Live Underwater Munitions Detection & Classification: Maine Bombing Range

MR25-8992

Greg Schultz
White River Technologies

In-Progress Review

14 January 2025

Project Team

white river technologies

Greensea IQ

PIKA INTERNATIONAL, INC.

Dr. Gregory Schultz (PI), WRT
MAG & EM UXO Sensing

Joe Keranen, WRT
Lead AGC Analyst
DAGCAP GDC/GDA/QGC

Michael Gunnels, WRT
Lead Part 107 Pilot &
DAGCAP GDC/GDA

Tom Spiro, GSIQ
Lead Crawler Ops Eng

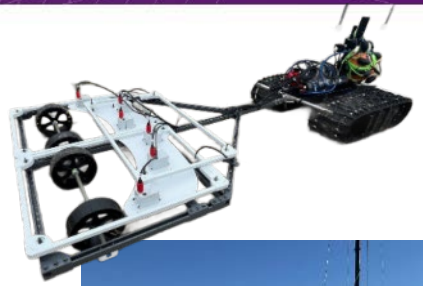
John Dunn, GSIQ
Chief Operations Officer
Marine Operations Expert

Shawn Cochran, PIKA
UXO Program Manager
USN Master EOD Disposal

Bottom Line Up Front

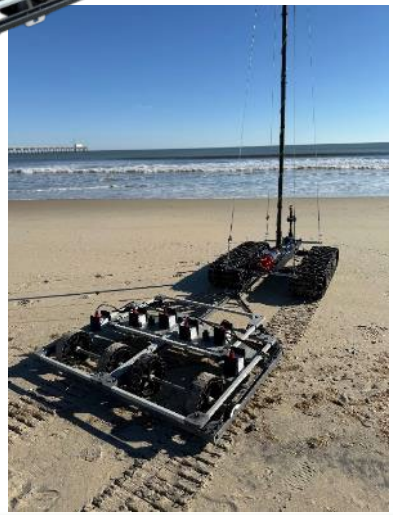
Technology Focus

- *Nearshore operations for munitions response needs rapid and cost-effective deployment for both in-water and over-water (air) surveying*
- *Transition to full-scale in-water detection & classification needed*



Accomplishments

- *Fully planned, mobilized, and completed Duck FRF crawler-EM surveys*
- *Analyzed blind grid data and submitted dig lists*
- *MBA stakeholder coordination, UAS-MAG follow-on mission planning completed*
- *MBA Demo Plan drafted and IPT (UAS, GSIQ, PIKA) coordination underway*



Challenges

- *Positioning errors for completely submerged implementations (INS NAV/POS)*
- *Environmental noise may generate additional anomalies*

Implementation Support

- *Site access / stakeholder coordination and site preparation support (seeds, bathy)*

Site Description: MBA

Former Maine Bombing Range
700-ac State Park Mid-Coast ME

- **FUDS naval air training site**
- **Active from 1940-1973**
- **30-Acres Covered w/ UAS-MAG in March 2024 by WRT**
- **VSW, Surf, Beach, Dunes**

Surf *Beach* *Dunes* *Marsh*

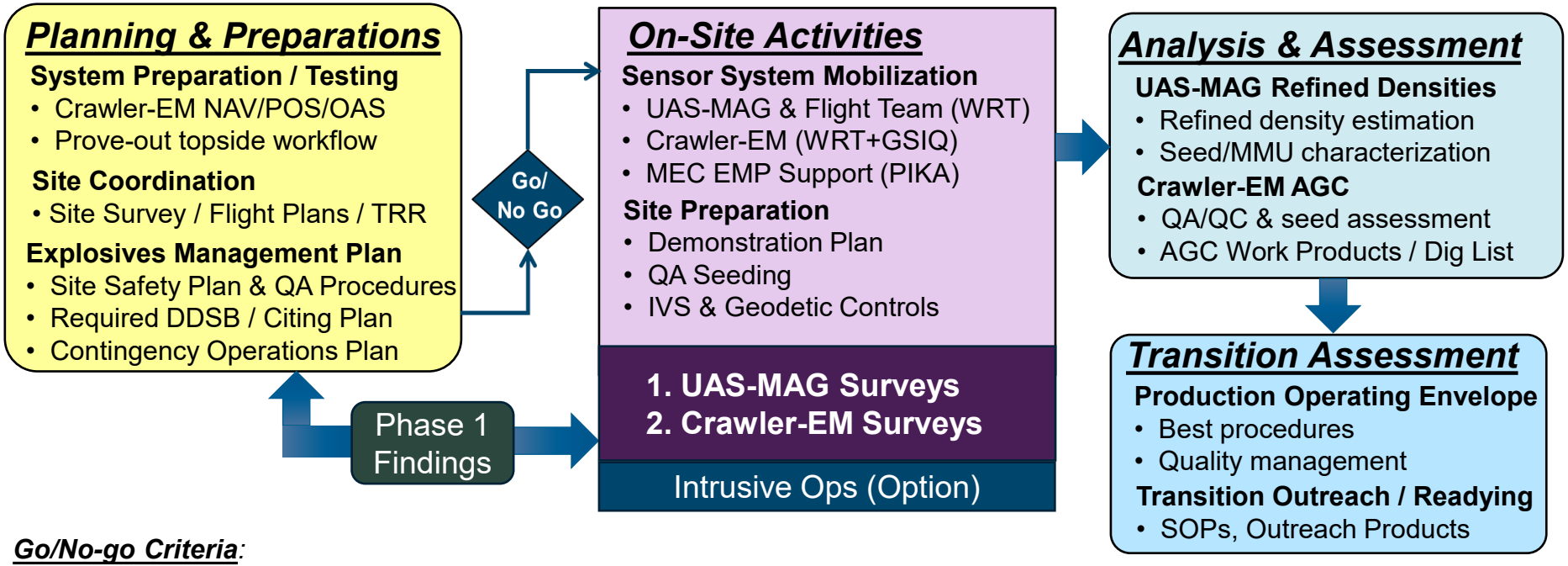
Phase 1 flight team →

MBA Live Site: Overarching Goals

*Combining **amphibious platforms** with **electromagnetic sensor payloads** fills current gaps in munition detection in challenging shallow UXO environments.*

1. Expand and improve UAS-MAG to provide enhanced focus, refinement, and time-lapse monitoring of munitions concentrations & mobility
2. Combine aerial imagery, 3D topographic mapping, & aerial magnetometry to guide crawler-EM AGC surveys
3. Demonstrate full-scale amphibious crawler-EM AGC to detect & classify individual target anomalies in water depths up to 15 feet
4. Provide prioritized precise locations for potential intrusive investigations
5. Develop MBA work products based on lessons learned from demos
6. Support transition via UW Live Site WG & EDQW on-going efforts

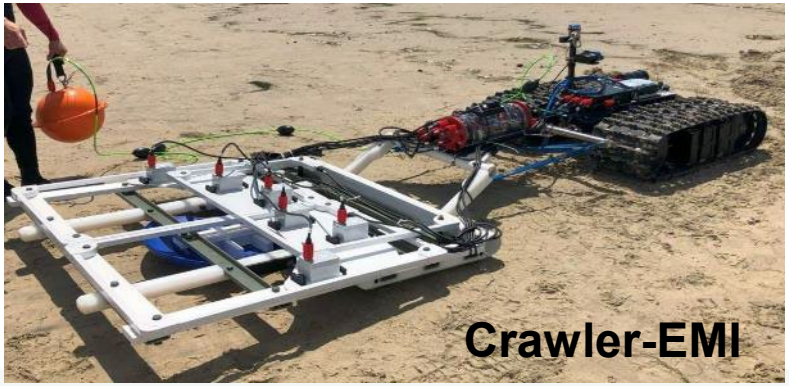
Technical Approach



Go/No-go Criteria:
In-water validation of Crawler-EM System

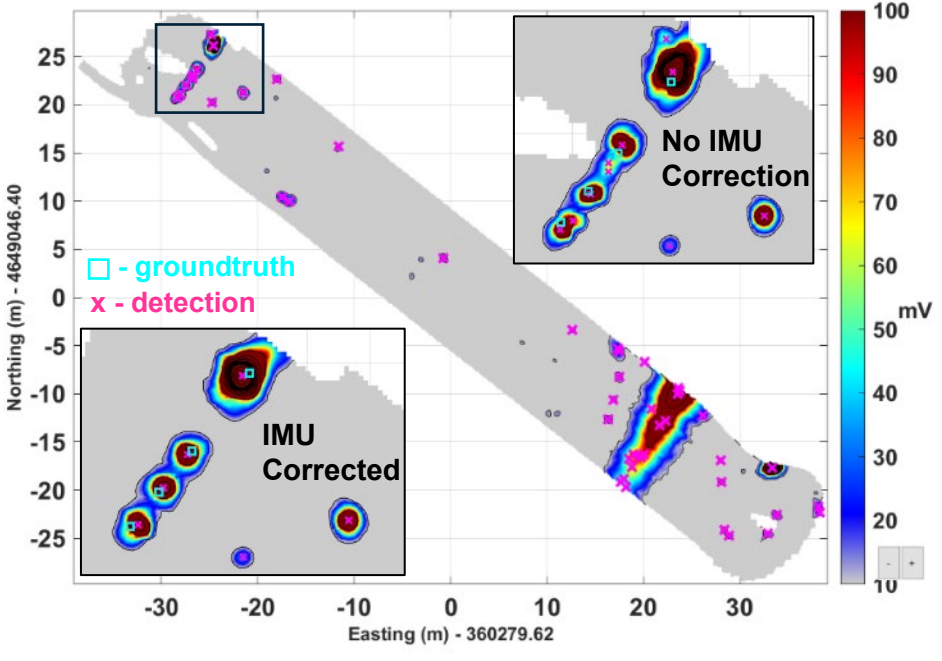
Integrated Demonstration Technologies

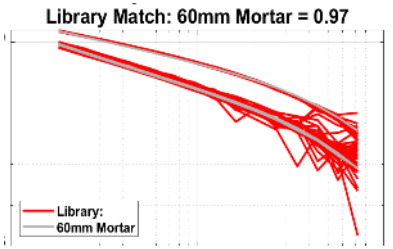
1. Marine APEX 3D EMI Classifier Array
2. GSIQ Bayonet Crawler AUGV
3. UAS-integrated Atomic Magnetometer Units (UAS-MAG)
4. Supporting NAV/POS and Surveying Systems

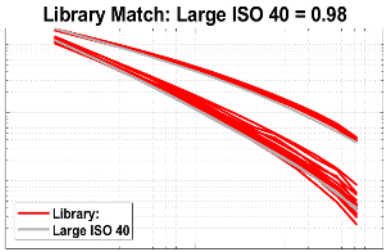


Technology: Crawler-EM AGC

Shakedown Testing: Cordage Park OCT-2025







Technical Progress Summary

Task 1. System Prep & Site Coordination

- *MBA Stakeholder Meeting, Coordination, Mission Planning*

Task 2. Explosives Mgt / Safety Planning

Task 3. Sensor Mob & Site Preparation

- *Duck FRF Demo Plan Completed, Duck FRF Blind Analysis Submitted*
- *MBA Ph2 Demo Plan Drafted, UAS Ops Plan Submitted*

Task 4A. UAS-MAG MBA Site Demo

- *Airspace/Flight Mission Planning Complete*

Task 4B. Crawler-EM MBA Site Demo

Task 5. Data Analysis & Reporting

Task 6. Intrusive Investigations

Task 7. Transition & Quality Management

Duck FRF Proveout Demo

Shakedown test of end-to-end / full-scale APEX Hammerhead Crawler-EM system.

USACE Duck Facility

- Cal & Blind Test Areas
- Cal Line (3 Targets)
- Blind Grid: 25m x 130m
- 37mm to 155mm UXO
- Swash, Surf, Open Water
- 0.8-4.2m Water Depth

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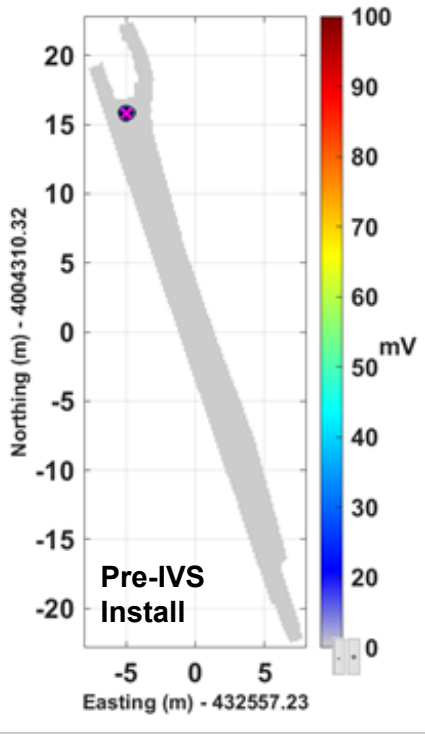
Duck FRF: 3DEM Objectives

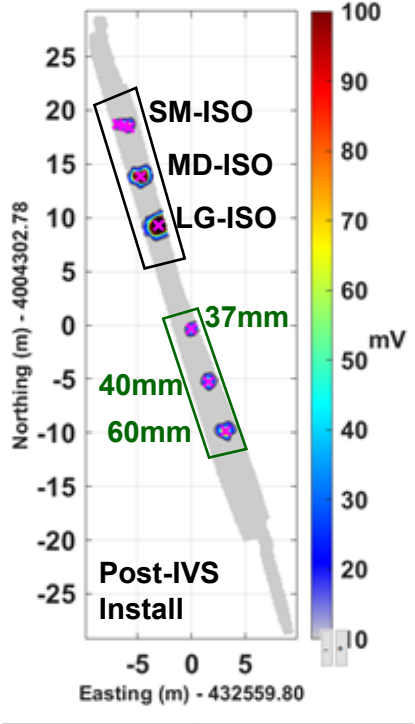
Crawler-based mAPEX 3DEM focus on AGC performance objectives

Objective	Metric	Criteria
Grid Coverage	Point-to-point cross-track spacing	100% cross-track spacing ≤ 1.5m
Area Coverage Rate	Average #Acres / hr	0.25 acre/hr; full coverage
Detection Performance	Pd (1.0m halo emplaced TOI)	100% TOI within halo
IVS Location Accuracy	ΔN & ΔE = ||est_XY – true_XY||	ΔN & ΔE < 40 cm
Seed Location Accuracy	ΔN & ΔE = ||est_XY – true_XY||	ΔN & ΔE < 75 cm, σ<35cm
Classification Accuracy	P_{class} = # True Labels / #TOI	P_{class} = 1.0, Clutter Rejection >50%
Ease of Use & Stability	Operator Observations	Compared to other marine OPS

Duck FRF: Site Set Up

- Installed IVS Area on Beach
- Daily SFT, IVS (AM/PM), QC Analyses
- Grid Surveys (Full Coverage)
  1. GPS-NAV Blind Survey (1-2ft surf)
  2. GPS-NAV Blind Survey (6-7ft surf)
  3. INS-NAV Blind Survey (2-3ft surf)





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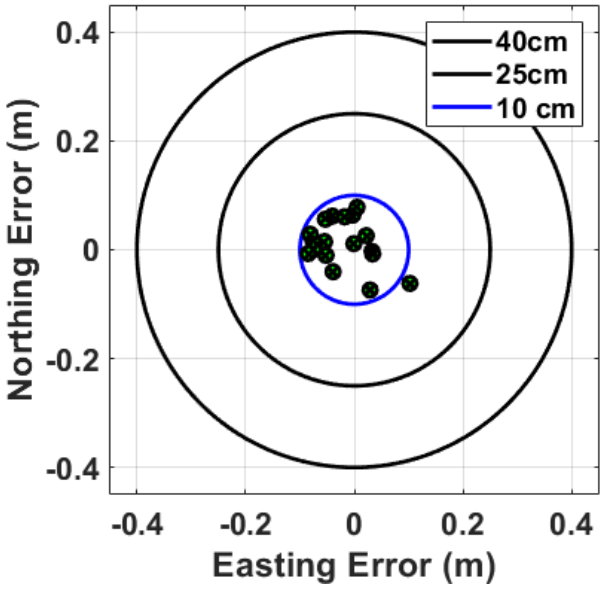
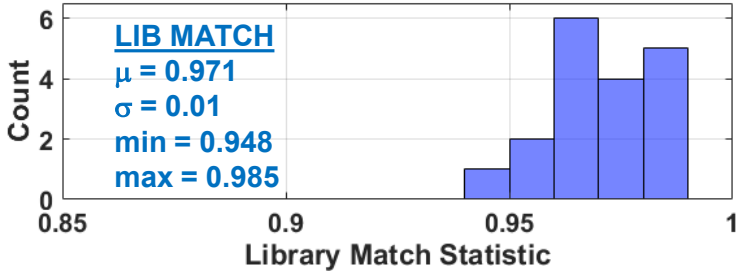
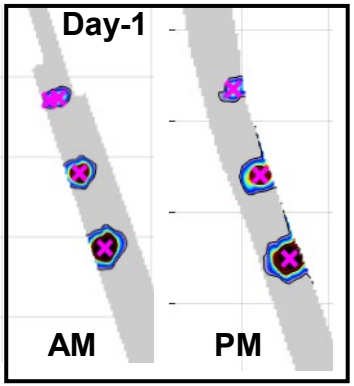
Duck FRF: IVS Results

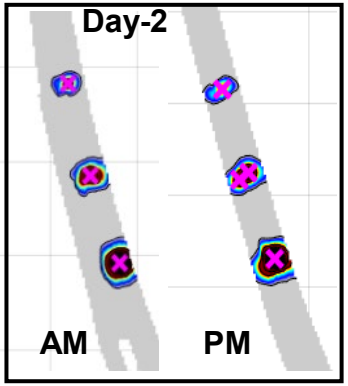
Instrument Verification Surveys (IVS)

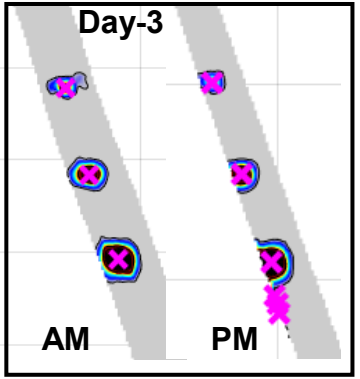


IVS Loc Error
μ = 6.4 cm
σ = 2.5 cm
max = 12.0 cm
CEP = 3.0 cm









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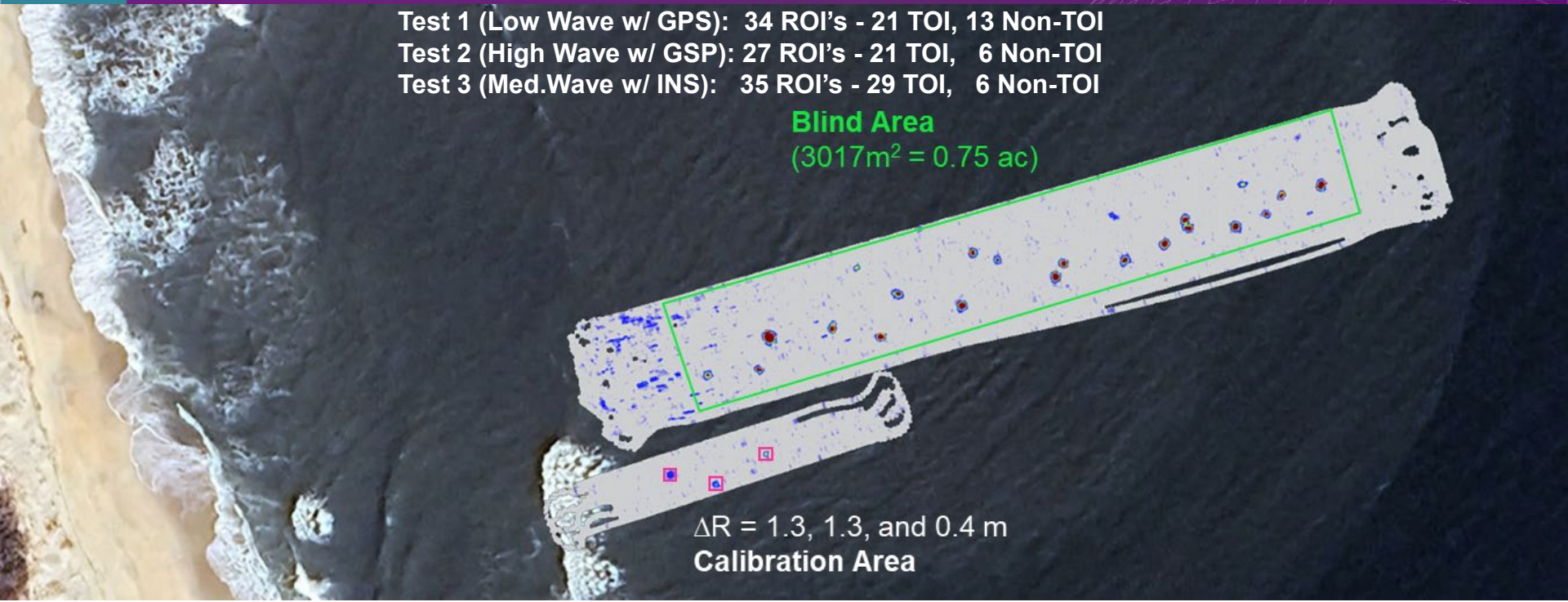
Duck FRF: Grid Coverage



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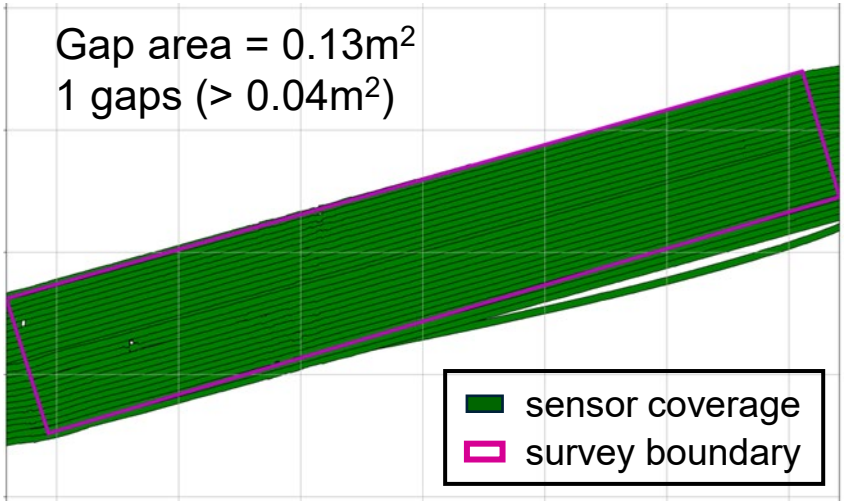
Duck FRF: Grid Coverage

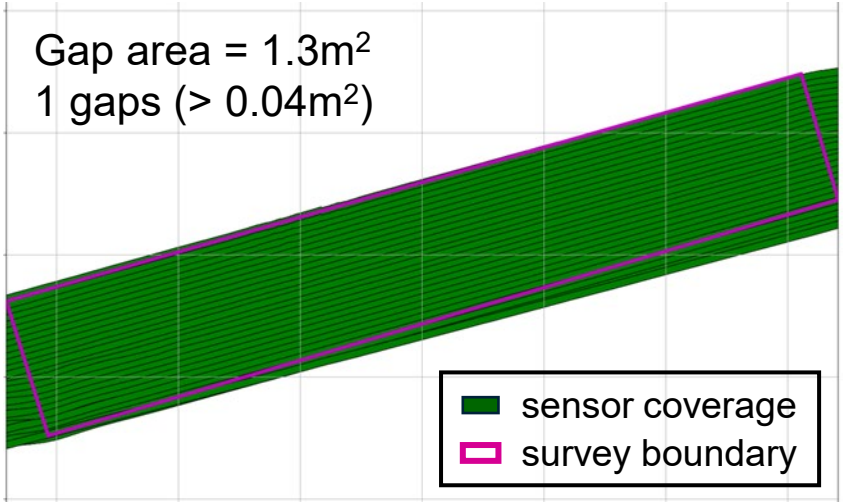
Day-1 GPS-based Survey

99.7% coverage (0.74 acres)
3010m^2 of 3017m^2
100% transects < 1.2m

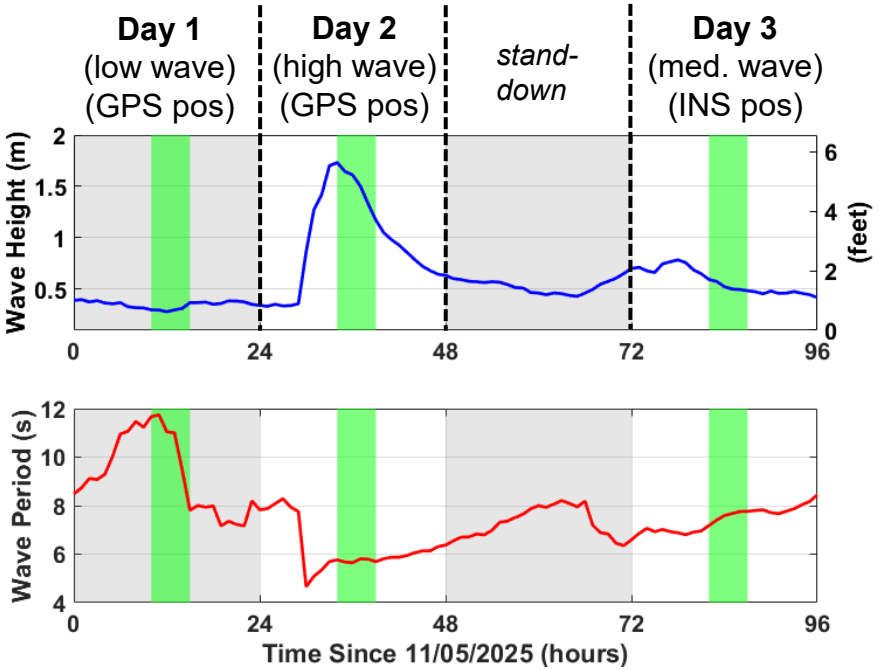


Day-3 INS-based Survey

99.9% coverage (0.75 acres)
3016m^2 of 3017m^2
100% transects < 1.2m



Duck FRF: Varying Conditions



Day 1
(low wave)
(GPS pos)
0.4m Waves
10-11 sec

Day 2
(high wave)
(GPS pos)
1.7m Waves
5-6 sec

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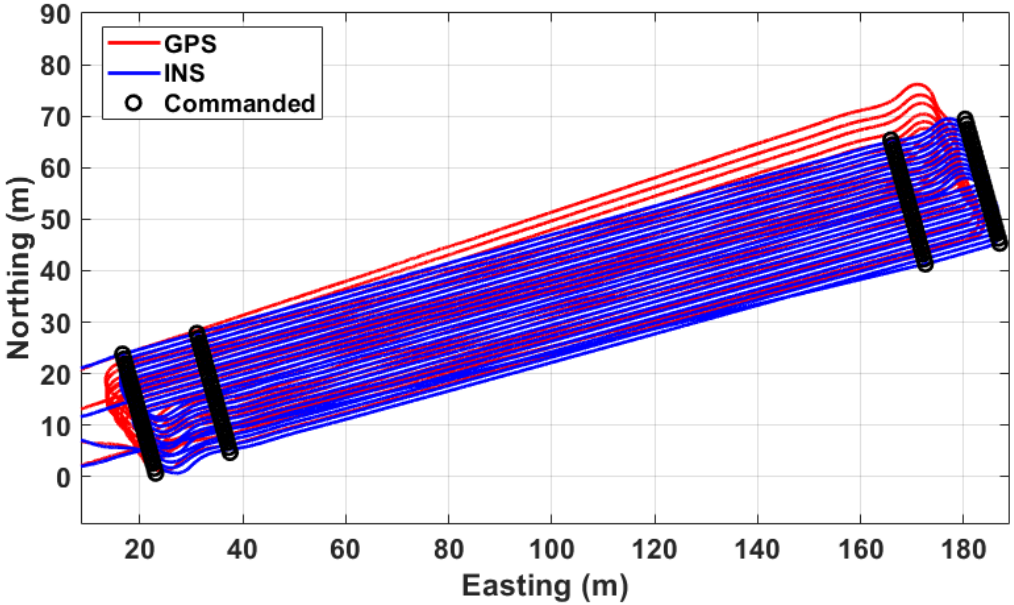
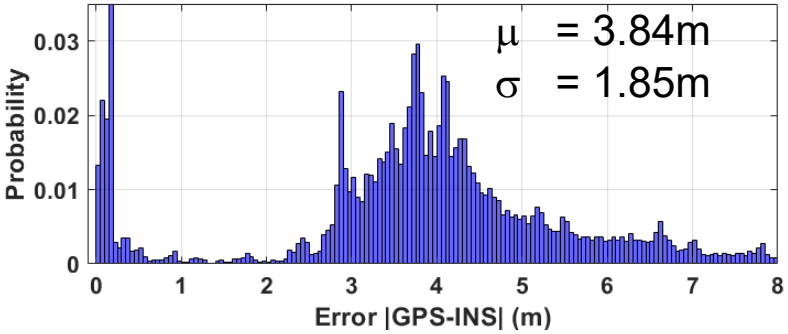
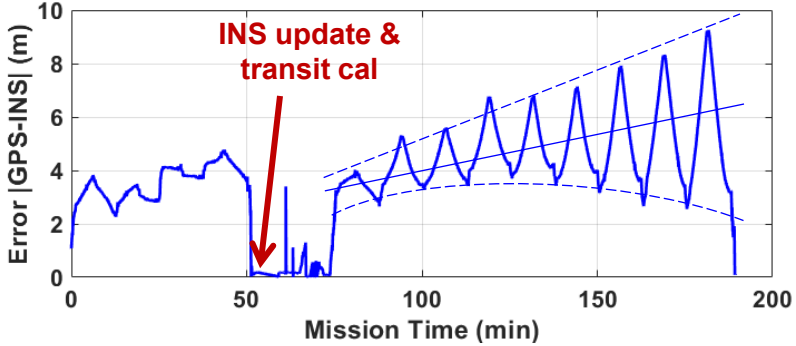
Duck FRF: GPS vs INS POS/NAV







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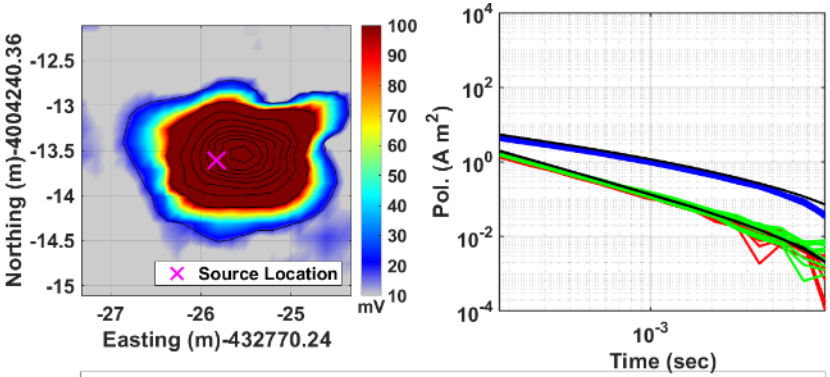
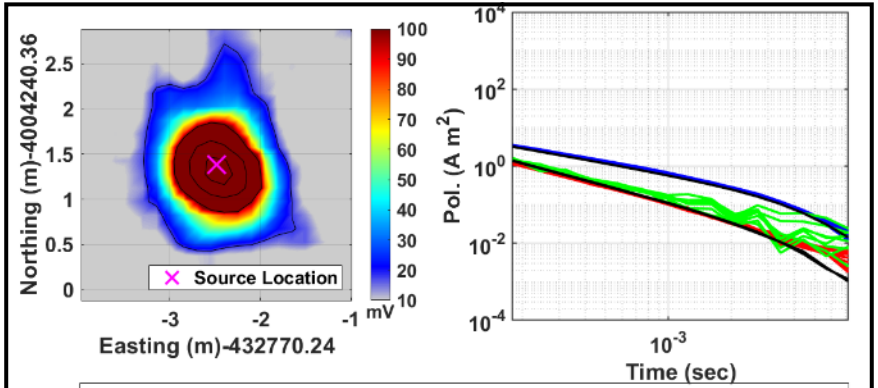
Example TOI Classification



Results

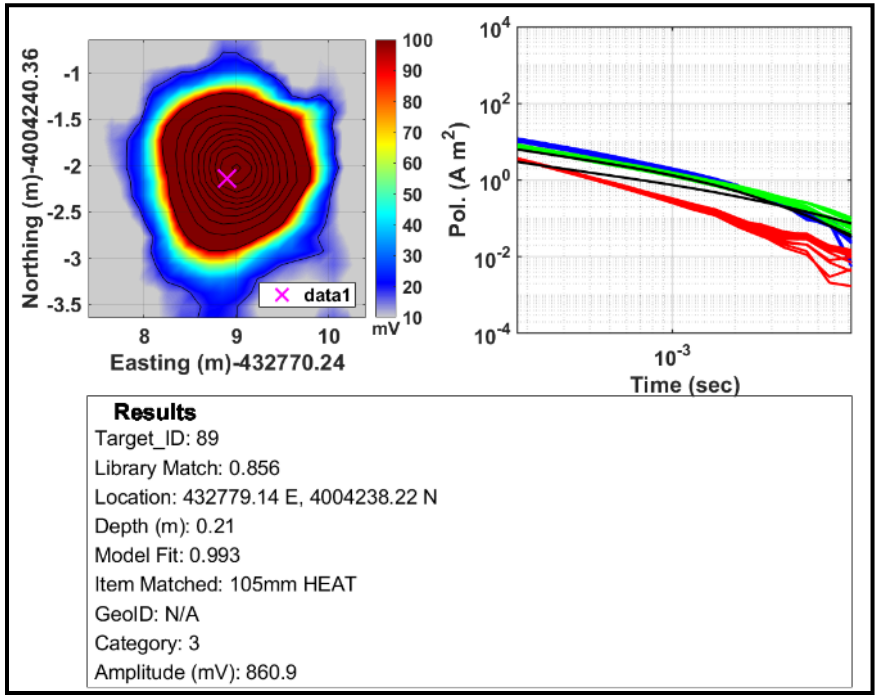
Target_ID: 74
Library Match: 0.962
Location: 432744.42 E, 4004226.75 N
Depth (m): 0.09
Model Fit: 0.997
Item Matched: Medium ISO 40
GeoID: N/A
Category: 1
Amplitude (mV): 657.6



Results

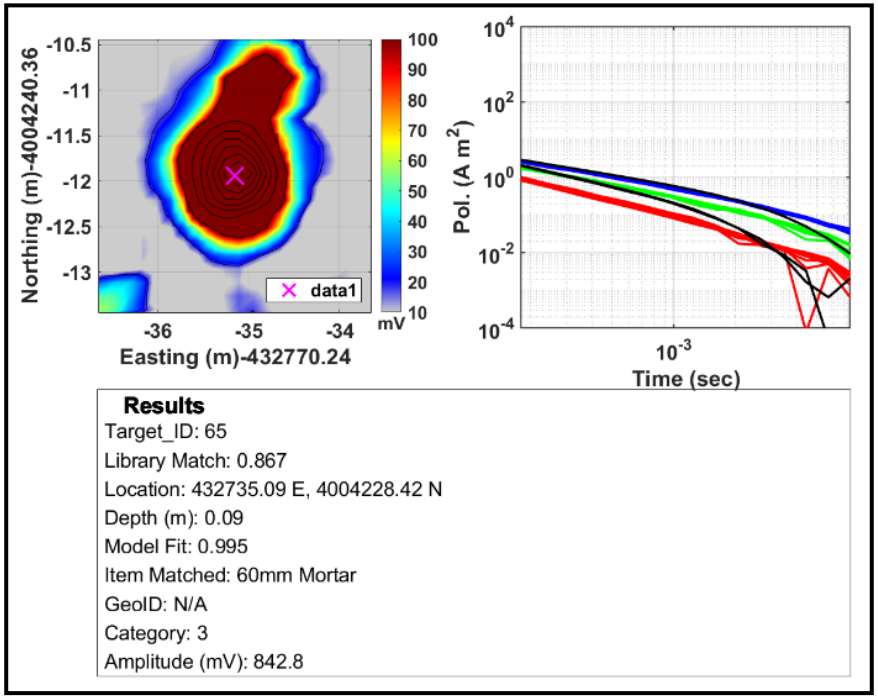
Target_ID: 87
Library Match: 0.949
Location: 432767.75 E, 4004241.74 N
Depth (m): 0.19
Model Fit: 0.988
Item Matched: 60mm Mortar
GeoID: N/A
Category: 1
Amplitude (mV): 319.2

Example Non-TOI (Clutter) Classification



Results

Target_ID: 89
Library Match: 0.856
Location: 432779.14 E, 4004238.22 N
Depth (m): 0.21
Model Fit: 0.993
Item Matched: 105mm HEAT
GeoID: N/A
Category: 3
Amplitude (mV): 860.9



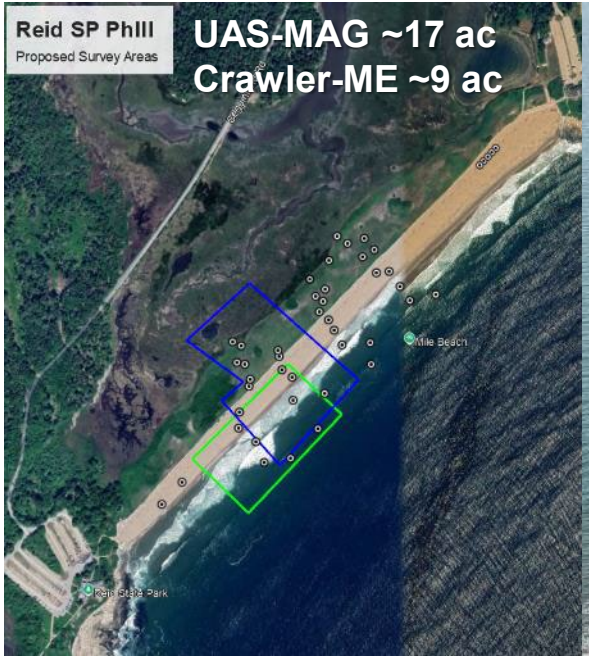
Results

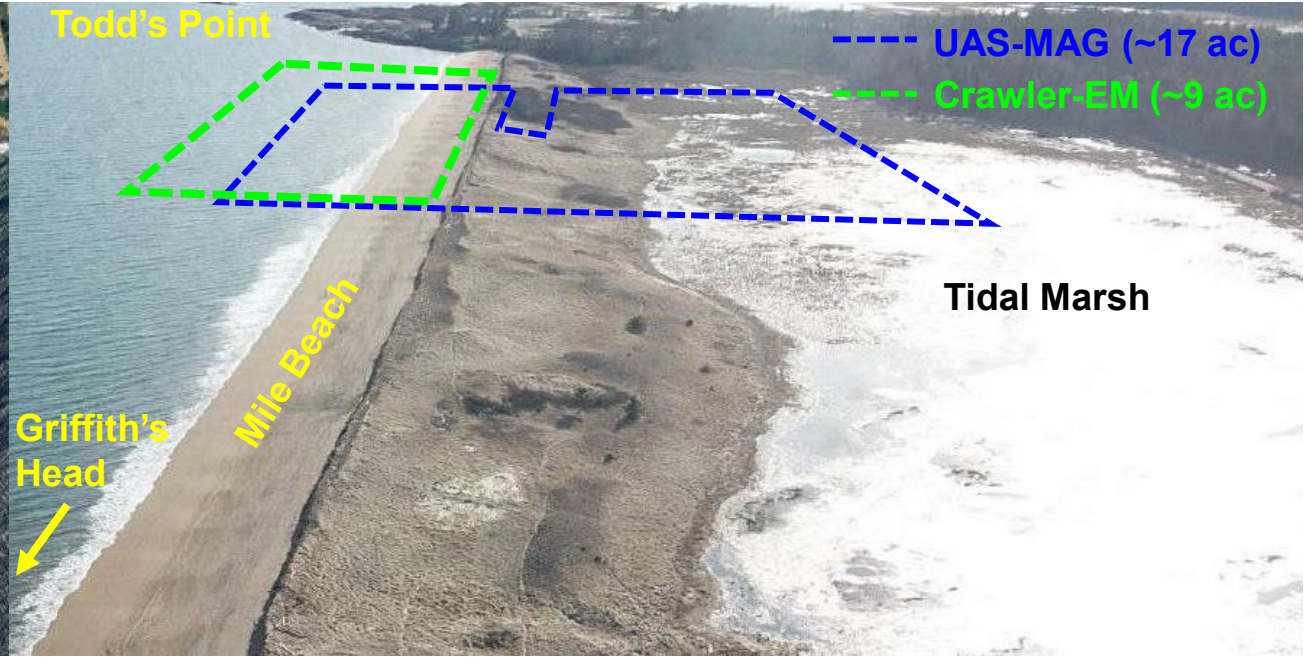
Target_ID: 65
Library Match: 0.867
Location: 432735.09 E, 4004228.42 N
Depth (m): 0.09
Model Fit: 0.995
Item Matched: 60mm Mortar
GeoID: N/A
Category: 3
Amplitude (mV): 842.8

Duck FRF: Lesson Learned

1. Added ballast to fit conditions
2. GPS mast robust in deep surf
3. Tilt compensation validated
4. Frequency of INS calibration?
5. Endurance underestimated (~3hr)
6. Environmental noise rejection

MBA Phase III Demo Plan





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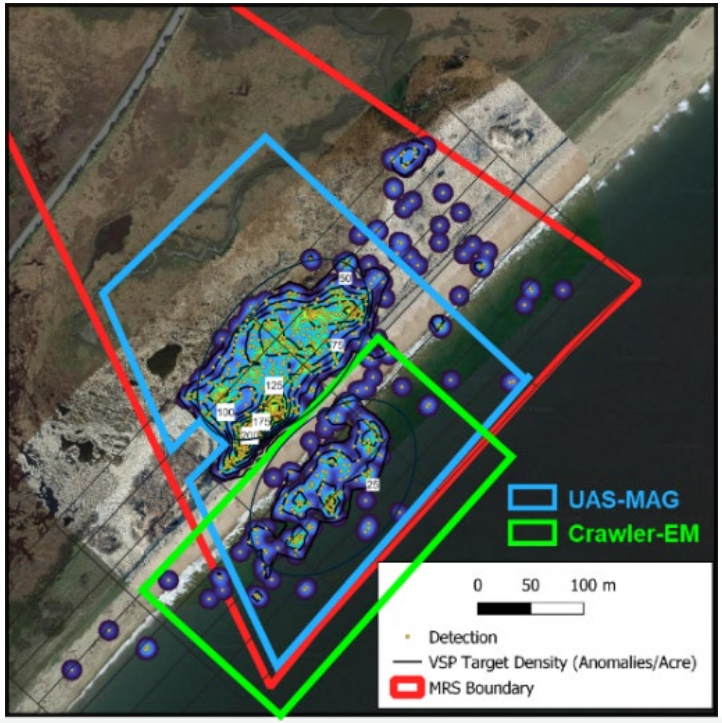
Phase III: UAS-MAG Updates

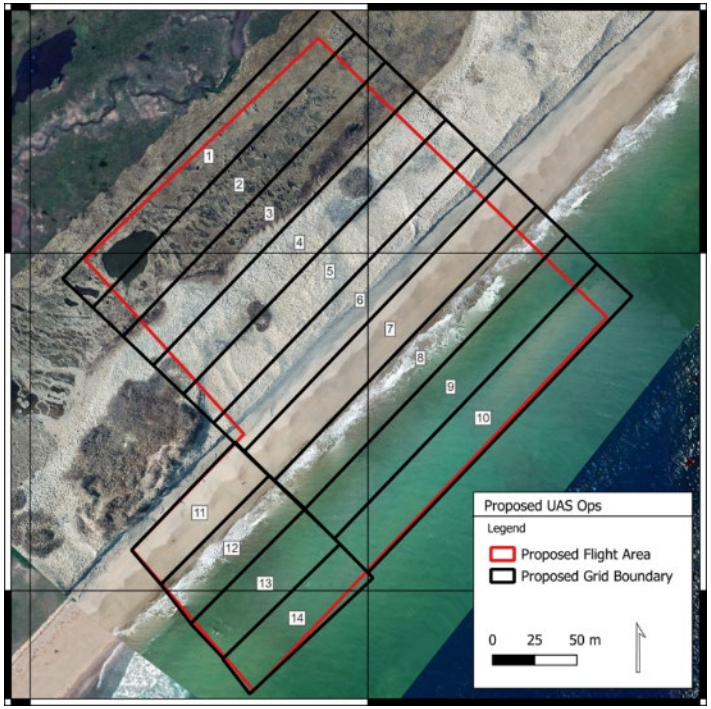


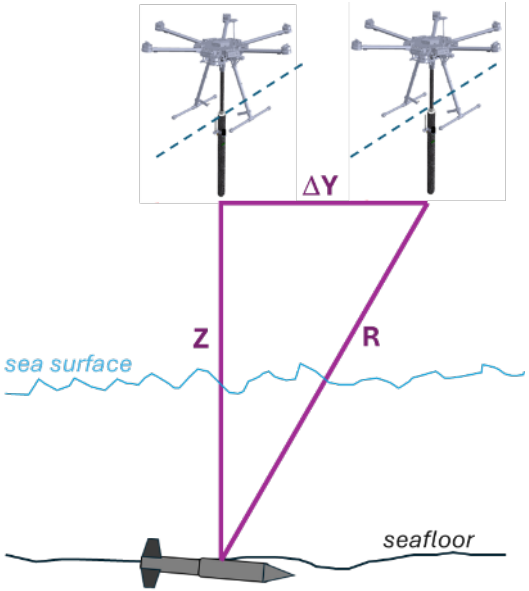
- Update ID'ed High-concentration areas
- Approx. 17 acres south-portion of Mile Beach and extending into tidal marsh
- Similar operations to Phase I (UAS-MAG deployment with team of 3 pilots)
- Recollect aerial imagery mosaics / DEM
- Evaluate mobility and improved individual target localization and density estimates
- *Proposed Timing: January 2026 (4 days)*
- Special Activity Permit (re)submission

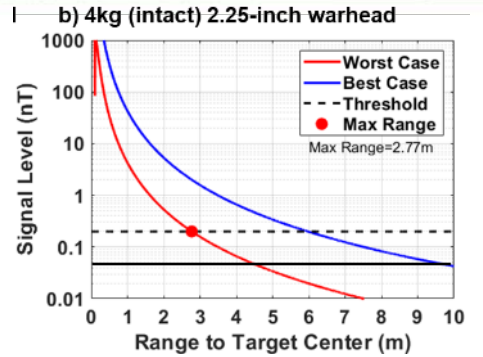
Technical Approach: MAG Objectives

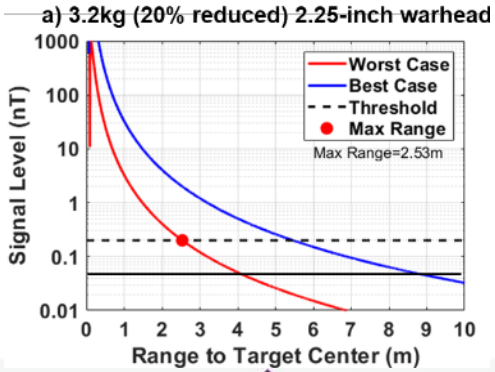
Objective	Example Metric	Example Criteria
Localization Accuracy	ΔN & ΔE = ||est_XY – true_XY||	ΔN & ΔE < 100 cm
Detection Performance	Pd (1.0 m halo TOI)	100% TOI within halo
Transect QC	$\Delta R < LSPA = (\Delta N^2 + \Delta E^2)^{1/2}$	100% Line Spacing ≤ 2.0m
System Noise	Median Amplitude Spectral Density (ASD) of System Noise	ASD over 0.05-5 Hz < 250 pT/√Hz (Static Observations)
Coverage Rate	Acres / day	5 acres/day; full coverage
Launch & Recovery	Shore / Ship	Successful LAR
Ease of Use & Stability	Operator Observations	Compared to other marine OPS

Phase III: UAS-MAG Ops









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Phase III: Crawler-EM Ops

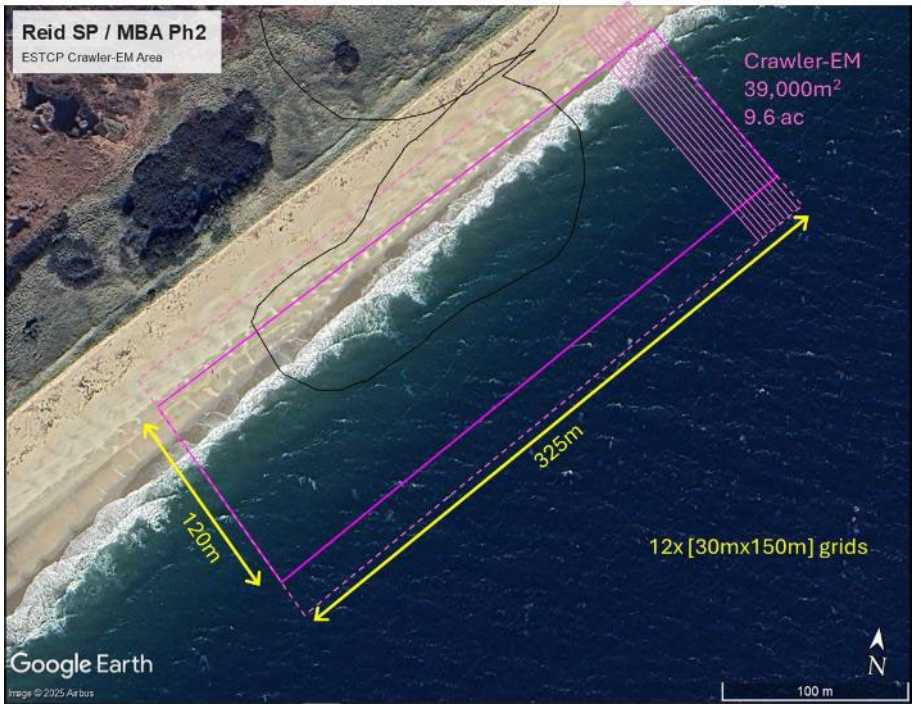
- Shore-based OCS
- Planned Auto Missions
- 3-hour Survey Missions

- Continuous Radio Link & System Monitoring
- Emergency Stop
- At-Sea Recovery

- Intrusives by certified MEC/EOD specialists (PIKA)
- Simplified excavation (dry)
- Any Required Disposal by Qualified UXO Specialists

Proposed Timing: February 2026 (10 days)

Phase III: Crawler-EM Ops



Issues

- No Significant Crawler-EM Technical Issues for MBA
- Detailed Bathymetry Information Needed for Reid SP
- Pending Site Access and Maine DEP Activity Permit
  - All Fieldwork Must Be Completed By 31 March (site restriction)
  - UAS-MAG Follow-On Fieldwork Must Be Completed NTL 15 Feb
  - Crawler-EM Fieldwork Must Be Completed by 28 Feb
  - Weather in Maine in Feb & March is Significant Risk to Completion

Technology Transition

1. **Production Transition Assessment**
   - Define operating envelope for full-scale implementation / operational concepts
   - Cost models: 1) “wet” lease option, 2) lease/contract option
2. **Outreach Products & Information Dissemination**
   - UAS-MAG & Crawler-EM Shallow Water Site Best Practices
   - Complexities of amphibious UXO surveys
   - Collaboration with Maine DEP, USACE, NAVFAC
   - Training and information sessions (e.g., NAOC, M2S2, SAGEEP)
3. **Quality Assurance Project Planning Support**
   - Co-development of quality management framework (e.g. QAPP Worksheets)
   - Support UW MR Tech WorkGroup, DOD EDQW, and EPA / DAGCAP PM’s

Technology Transition

1. **Commercial Transition Roadmap**
   - WRT & GSIQ already have a joint business plan for transition to production
   - WRT established dedicated manufacturing & sustainment facility, inventory system, MRP/ERP systems & has fielded over 67 APEX AGC units since 2021
   - Establish initial COCO IPT production price structure & service model
   - Develop quality systems, SOPs, O&M Documents, Work Instructions
2. **Dual-Use Potential**
   - Navy and USMC Mine-countermeasures, Engineering Recon, & EOD
   - Potential Swarm extensions to increase productivity
   - LRIP potential under DIU A2RV program extension (USMC LEON)
   - Emerging interest from European and Pacific marine construction industries
   - Foreign Military interests for UXO and MCM applications (e.g., UK, Netherlands, Israel)

Next Steps

- Site Visit and Finalize Crawler-EM Logistics: 21 JAN
- Complete Site Access Permit & Demonstration Plans
- Follow-on UAS-MAG surveying MBA: 26-30 JAN
- Refine Crawler-EM survey mission plans per UAS-MAG
- Mobilize and conduct Crawler-EM surveys: 16-27 FEB*
- Submit TOI list and coordinate intrusive activities: 6 MAR
- Complete all on-site work for Winter season by 31 MAR

** pending weather and site conditions*

Backup Slides

MR25-8992: Live Underwater Munitions Detection & Classification: Maine Bombing Range

Performers: *White River Technologies, Inc.; GreensealQ, PIKA Intl.*

Technology Focus

- *Amphibious nearshore UXO clearance in cost-effective and robust demo*

Demonstration Site

- *Former Maine Bombing Range*

Demonstration Objectives

- *Transition crawler-3DEM to full-scale in-water detection and classification*

Project Progress and Results

- *Robust navigation and control during autonomous mission demonstrated*
- *Transition from RTK-GPS to subsea INS-aided NAV proven*
- *Completed blind demonstration of full-scale Advanced 3DEM Classification*

Implementation Status

- *In-water blind proveout tests completed at USACE Duck FRF, North Carolina site*

Plain Language Summary

- Transition to full-scale in-water detection & classification needed
- Shallow munitions response sites, such as MBA, in <5 meters of water are a priority interest due to the increased probability of exposure & difficulty in deploying ship-towed sensors
- Among the challenges of amphibious nearshore operations for munitions response is rapid and cost-effective deployment for both in-water and over-water (air) surveying.
- Existing geophysical survey systems purpose-built for deployment across land-nearshore-offshore areas are currently large, cumbersome, expensive, & lack configurability for wide-spread use

.

Action Items

Shakedown Test Plan Closed	Deliverable: Other	Action Type: Subtask	Due Date: 9/12/2025
August MFR for FY25 funds Closed	Deliverable: None	Action Type: MFR	Due Date: 9/15/2025
Banner Image for SERDP ESTCP Webpage Closed	Deliverable: Other	Action Type: Subtask	Due Date: 9/30/2025
September MFR for FY25 funds Closed	Deliverable: None	Action Type: MFR	Due Date: 10/14/2025
October 2025 Quarterly Progress Report Closed	Deliverable: None	Action Type: QPR	Due Date: 10/15/2025
SPP Meeting with Stakeholders Closed	Deliverable: None	Action Type: Subtask	Due Date: 10/17/2025
Shakedown Test Plan (v2) Closed	Deliverable: Other	Action Type: Subtask	Due Date: 10/31/2025
October MFR for FY25 funds Closed	Deliverable: None	Action Type: MFR	Due Date: 11/14/2025
Shakedown Test Submitted	Deliverable: None	Action Type: Subtask	Due Date: 11/15/2025
November MFR for FY25 funds Closed	Deliverable: None	Action Type: MFR	Due Date: 12/14/2025

Impact to DOD

- Overarching benefit = accelerated cleanup of estimated 10M+ acres of underwater munitions contamination areas
- Fill gaps for UXO surveying in particularly challenging shallow water nearshore areas where exposure is maximum and current techniques are most challenged
- Reduce cost by implementing underwater 3DEM classification
- Crawler-sensing technologies are expected to shorten survey times by 10x over divers
- Crawler-based EM AGC may provide as much as 60% total cost savings relative to convention methods
- Where sites are shallow enough for divers, there is significant health and safety risks for personnel and dives costing $2-$3K can be reduced to <$1K
- As amphibious sensing continues to be more automated and proliferates, emerging technologies can be leveraged in this technology suite to further improve UXO operations on beaches, in surf zones, marshes, sea cliffs, and other areas of concern.

Publications

- Provide a list of all publications, patents, awards, etc., resulting from this work.

Literature Cited

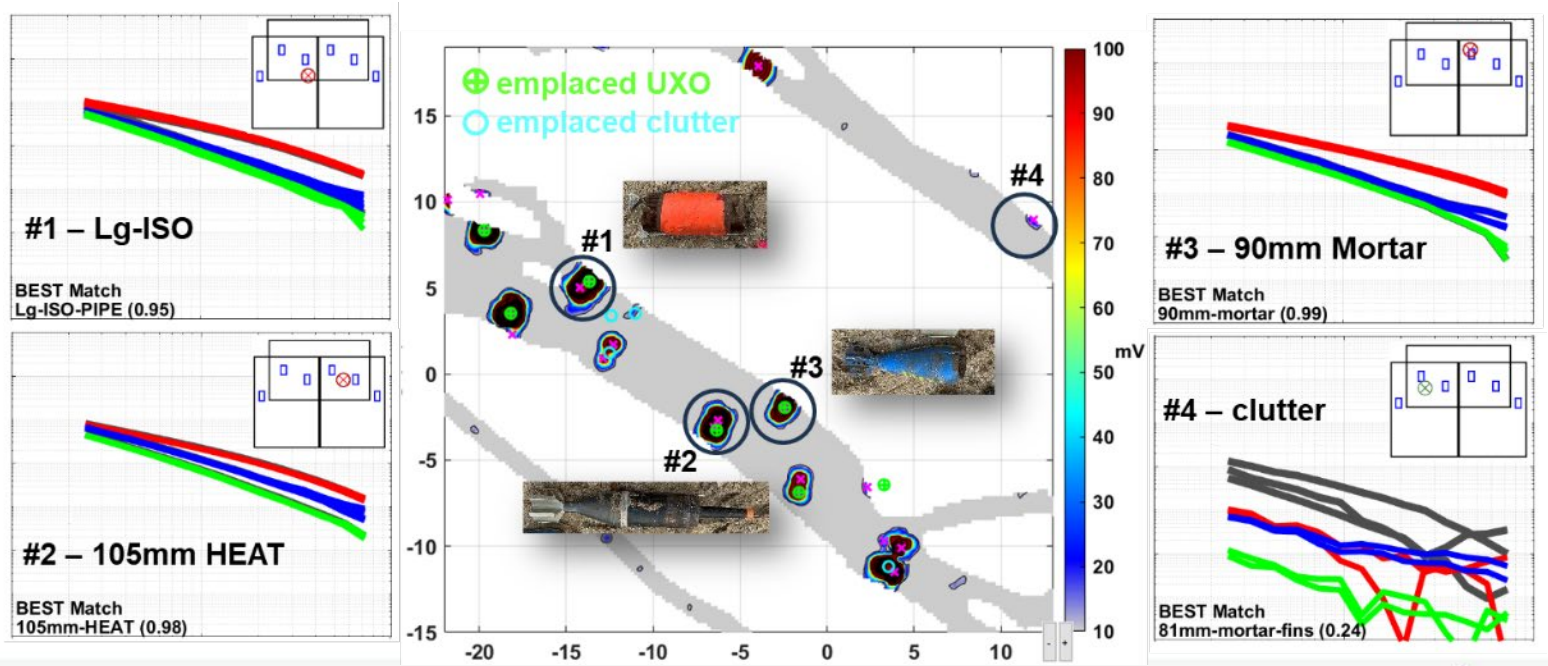
- Provide a list of all the published work you cited in the presentation.

Additional Slide(s) for High-Quality Photos

Acronym List

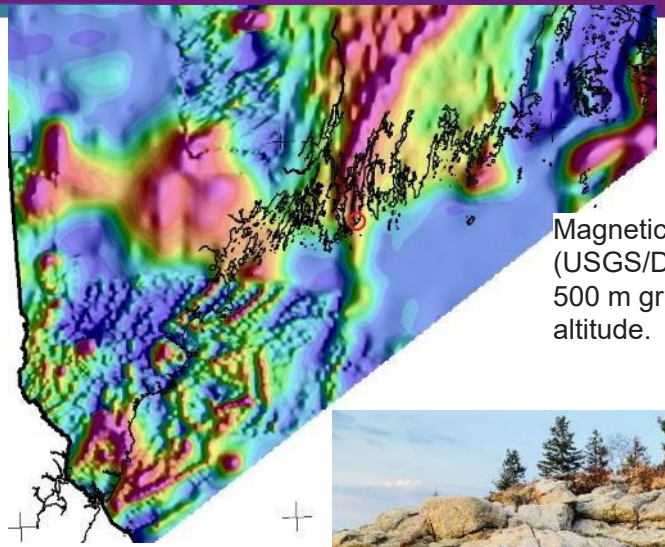
Technology: Crawler-EM AGC

In-water Mapping-Detection-Classification Testing: Cordage Park SEP-2024



ESTCP

Site Description: MBA

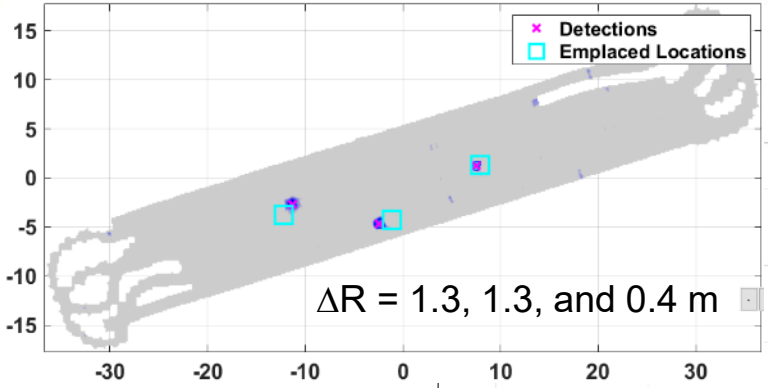


Magnetic map of Maine (USGS/Daniels) with 500 m grid from 305 m altitude.

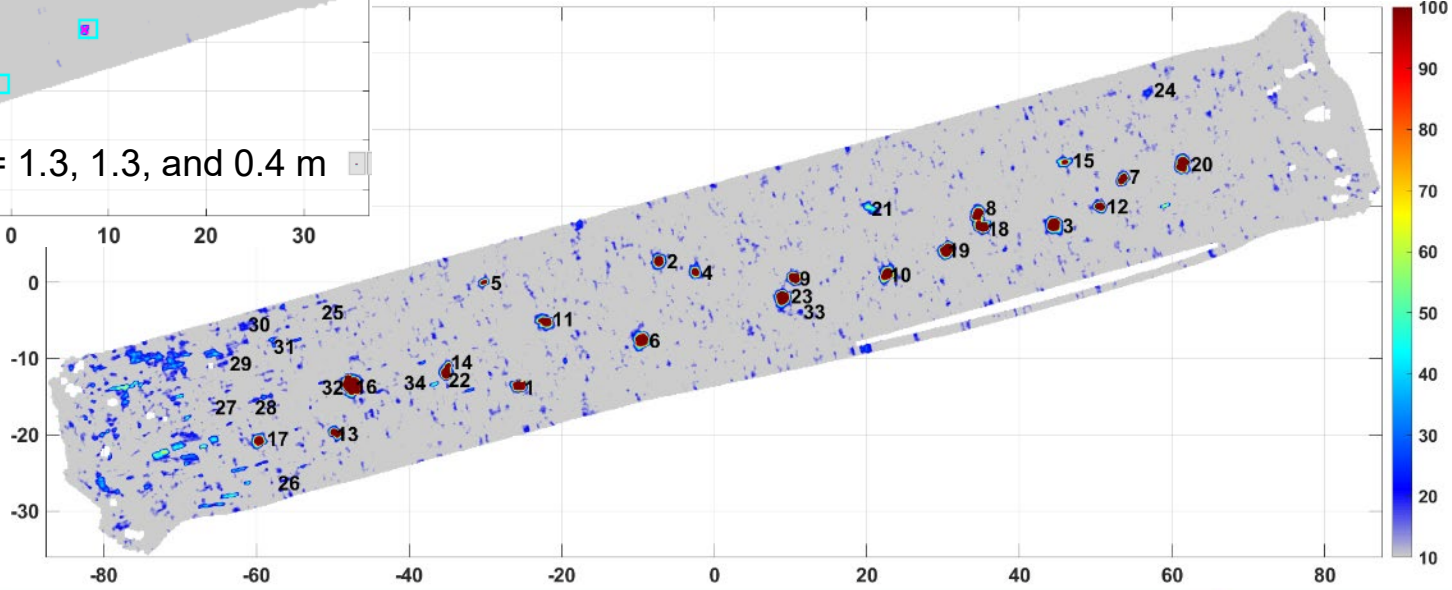
Metavolcanic mafic rocks (could be amphibolite /magnetite) with pegmatite intrusions at Todds Point

ESTCP

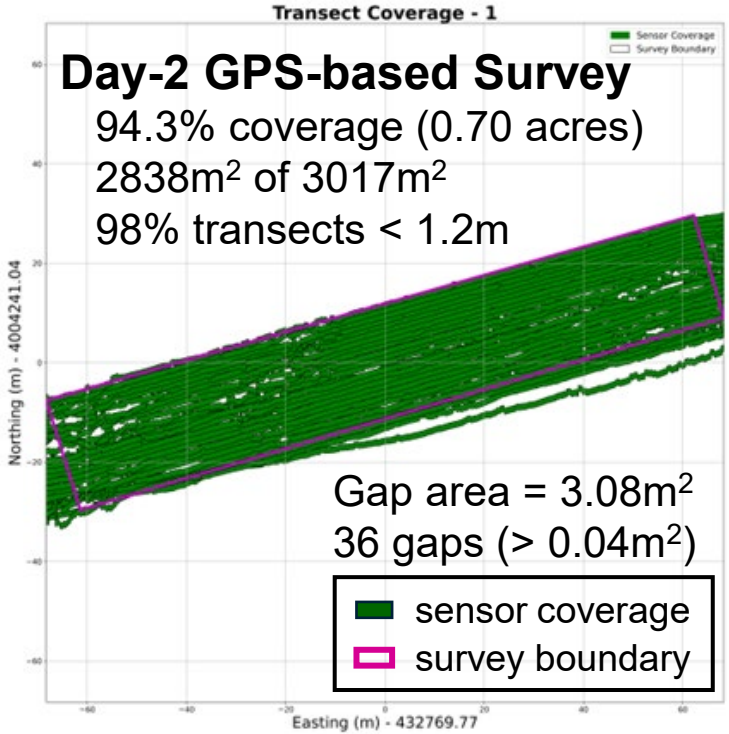
Duck FRF: Anomaly Selection

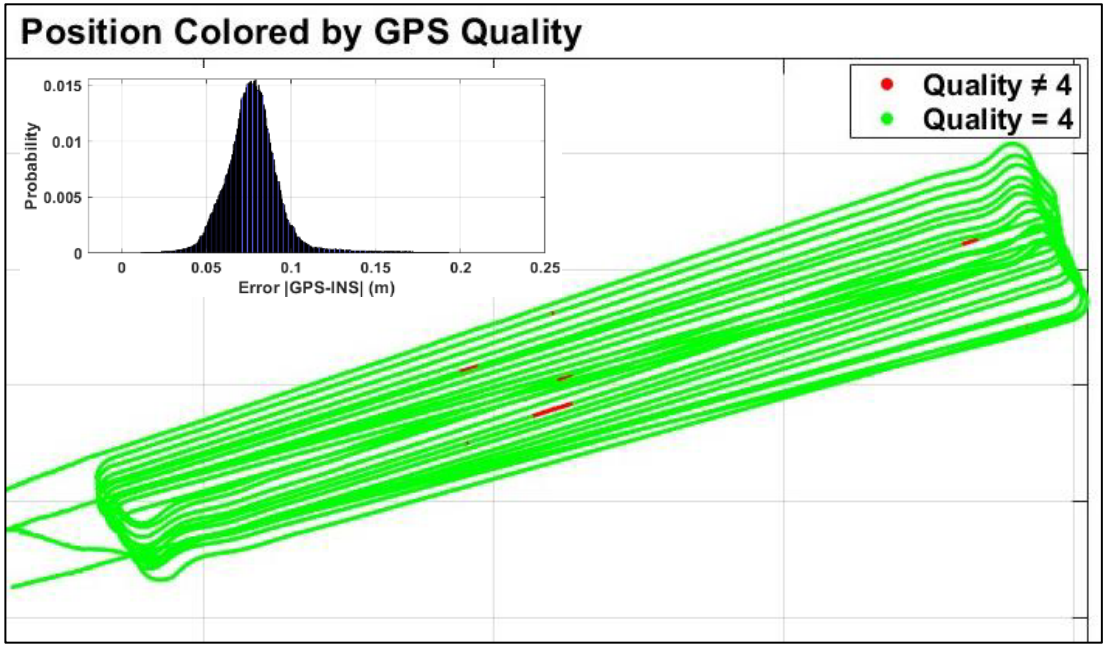


Test 1 (Low Wave w/ GPS): 34 ROI's - 21 TOI, 13 Non-TOI
Test 2 (High Wave w/ GSP): 27 ROI's - 21 TOI, 6 Non-TOI
Test 3 (Med.Wave w/ INS): 35 ROI's - 29 TOI, 6 Non-TOI



Duck FRF: High Wave Conditions

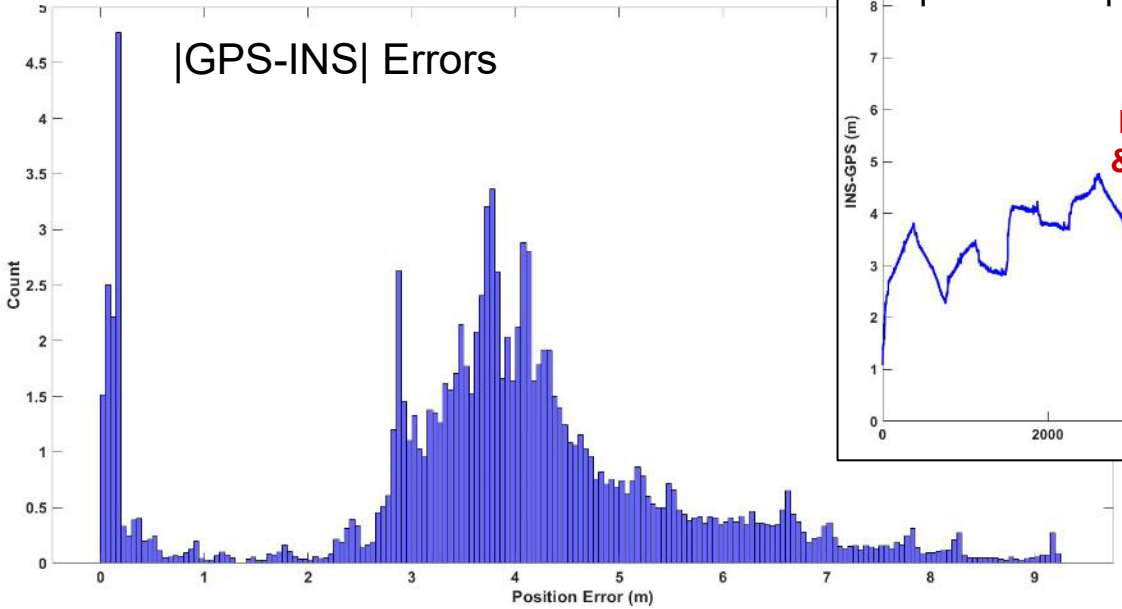


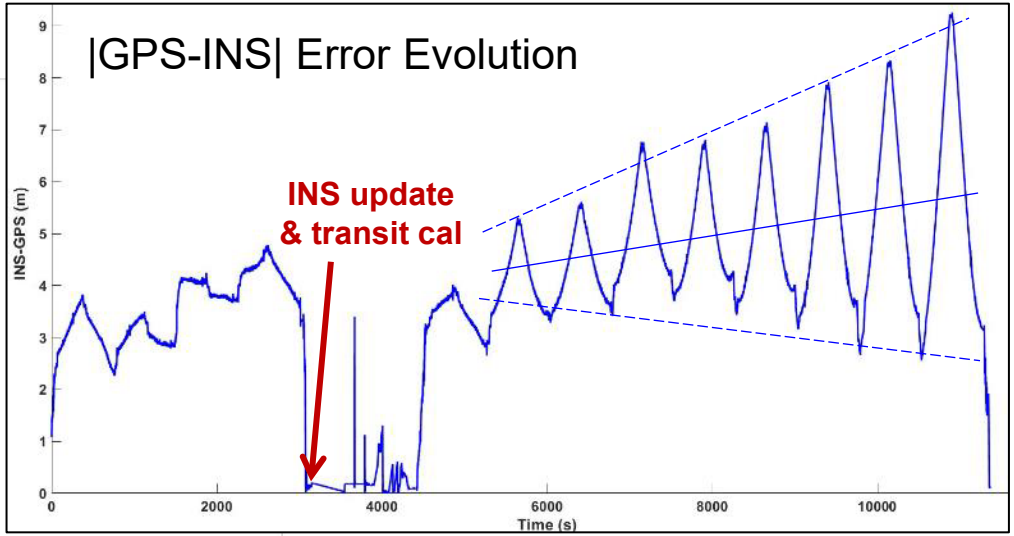


ESTCP

Duck FRF: GPS vs INS POS/NAV

Day-3 INS-based Survey





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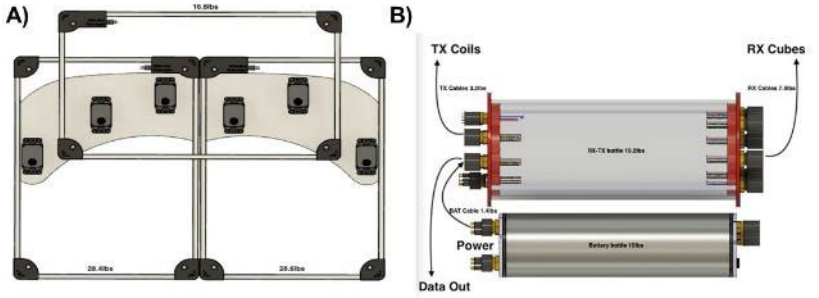
Technology/Methodology Maturity

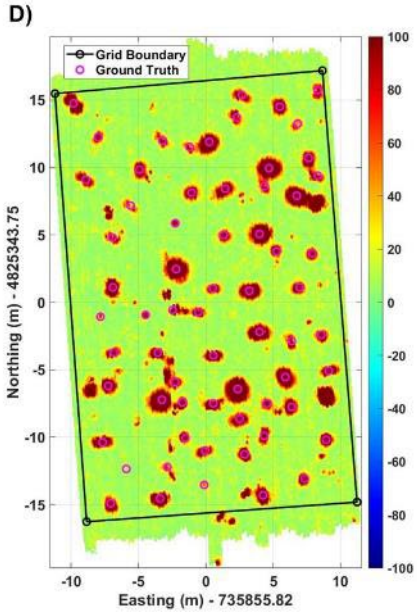
Tech Element	*Development History*	*Software*	*Demos/Proveouts*	*User Groups*
mAPEX 3D EMI Array	• Same electronics as DAGCAP approved ver. • 5 units in N. America	• APEXCOM • EMClass v3.2	• ESTCP 2016-2020 • DIU A2RV CA Ops	• USMC LEON, COCO
Bayonet Crawler	• 3-Sizes: 150, 250, 350 • 10 current build units	• OpenSea EDGE • EODworkspace	• DIU AR2V LRIP • Worldwide Demos	• ERDC FRF, JHU APL, Others
UAS-MAD Units*	• 1st Prototype-2008 • Over 30 units produced	• MADCOM • Geosoft *or* MADProc	• ESTCP 19-5212: NJ, FL, ME (2019-24) • TRL-6/7 Demos	• ONR, NSWC, NUWC, UMSC LEON, NIWC

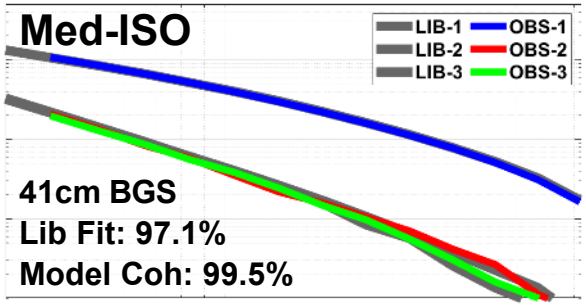
Extended UAS-MAG capability developed since Mar-2024 Phase 1 surveys available for Phase 2: i) Titan Airframe ii) MAD gradiometer, iii) Nighttime UAS Ops, iv) Improved PMA software

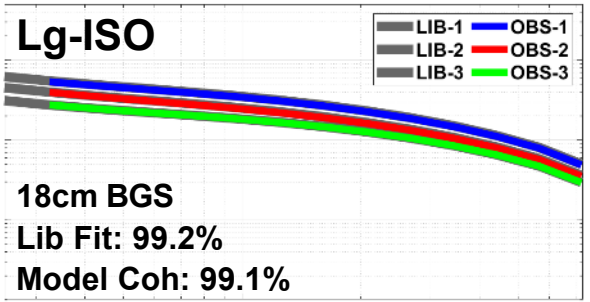
Technology: Crawler-EM AGC

Marine APEX 3D EMI Classifier Array









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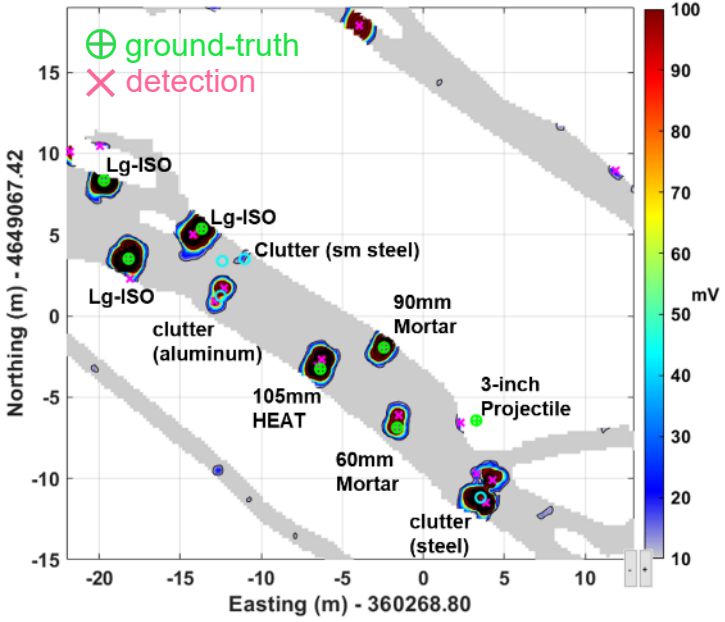
Technology: Crawler-EM AGC

Marine APEX 3D EMI Classifier Array

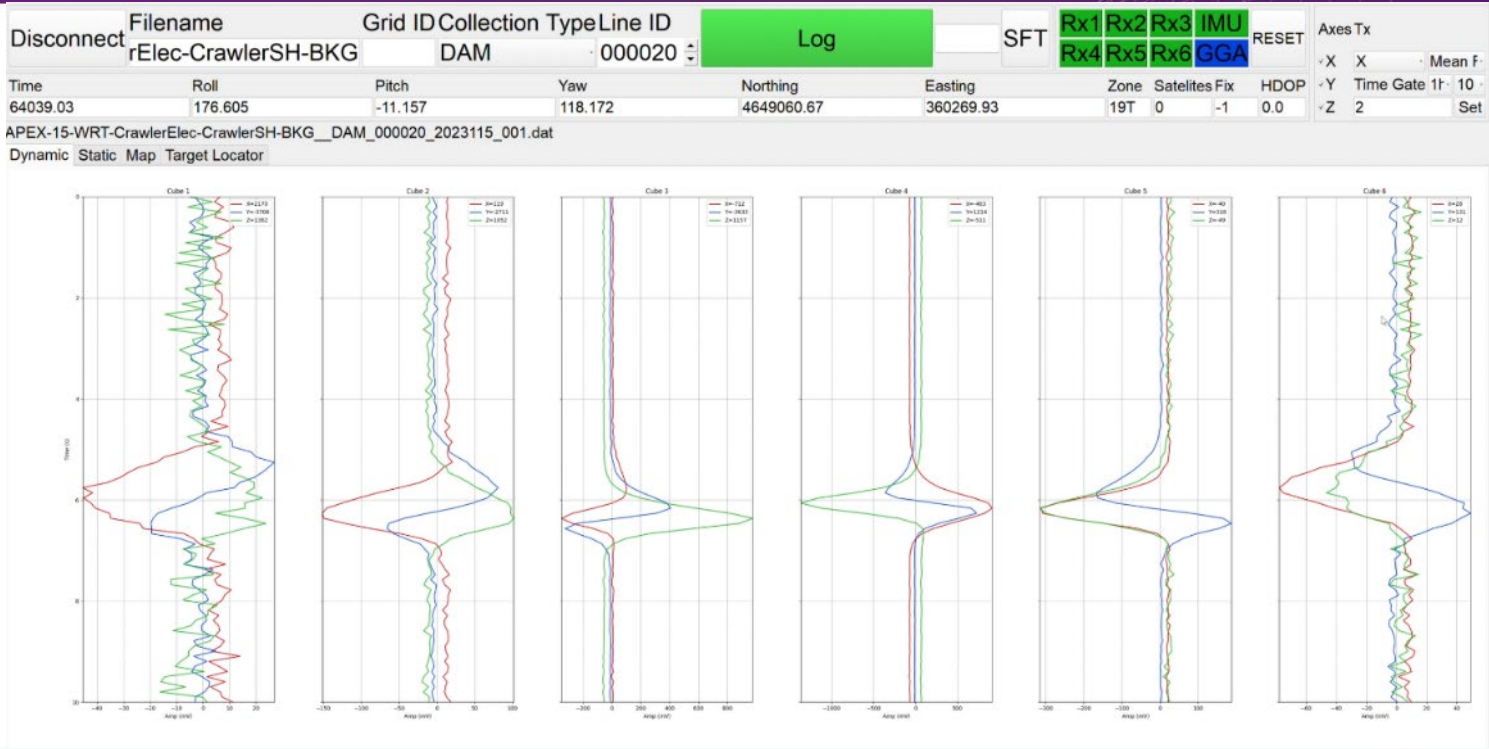


mAPEX HH6 Array

- 3 Transmitters
- 6 Receivers
- 288 Data Channels
- 864 Data Elements/scan
- 10 or 30 Scans per second

ESTCP

Technology Description

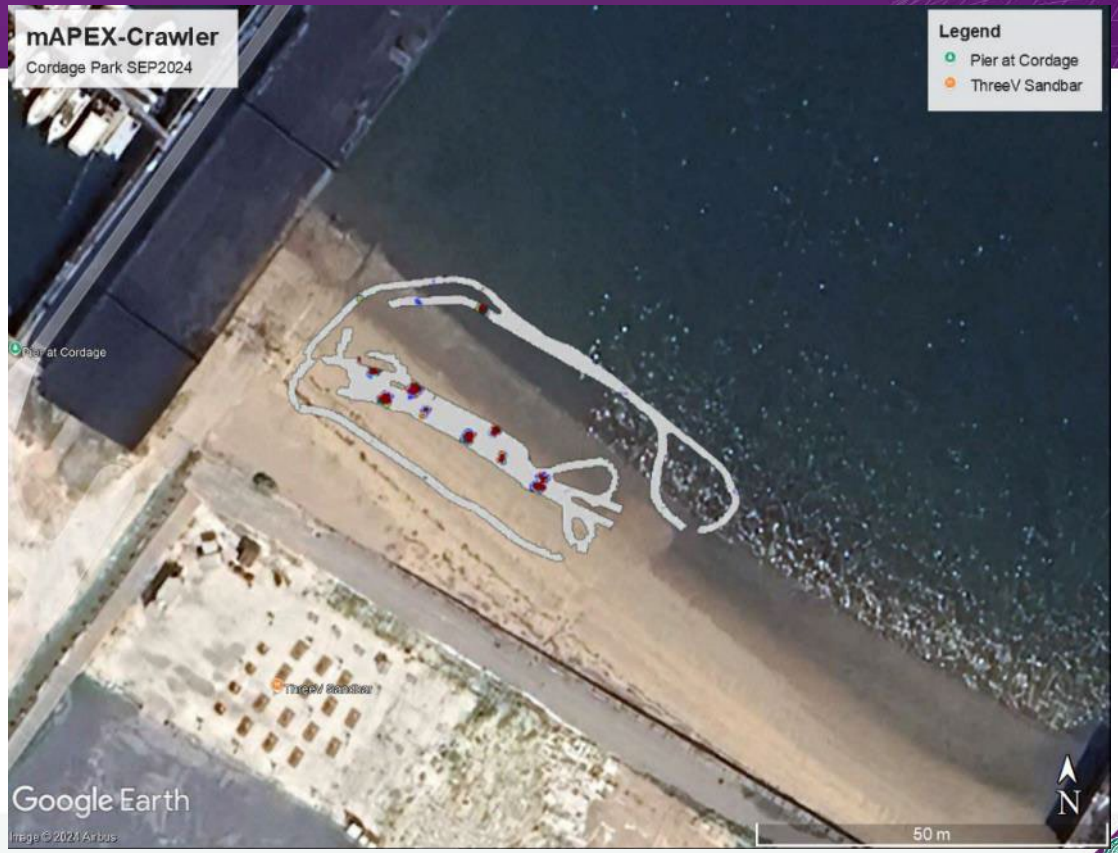


Technology Description

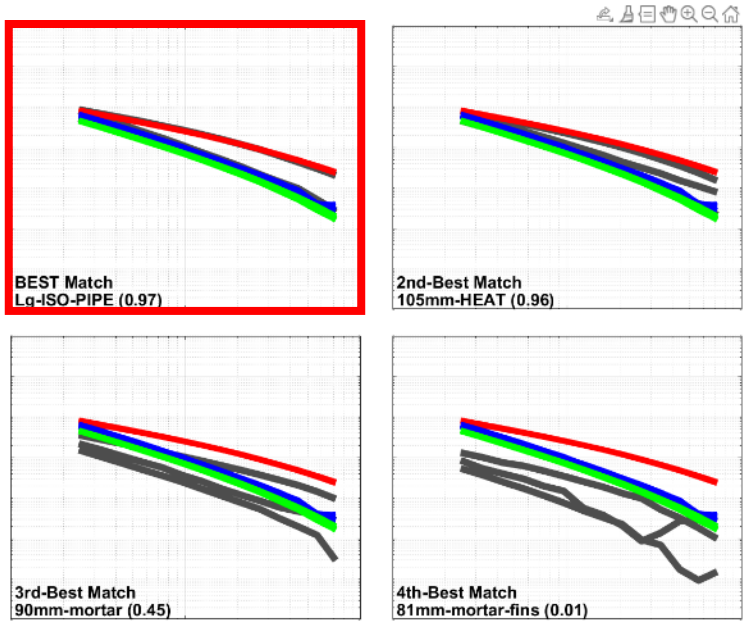
Feature	Specifications	Notes
Towed Sensor Array		
Dimensions (LxWxH)	122.0cm X 160.0cm X 12.8cm	48”L X 63”W X 5”H
Weight	29.3 kg (64.4 lbs)	sensor array only
Electronics Pressure Vessel		
Dimensions (DxL)	20.5cm X 46.0cm (8” X 18.1”)	
Weight	9.25 kg (20.4 lbs)	
Depth Rating	100 m seawater	
Power Specifications	22 A-hrs, Approx. 100 W	configurable
Power Supply	2 x 13.2VDC LiFeO4 Batteries	
Endurance	4 hours, 10 line-km	depends on conditions
Sampling Rate	10 Hz (full 3D sample)	configurable
Data Interface	10BASE-T Ethernet (UDP)	
Advance Rate	0.5-1.2 m/s (1-2.3 kts)	
Locating Accuracy	Approx. 2% Depth (5cm XYZ to 2m)	AGC to 11 x Tgt. Diam.
Data Work Products	Geotiff, KML, Target Decision List	
Software	APEXCOM v4.5	Real-time telemetry

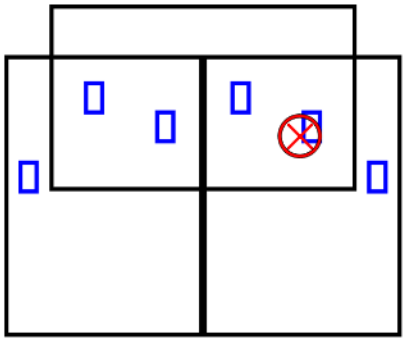
Cordage Park, MA 2024 Tests

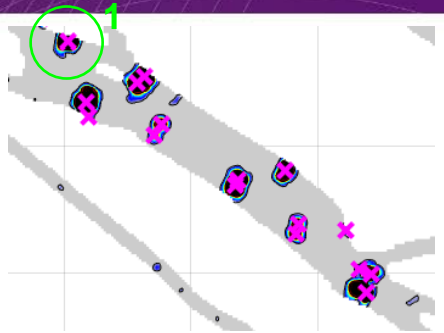
GeoTiff
Google Earth
Overlay



Cordage Park, MA 2024 Tests







TARGET IDENTIFIED !!UXO!!
Best Match: Lg-ISO-PIPE
Decision: 0.97
Model Fit: 1.00
X = 0.39, Y = 0.08, Z = -0.32 m

** depth (Z) is total range including standoff above ground to obj center*

#1 Emplaced Target:
Lg-ISO (13cm)