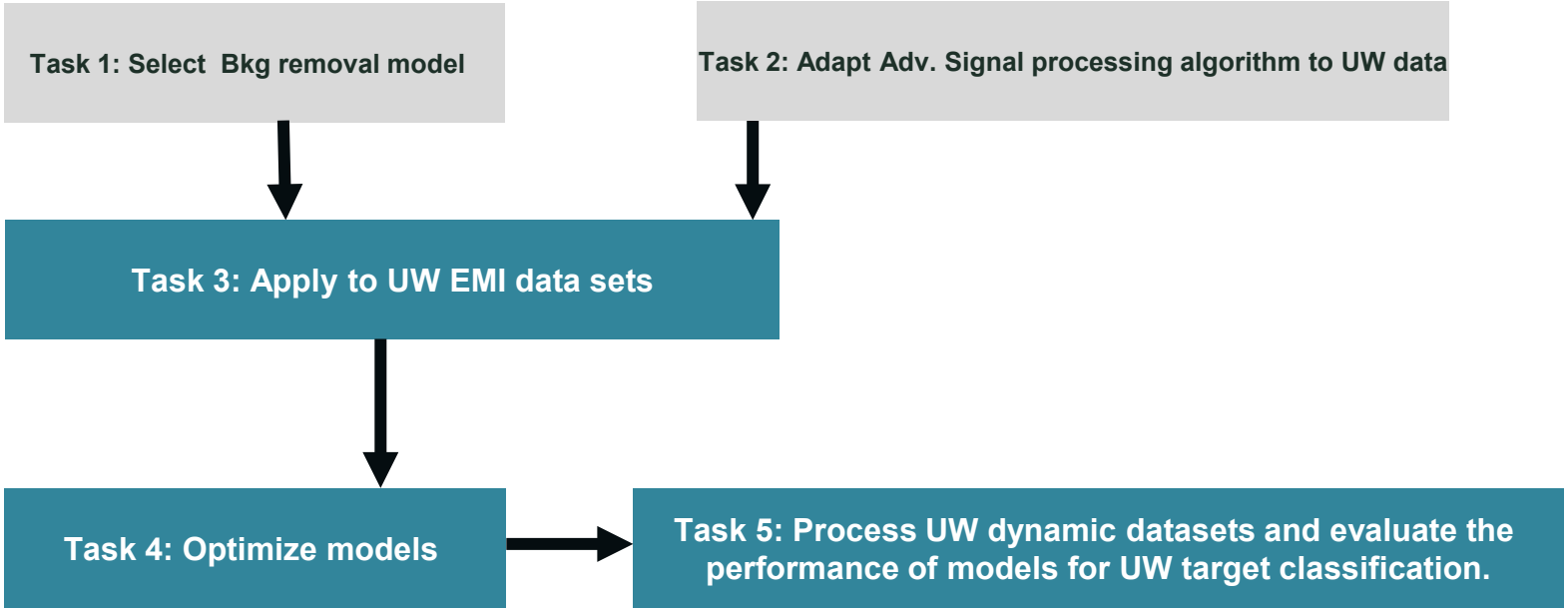
Technical Approach



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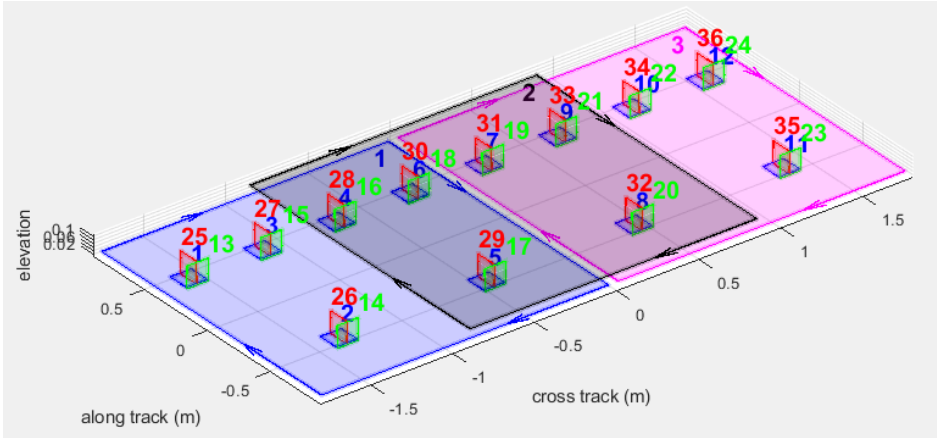
Performance Objectives

Performance Objective	Data Requirements	Success Criteria
Quantitative Performance Objectives		
UW anomalies detection	UW blind data set and GT	•All anomalies located within 20 times their diameter from the transmitter are detected.
Accuracy of locating all seeded UW targets	Targets GPS locations	•Less than 0.75 meters distance between actual and predicted locations for buried anomalies. •less than 3.5 meters for proud and surface anomalies.
Targets classification	UW blind data set and TOI information	•All detected Targets of Interest (TOI) are classified accurately, while maintaining minimal false positives (less than 20% of TOI)."

UltraTEMA: Single-Pass UW EMI detection and classification system



The UltraTEMA system consists of three transmitter coils and twelve vector receiver sensors. It measures complete EMI response of a target at each dynamic data point and provides 108 data value at each n^{th} (n=1,2, .., 25) time gate.

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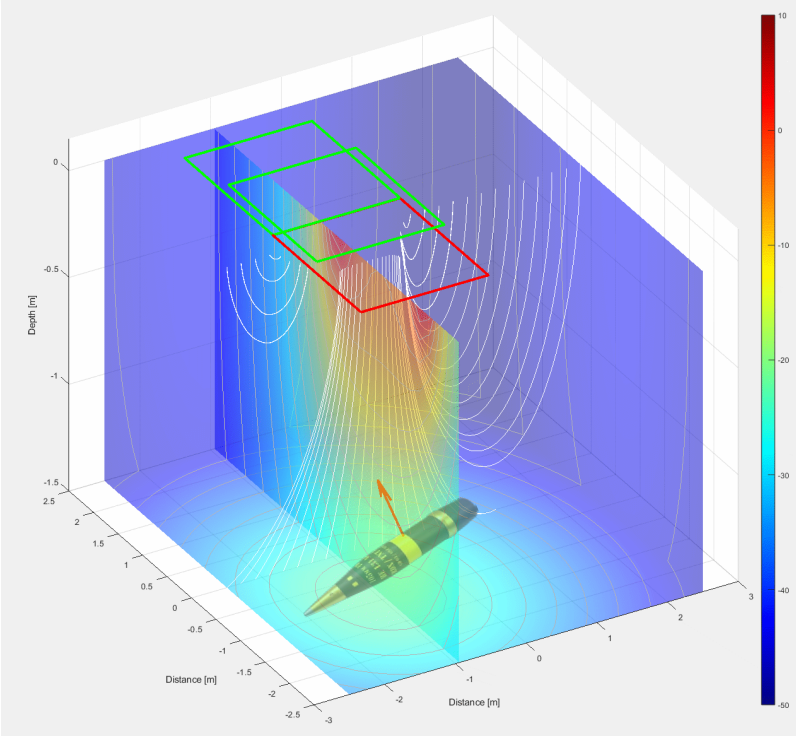
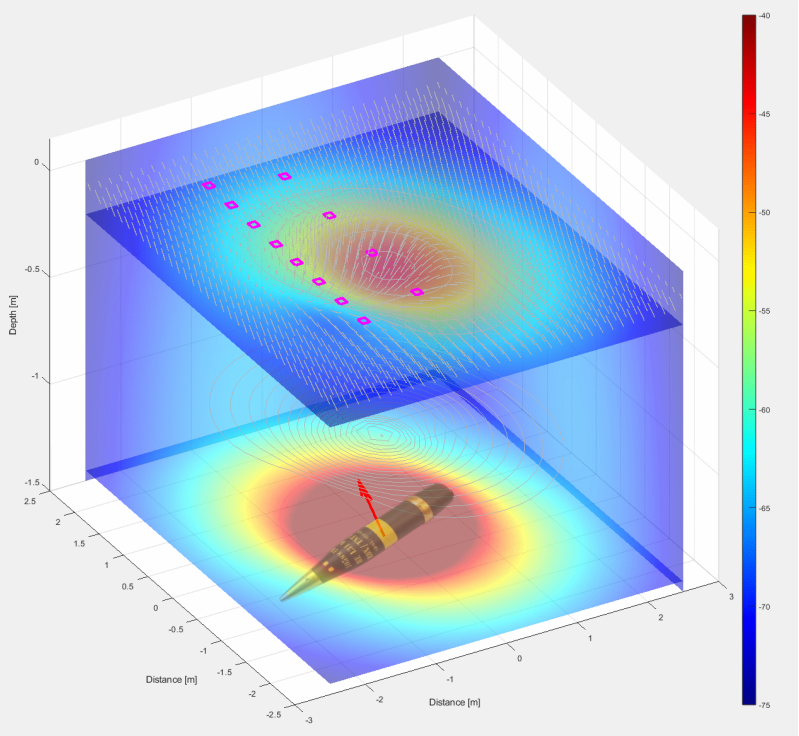
ULTRATEMA Operation principles





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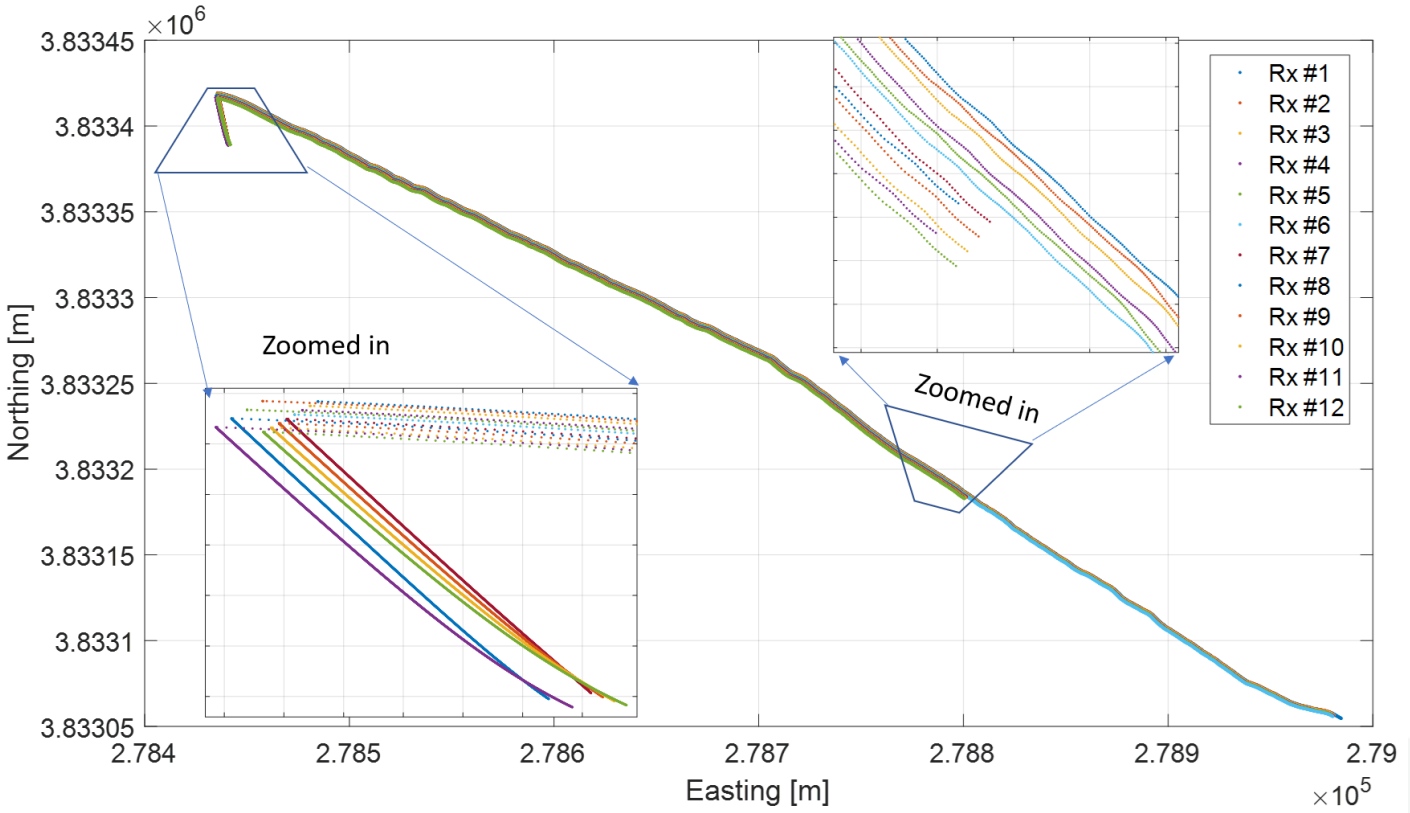
Position Errors



Data Errors

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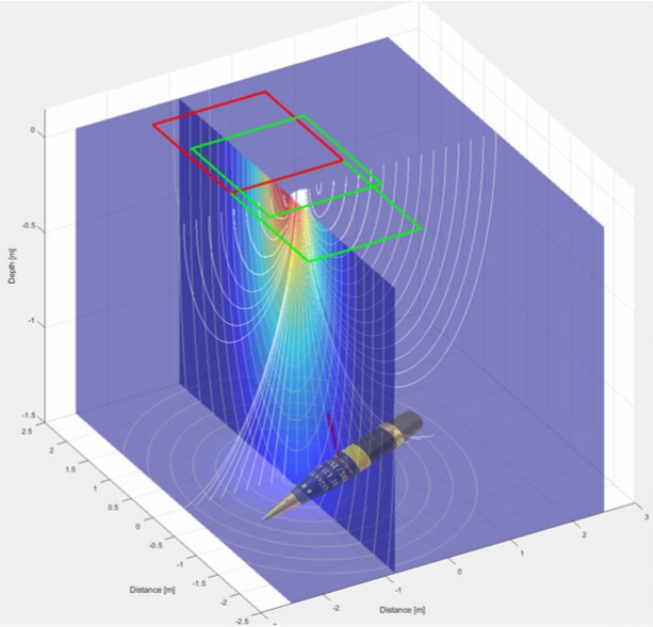

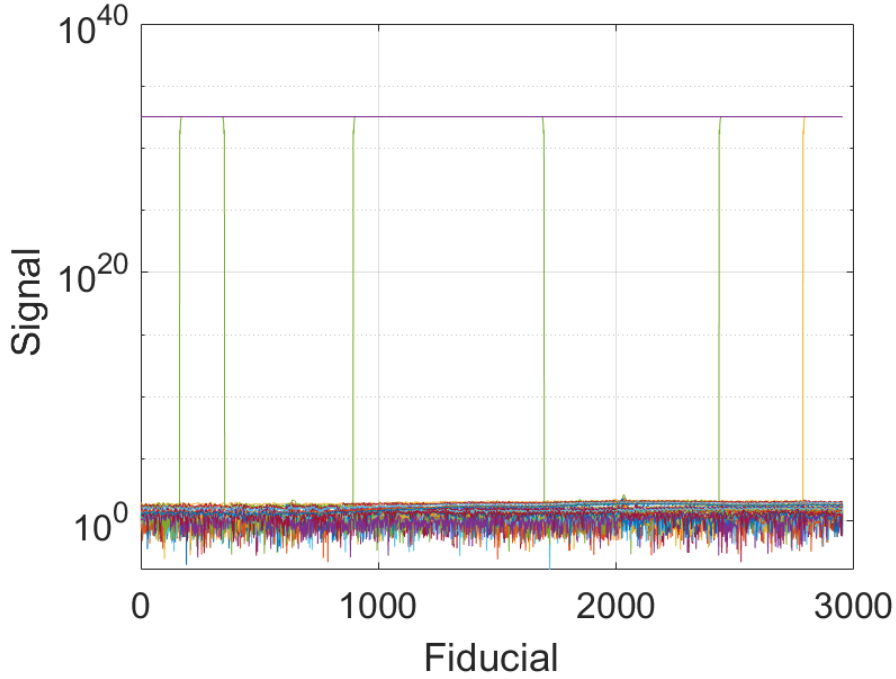

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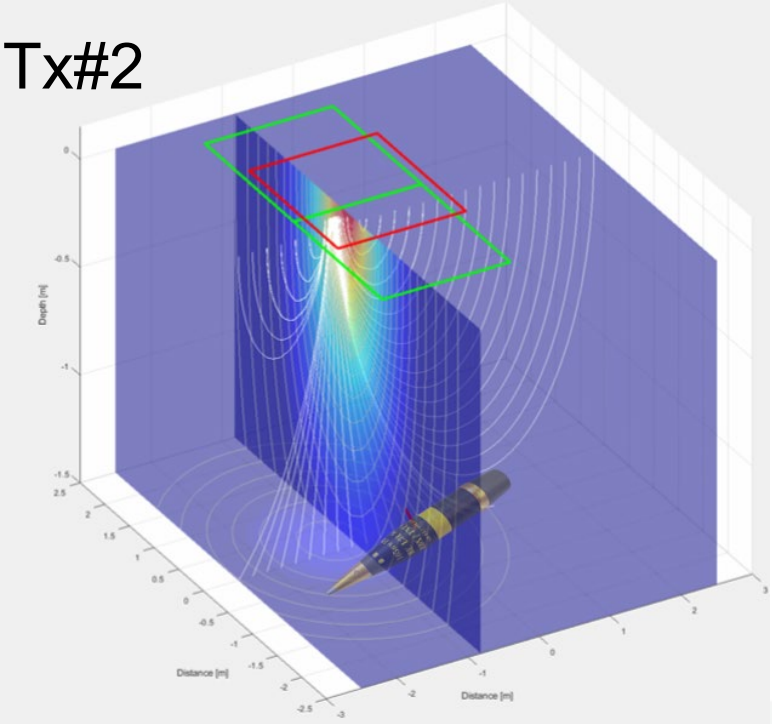

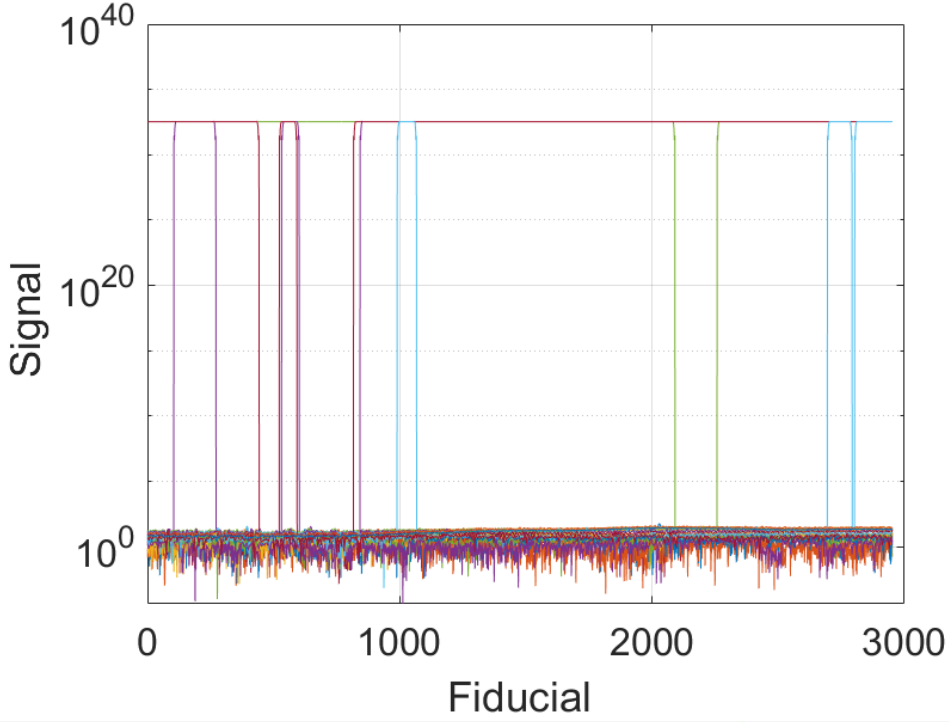

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Data Errors

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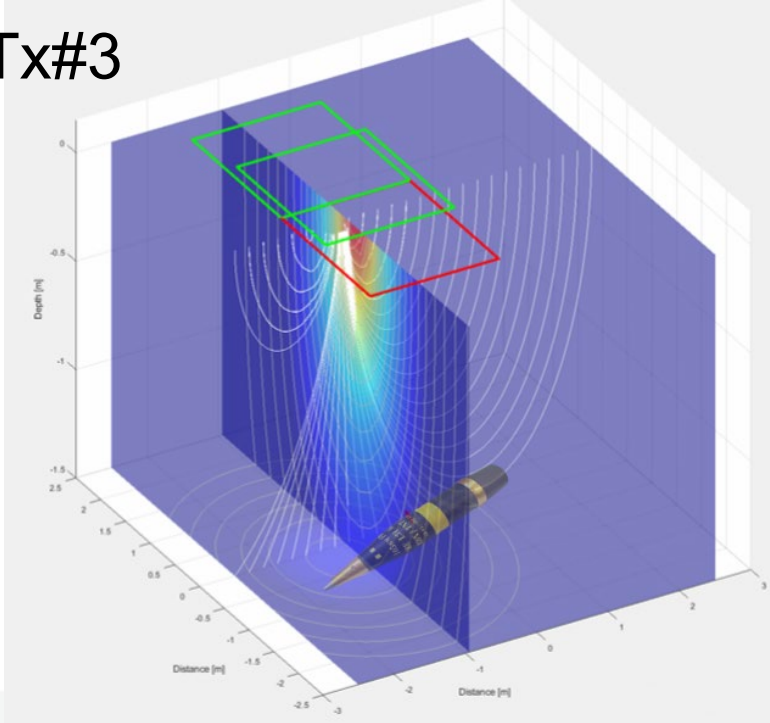

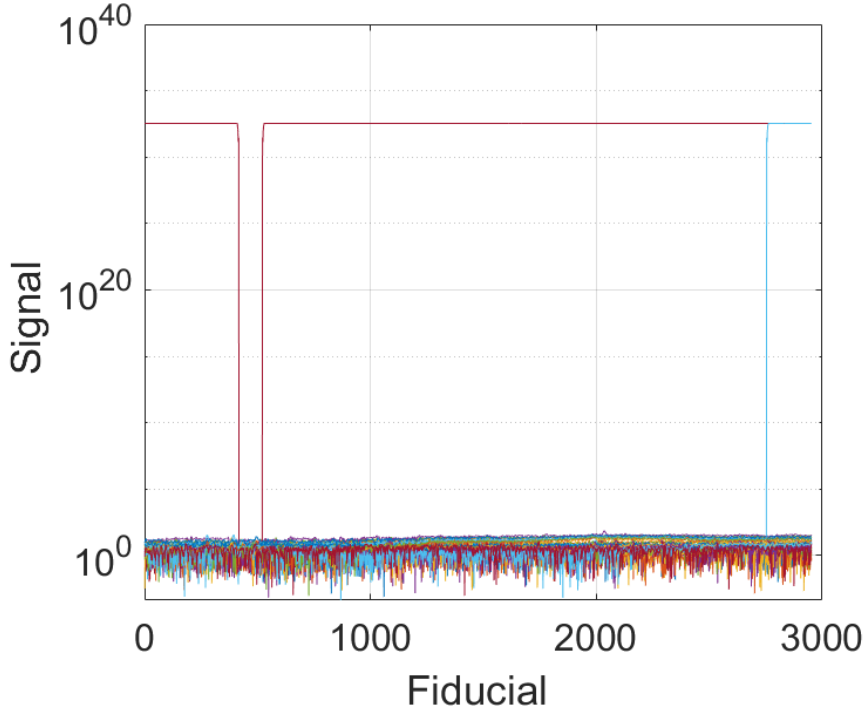

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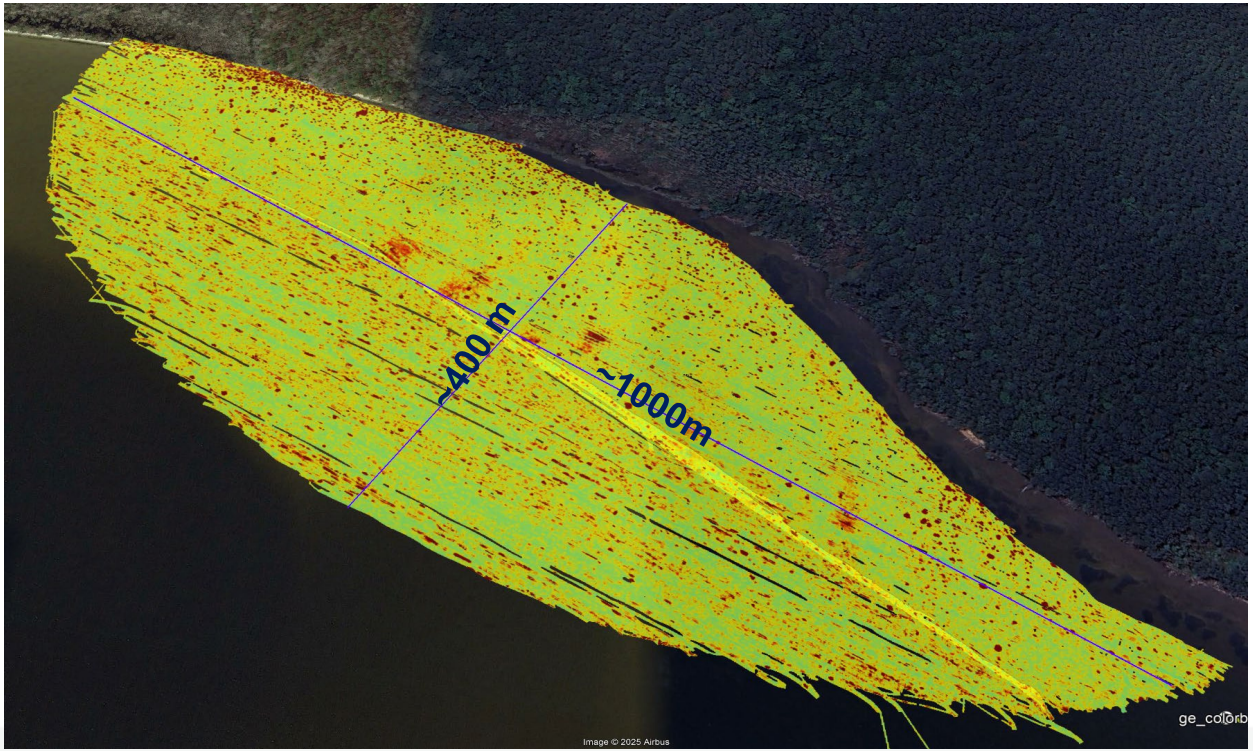
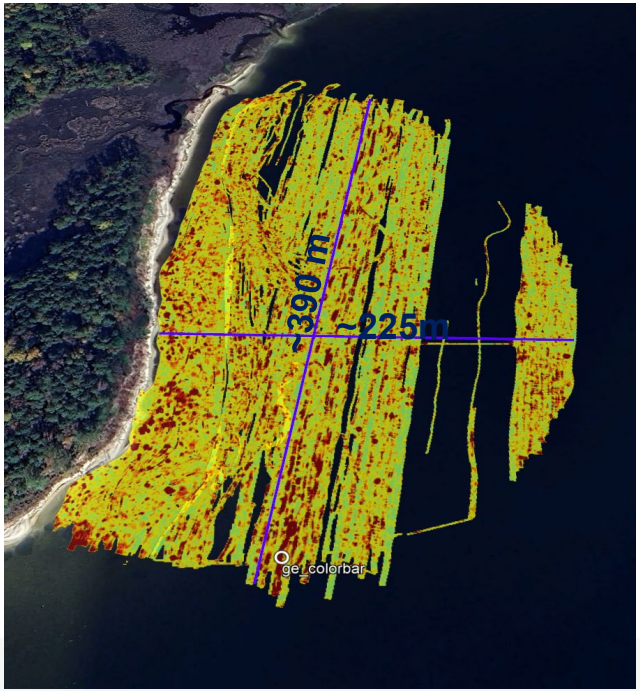
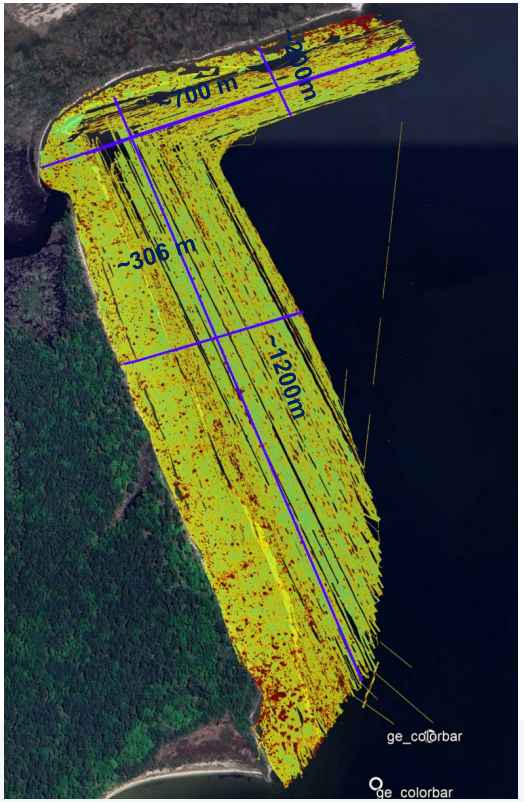
Detection map for area #1



Detection maps for area #2 and area #3

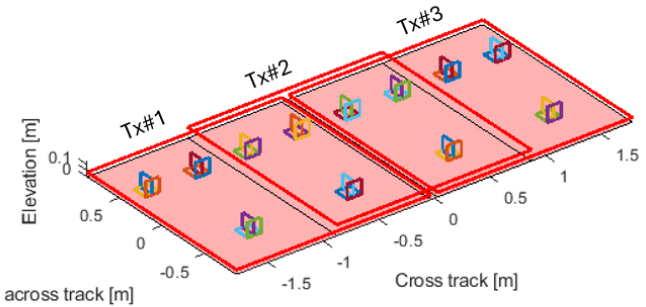




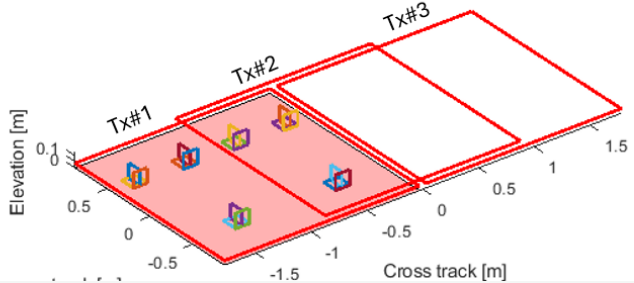
Data Inversion Scheme

Using four receiver sets for each dynamic data inversion

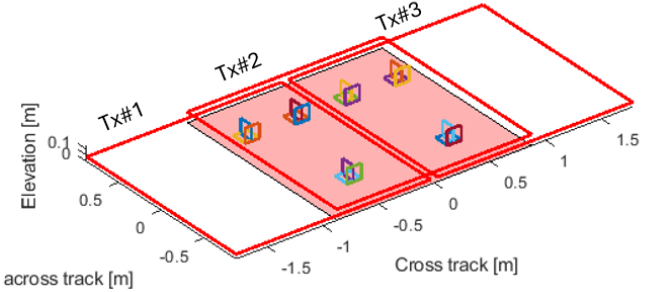
•**Set #1:** Complete array of 12 triaxial receivers



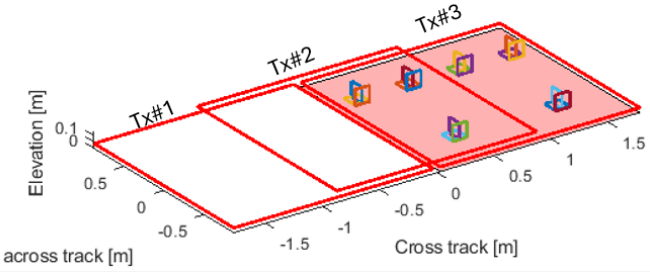
•**Set #2:** Subset of triaxial receivers 1–6



•**Set #3:** Subset of triaxial receivers 4–9



•**Set #4:** Subset of triaxial receivers 7–12



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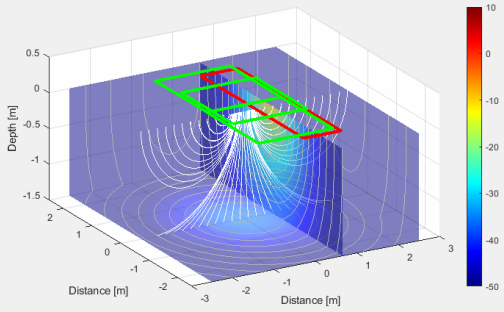
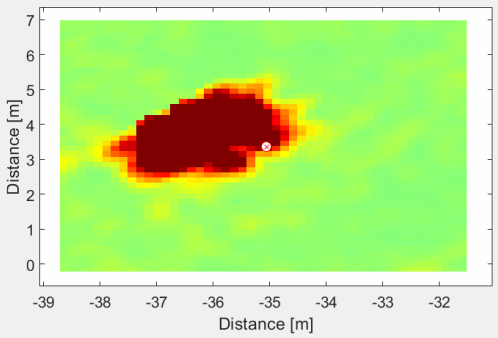
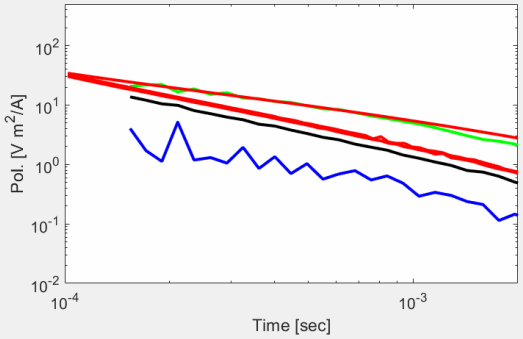
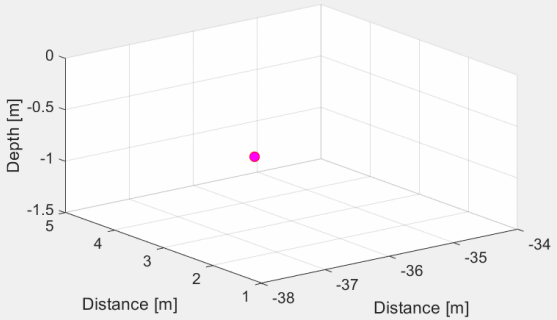
Results: Single-Pass data processing



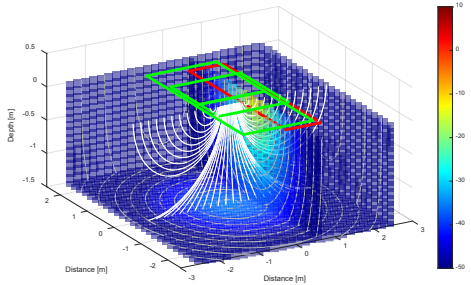


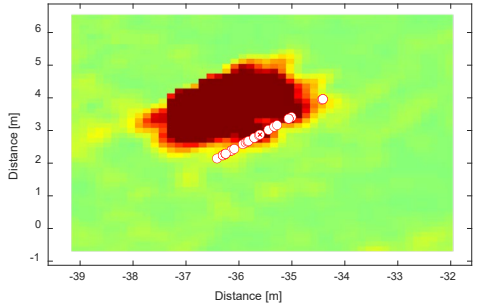


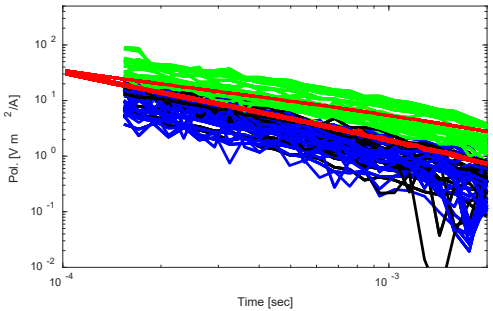


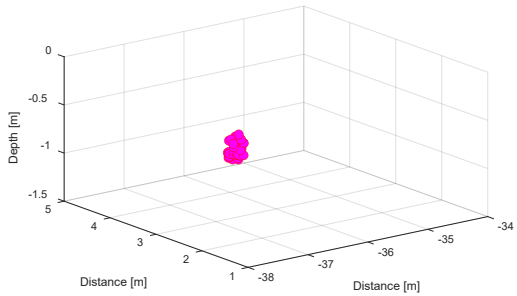
- A set of dynamic data points is identified around the target.
- An objective function is defined as the simple difference between two data points.
- The target's location and classification features are extracted from each objective function.

Results: Clustering polarizabilities and locations





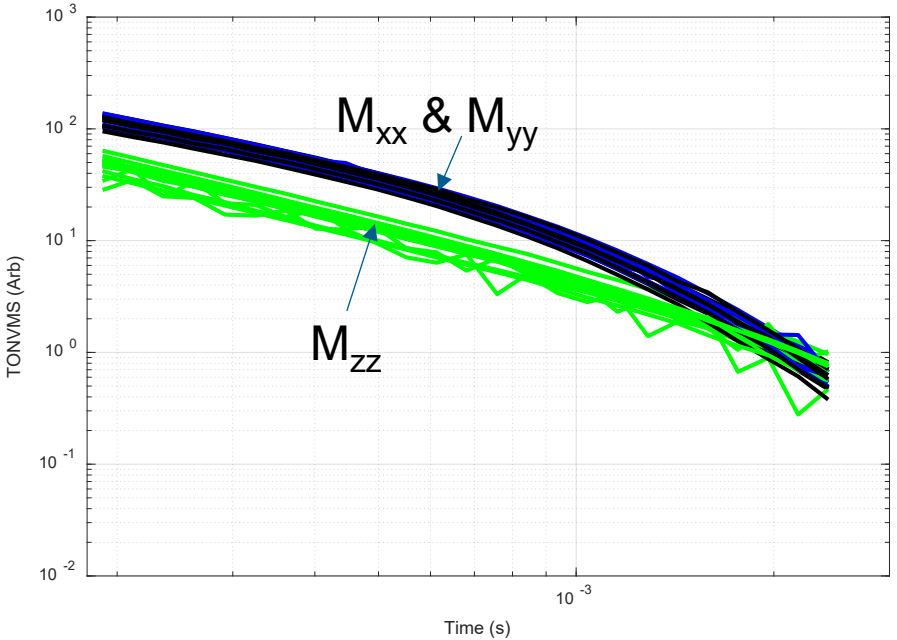


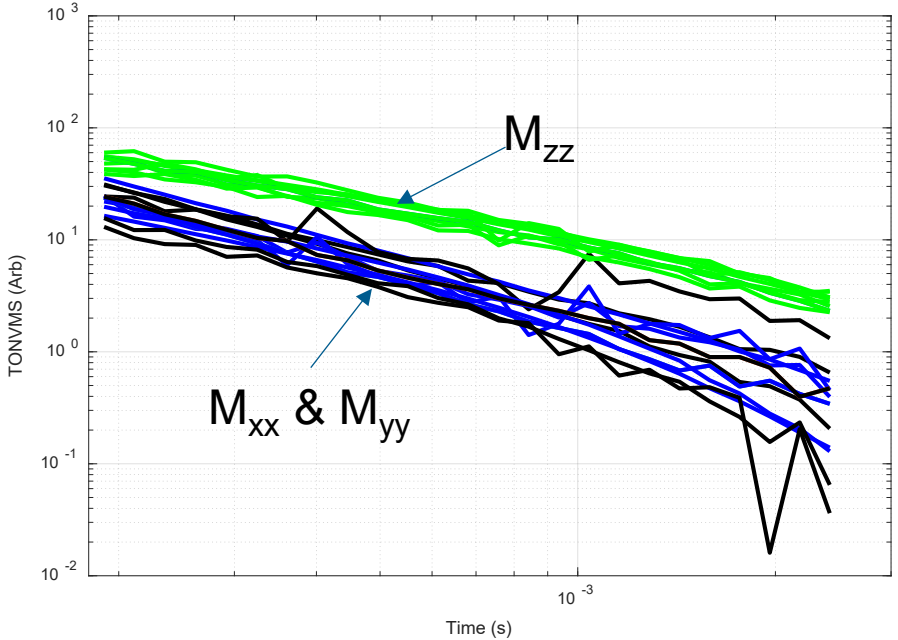


- The extracted noisy effective polarizabilities and their corresponding locations are discarded.
- The remaining locations are grouped into clusters.
- Within each cluster, the effective polarizabilities are sorted and stacked.

Results: Extracting Classification Features of Targets

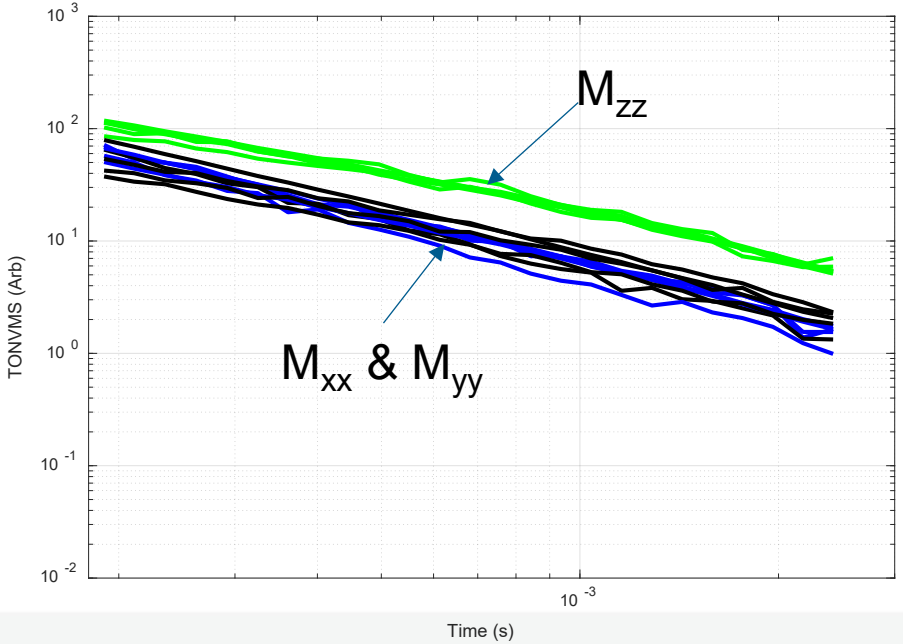
Extracted effective polarizabilities

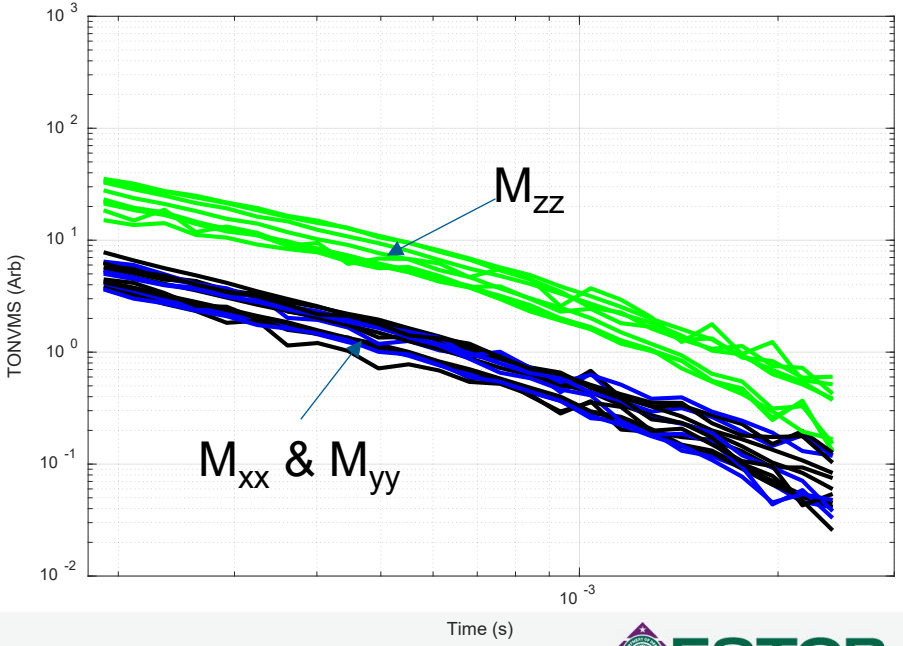




Results: Extracting Classification Features of Targets

Extracted effective polarizabilities





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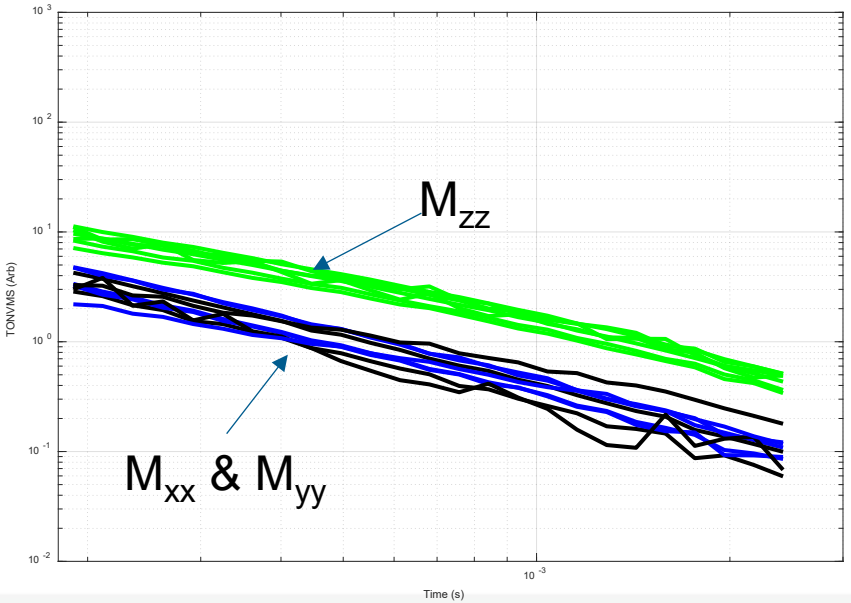
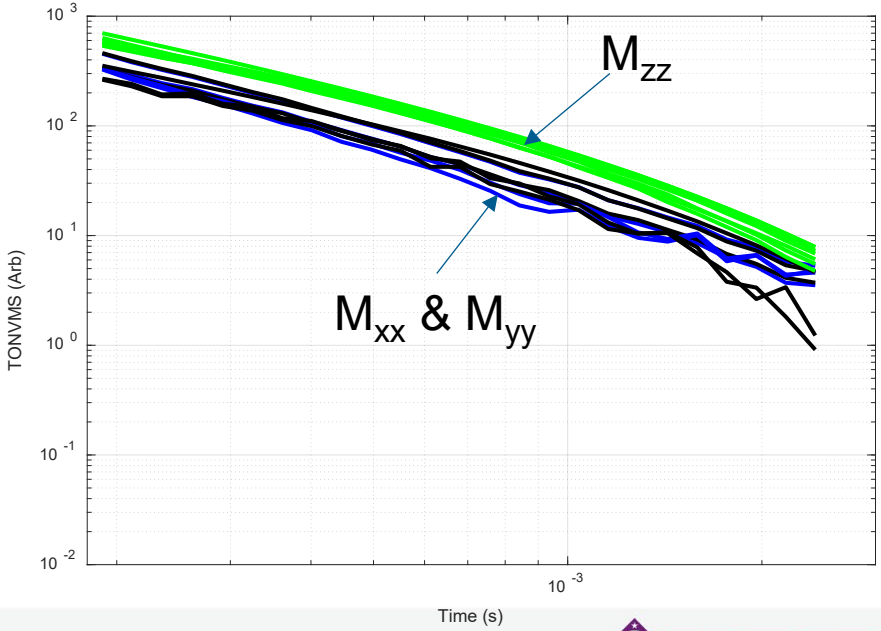
Results: Extracting Classification Features of Targets

Extracted effective polarizabilities





Issues

- GPS locations

Next Steps

- Classify the targets.
- Evaluate the models' classification performances for detecting and classifying UW targets.
- Submit a journal paper by 03/31/2026
- Submit the final report by 7/31/2026.

Technology Transfer

- The numerical models and classification results will be presented at conferences and published in peer-reviewed journals.
- The final report will provide a detailed overview of the technologies and results for the broader UXO community.
- Additionally, the UW data processing modules and target classification algorithms will be adapted for use with other UW EMI systems.

BACKUP MATERIAL

These charts are required and will be used by the Program Office but may not be presented.

Publications

Publications and Conference Presentations

1. Shubitidze, F., Orman-Kollmar, M. A., Shamatava, I. (2025).
   Innovative Background Noise Removal Technique for Underwater Target Detection and Classification.
   In Proceedings of the 37th Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP 2025) and 3rd Munitions Response Meeting, Denver, Colorado, USA, April 13–17, 2025.
2. Shubitidze, F., Reynolds, R., Orman-Kollmar, M. A., Maxson, M., Barrowes, B., Philippeau, H., Arrieta, R. (2024).
   ULEMA-SEAL: Explosive Ordnance Detection, Localization, and Identification.
   Presented at the U.S. Bomb Technician Association (USBA) Conference, National Harbor, Maryland, December 2024.
3. Reynolds, R., Maxson, M., Barrowes, B., Shubitidze, F. (2024).
   Ultra High-Frequency EMI System for Detecting Explosive Remnants of War.
   In Summit of Geophysical Detection of Explosive Remnants of War, Environmental and Engineering Geophysical Society (EEGS), pp. 25–26.
4. Maxson, M., Reynolds, R., Orman-Kollmar, M. A., Barrowes, B., Shubitidze, F. (2024).
   ULEMA Systems: Detecting and Identifying Explosive Remnants of War (ERW) in Hazardous Environments.
   In Summit of Geophysical Detection of Explosive Remnants of War, Environmental and Engineering Geophysical Society (EEGS), pp. 25–26.
5. Shubitidze, F., Shamatava, I., Barrowes, B. (2023).
   Enhanced EMI Models for Underwater Target Detection and Classification.
   In Applied Computational Electromagnetics Society (ACES) Conference Proceedings, ISBN 978-1-7335096-3-3, © 2023 ACES.

Literature Cited

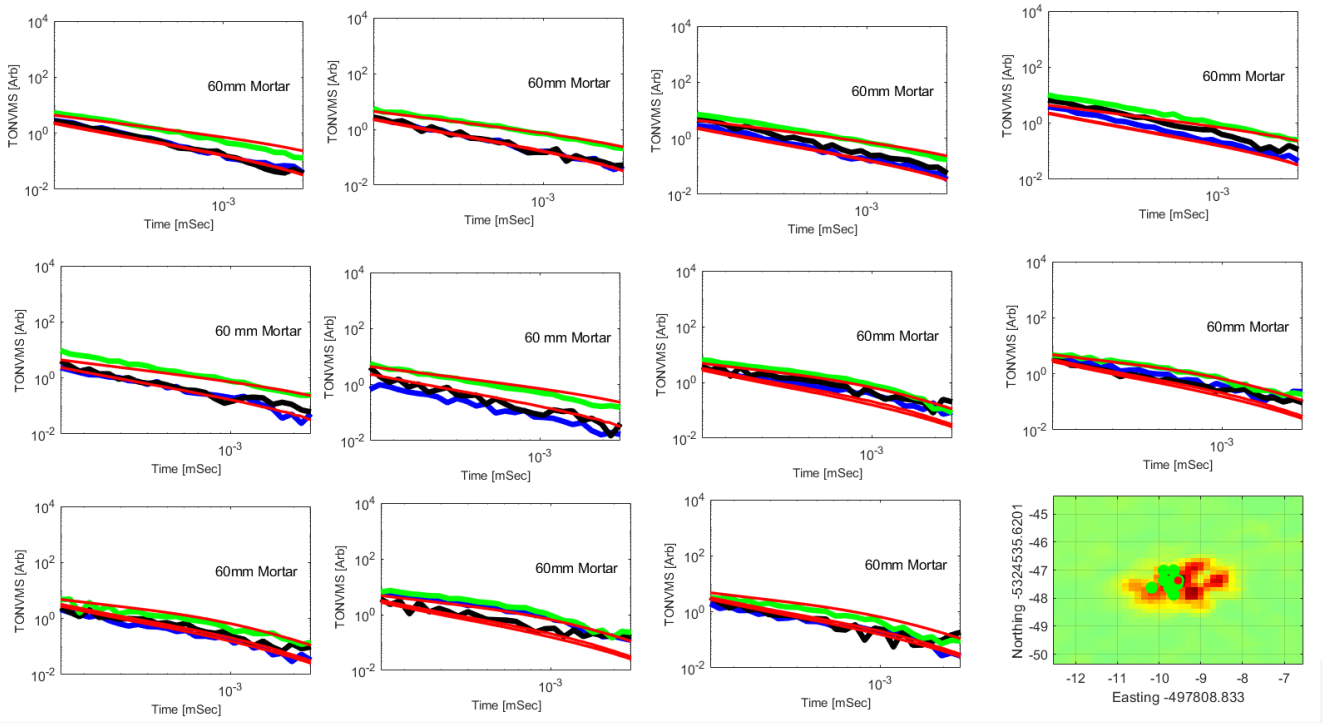
1. Stephen Billings and S. Lin-Ping, SERDP-Project # MR-2412: “Determining Detection and Classification Potential of Munitions Using Advanced EMI Sensors in the Underwater Environment” Final report.
2. S. Cazares, M. Tuley, and E. Ayers, “The UXO Classification Demonstration at Former Camp Butner, NC,” 2011 [Online]. Available: http://serdpestcp.org/content/download/12777/151554/version/1/file/IDA_Camp+Butner_Report_1-13.pdf.
3. F. Shubitidze et al., “A complex approach to UXO discrimination: Combining advanced EMI forward models and statistical signal processing,” SERDP MR-1572 Final Report, January 2012.
4. F. Shubitidze, J. P. Fernández, B.E. Barrowes, I. Shamatava, A. Bijamov, K. O’Neill, D. Karkashadze, " The orthonormalized volume magnetic source model for discrimination of unexploded ordnance", *IEEE Transactions on Geo-Science and Remote Sensing, Digital Object Identifier 10.1109/TGRS.2013.2283346*
5. Stephen Billings, Richard Funk, Jeff Gamey, September 2022, UltraTEM Marine towed system for detection and characterization of buried ordnance, ESTCP MR19-5073 Sequim Bay Demonstration Plan,

Acronym List

AGC	Advanced Geophysical Classification
cm	Centimeter
CRREL	*Cold Regions Research and Engineering Laboratory*
DAQ	Data acquisition
DoD	Department of Defence
EMI	Electromagnetic induction
ERDC	*Engineering Research and Development Center*
ESTCP	Environmental Security Technology Certification Program
µs	Microsecond
ISO	Industry Standard Object
kHz	*Kilo Hertz*
MAS	Method of auxiliary source
mm	Millimeter
ms	Millisecond
MuST	Multi-Sensor Towbody
ONVMS	Orthogonal normalized volume magnetic source
ONV/SMS	Orthonormalized volume or surface magnetic source models
PI	*Principal investigator*
Rx	*Receiver*
SERDP	Strategic Environmental Research and Development Program
TD	Time domain
TRL	*Technical Readiness Level*
Tx	*Transmitter*
UltraTEMA	Ultra transient electromagnetic Array
USACE	*United States Army Corps of Engineers*
UXO	Unexploded ordnance
UW	Underwater

Results: Extracting Classification Features of Targets

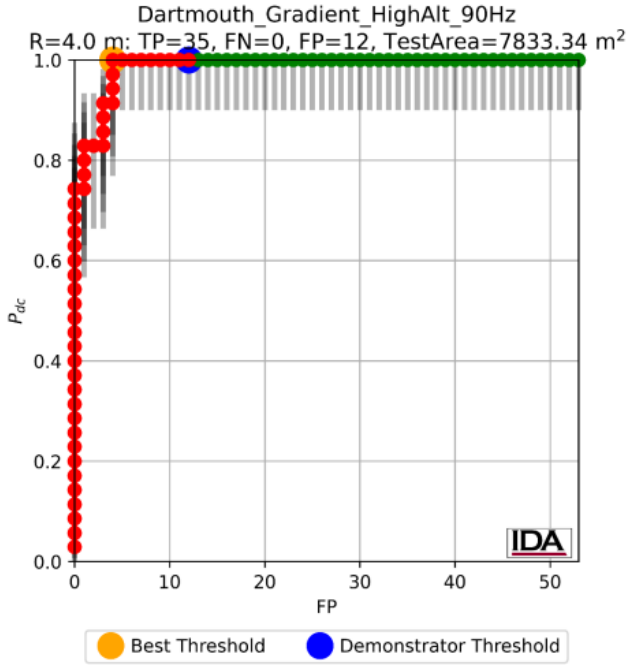
Extracted effective polarizabilities



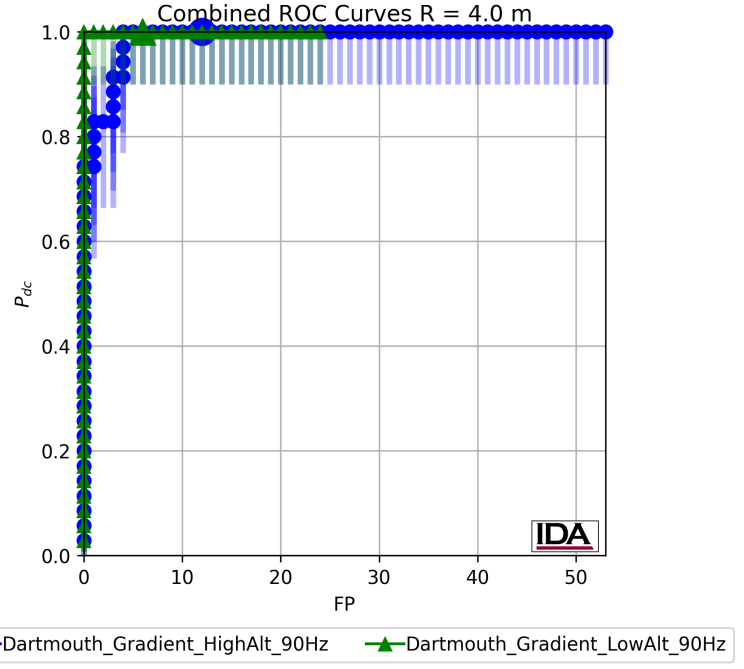
60 mm mortar

ROC Curves for high altitude data

High Altitude



Comparison between low and high altitude ROCs.



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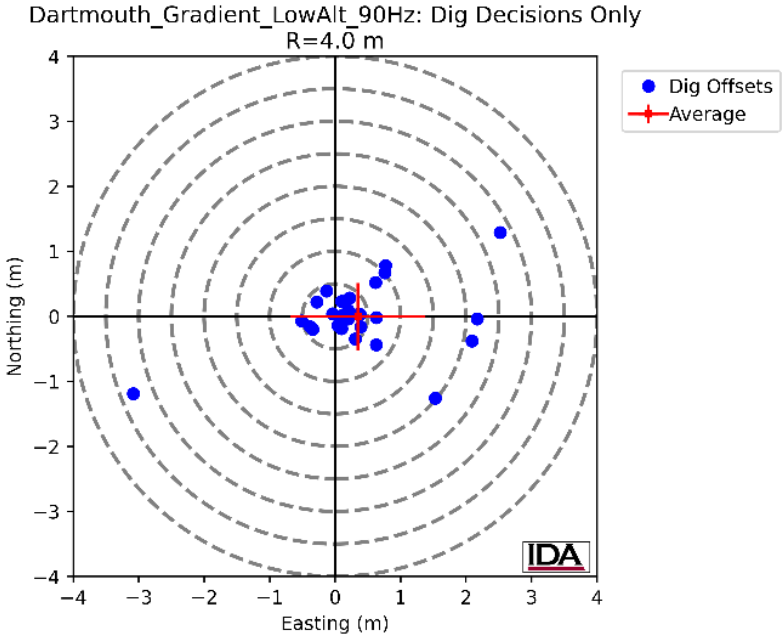
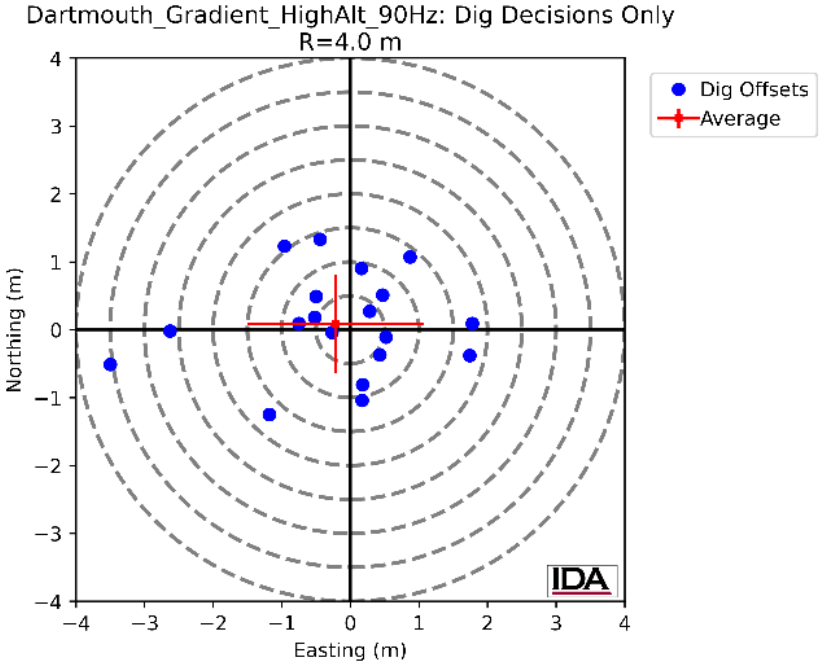
Comparison Between Location offsets





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