Highly Integrated Autonomous ROV-based 3DEM for Underwater AGC

MR22-7454

Greg Schultz

White River Technologies

In Progress Review Meeting

14 January 2026

Project Team

WHITE RIVER TECHNOLOGIES

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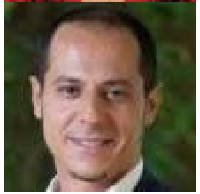

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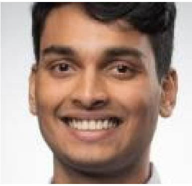


DB Bhowmick, WRT←UNH
Robotics Test Engineer

Bottom Line Up Front

Technology Focus

- *Cost-effective methods for integrated Remotely Operative Vehicles & underwater 3DEM technology for shallow water UXO site assessment*
- *ROV-based AGC with optional deployment from an ASV*

Accomplishments

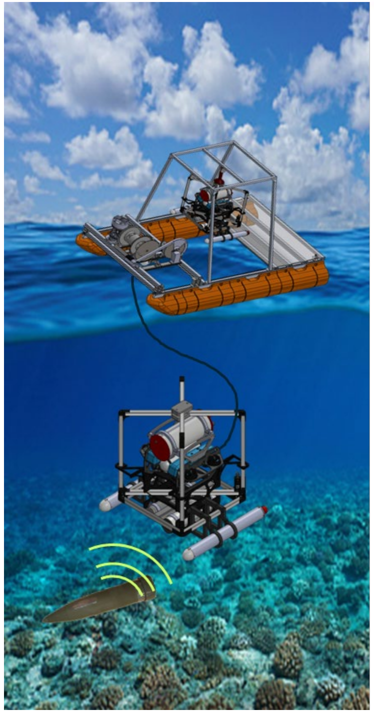
- *Transitioned mAPEX from BlueROV-2 to MSS Defender ROV unit*
- *Validated dynamic surveying and static AGC via in-water tests*
- *Implemented coherent noise filtering approach to reduce ROV motor noise*
- *Completed in-water demonstrations with two different sensor array configurations*

Challenges

- *Significantly reduced scope of project → abbreviated demonstration planned*
- *Geo-positioning and navigation of ROV-EM currently limited to ~1 m subsea*

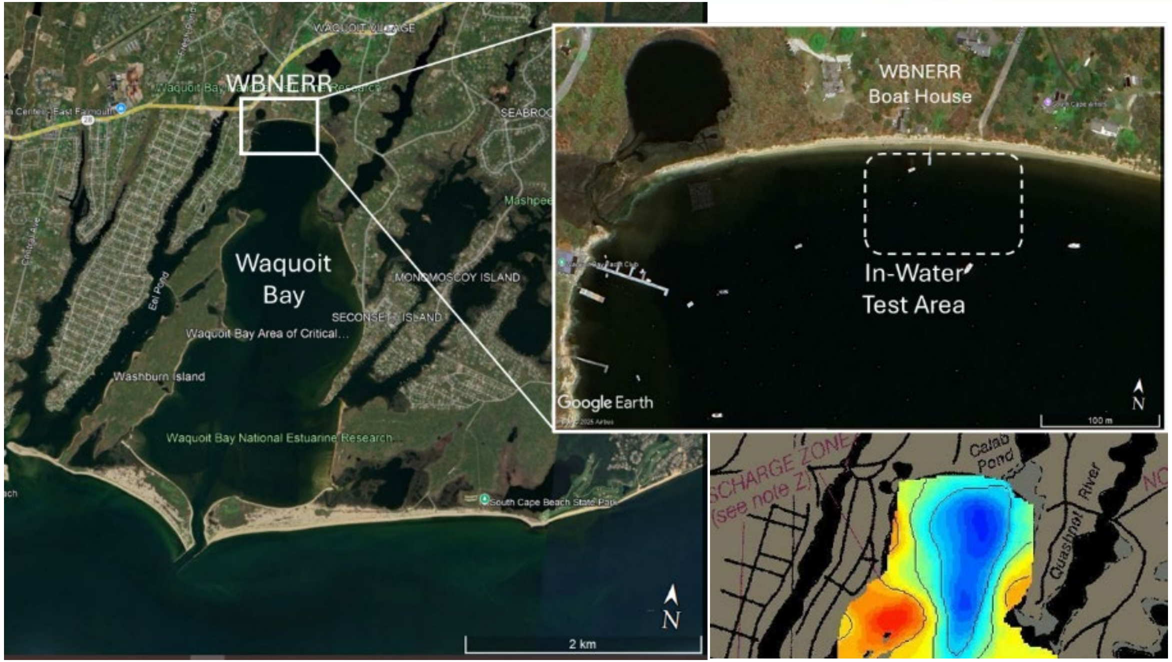
Implementation Support

- *In-water demonstrations (x2) were conducted at Waquoit Bay, MA (WBNERR)*



Site Description

Waquoit Bay National Estuarine Research Reserve (WBNERR)

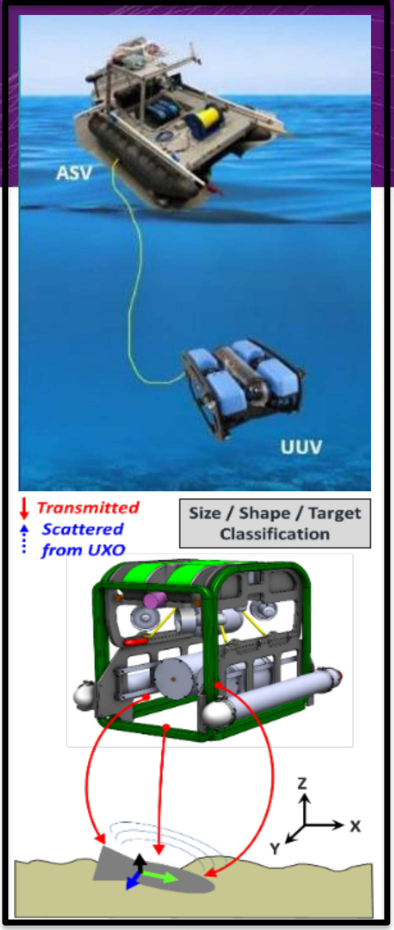


Sandy bottom; 2-3 ft tidal range; ~30PSU salinity (42 mS/cm); Maximum depth 3.5 meters (0.25 meter contours in bathy image)

ESTCP

Technical Approach

1. **Integrate underwater 3DEM UXO classification with marine autonomy control systems**
2. **Validate tightly integrated form factor on small ROV with autonomous survey control**
3. **Assess integrated solution: ASV-based launch & positioning of ROV-EM system** (centralized communication, coordination, and positioning)
4. **Demonstrate full scale operations at a prepared test site**
5. **Develop transition products including use-case scenarios, best operating practices, and docs**



ESTCP

Technical Approach

Integration Testing

ROV2-EM Integration / Testing
- Simulations: EM + Hydro + CAD
- Hydrodynamic feasibility analysis

3DEM & Hydrodynamic Optimization
- Embedded EM design
- Initial noise / performance testing

Controlled Tests
- UNH indoor test basin
- UNH open water basin

Go/ No Go

System Prep & Proveout

ASV-ROV Control / Positioning
- Launch & recovery
- UGPS configuration & testing
- Mission planning & auto-control

Data Processing Workflow
- Detection & classification

Integrated System Proveouts
- Waypoint / bottom following
- UNH Engineering validation

Demo & Analysis

Preparation
- Site selection / set up; demo plan

Demonstration
- Mobilize & collect data
- Analysis & report

Transition Assessment

Production Operating Envelope
- Best implementation; cost analysis

Transition Outreach / Pilot Study
- Usage / SOPs; outreach products
- Pilot study use-case

Go/No-go Criteria: *Proven prototype integrated system control & EM AGC performance*

Technical Accomplishments

Task 1. ROV+3DEM Integration & Testing

- *Transitioned from BlueROV to MSS Defender ROV*
- *Hydrodynamic Optimization (Trim & Balance)*

Task 2. ASV-ROV Configuration & Mission Control

- *Demonstrated ROV deployment / recovery*

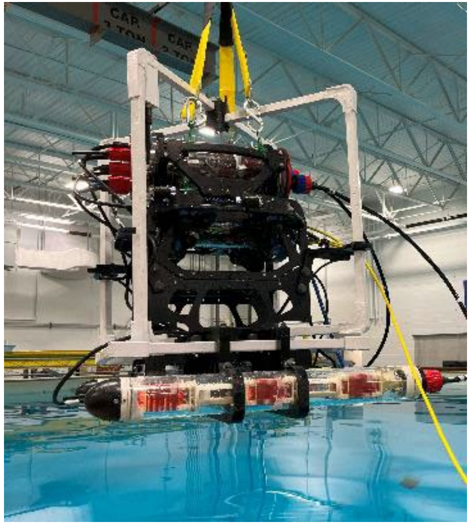
Task 3. Integrated System Prep & Proveouts

- *Waypoint mission planning & bottom tracking*
- *Demonstration Plan*

Task 4. Field Demonstration

- *Limited in-water demos (x2) conducted, FR draft submitted*

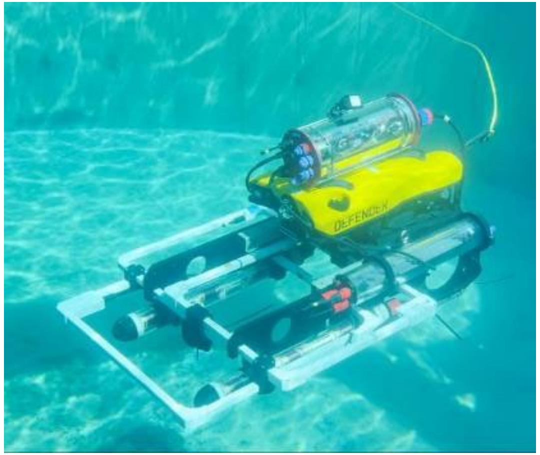
Task 5. Transition Assessment



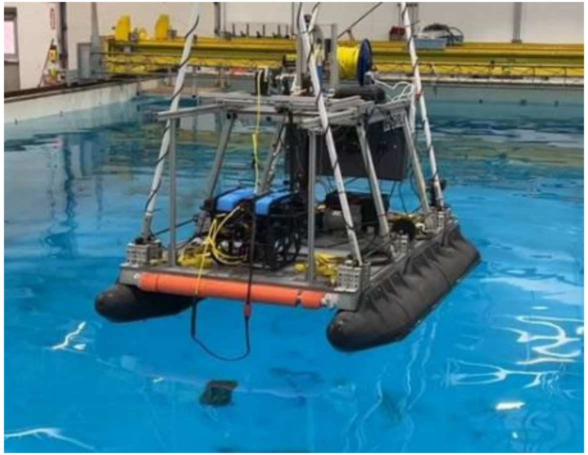
Key Technology Elements

1) ROV System
MSS Defender

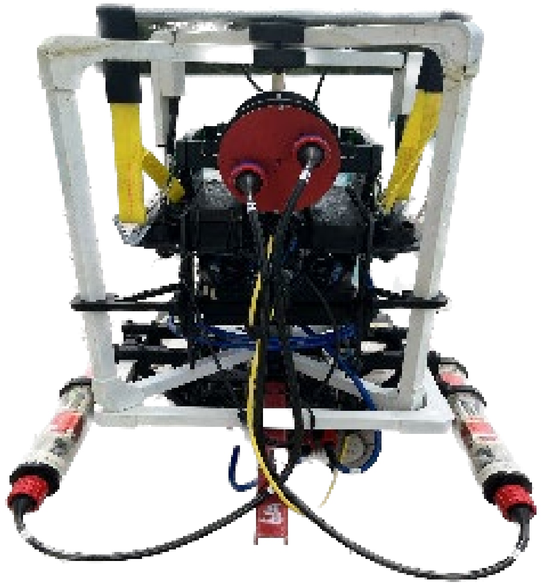
2) 3DEM Array
mAPEX H6

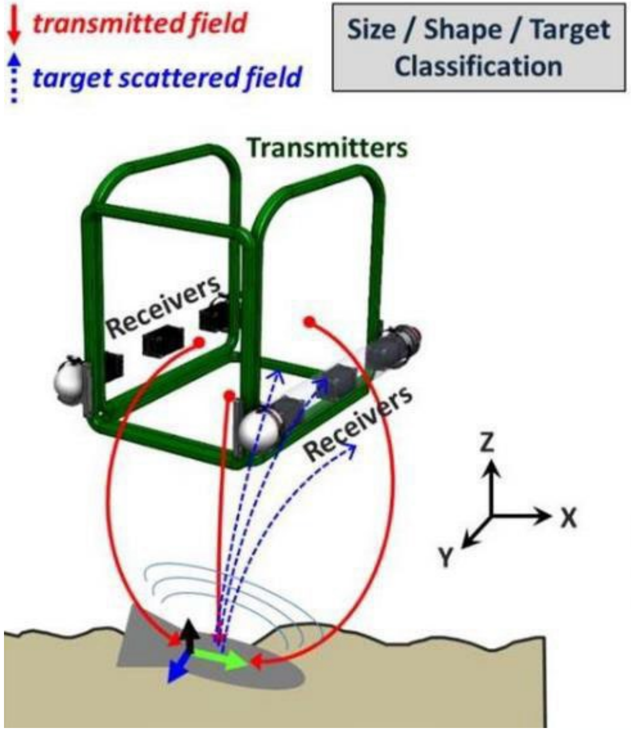


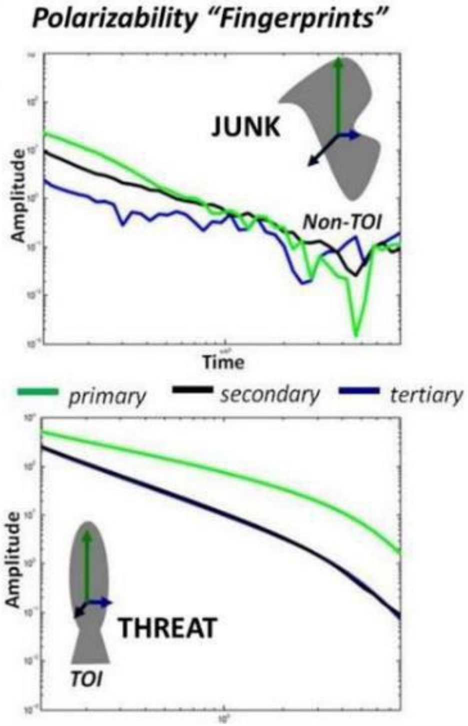
3) Autonomous Surface Vessel
mAPEX H6



ROV+APEX 3DEM Integration Design







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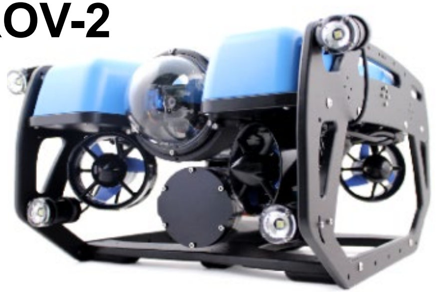
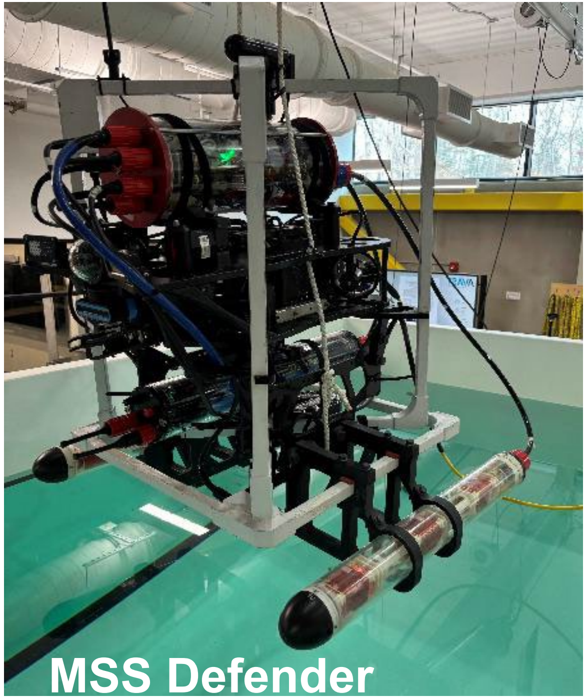
Transition BROV to MSS Defender ROV

BlueROV-2

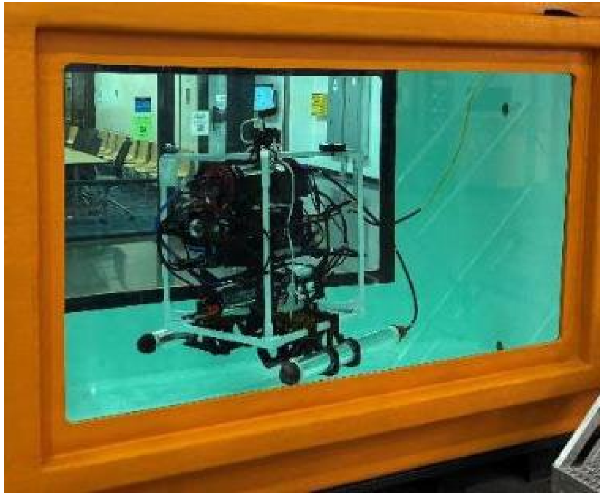


MSS Defender



Defender ROV-EM Trim & Balance

- UNH & WHOI Tanks
- Hydrostatic Trim/Bal
- Hydrodynamic Proveout



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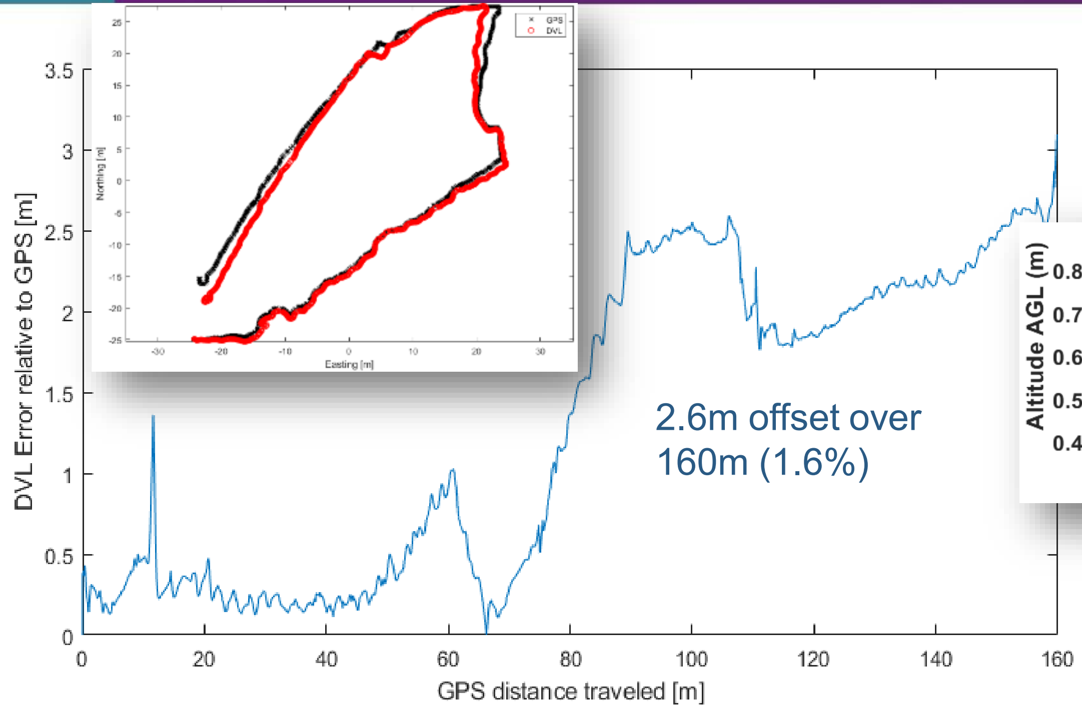
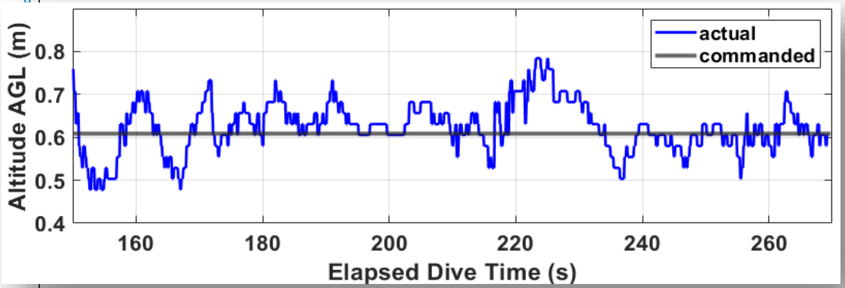
Nav/Pos & Bottom Tracking

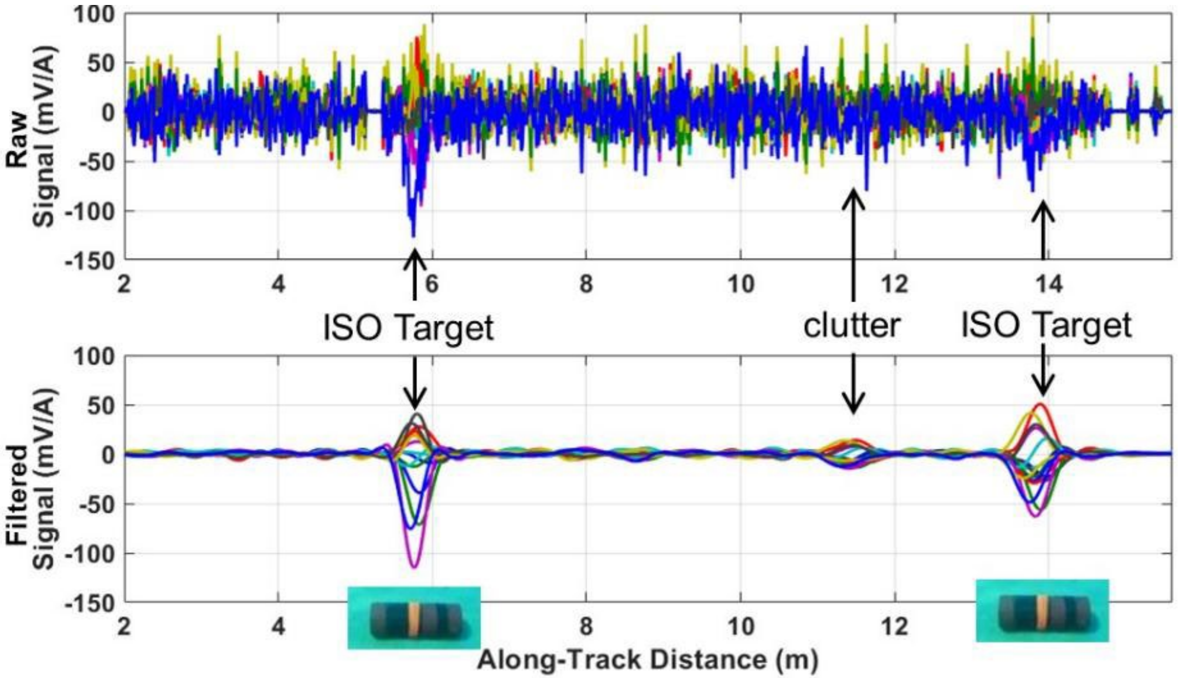


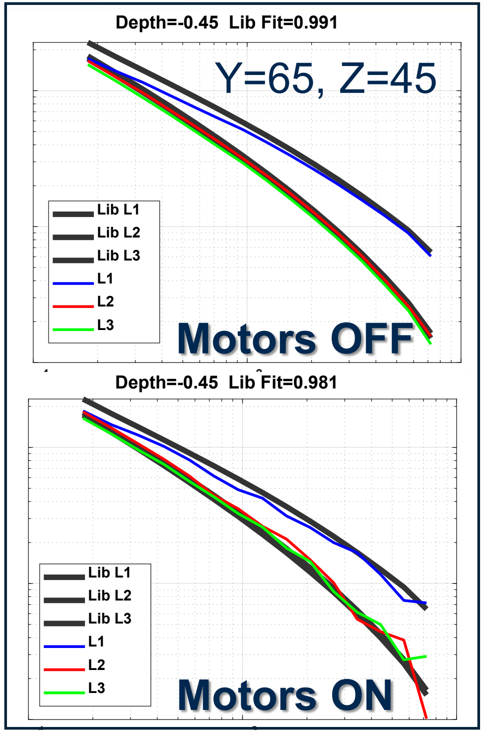
- DVL-INS Heading Changes
- Heading Errors ~ 1-2% DT



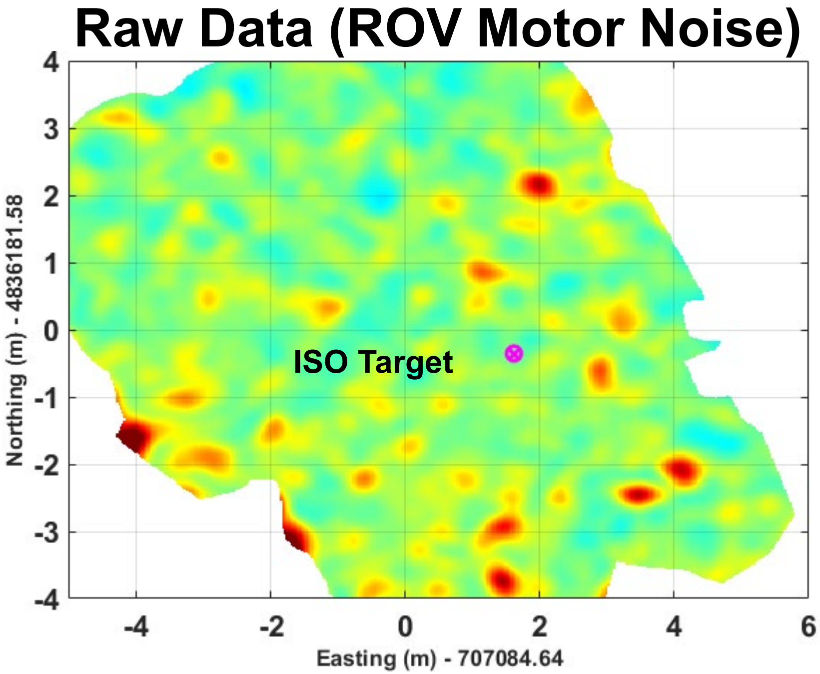
- Bottom Tracking Using DVL
- STD = +/- 5.8cm
- Max Deviation = 17cm

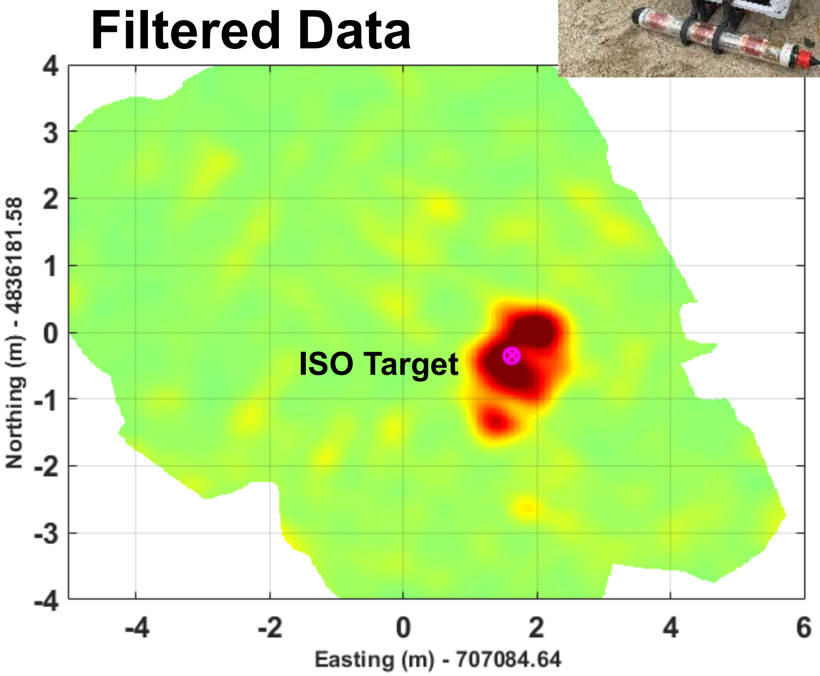
Defender ROV-EM Validation





In-Water Engineering Tests





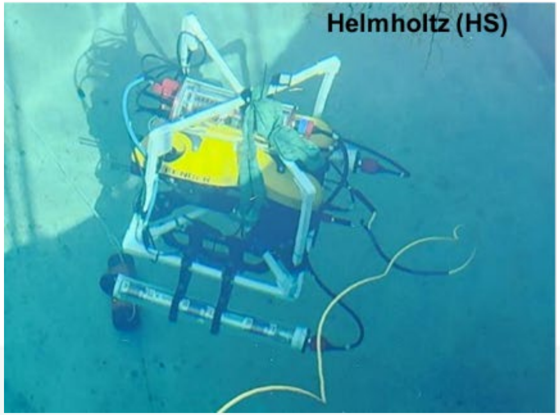
In-Water Testing & Demonstrations

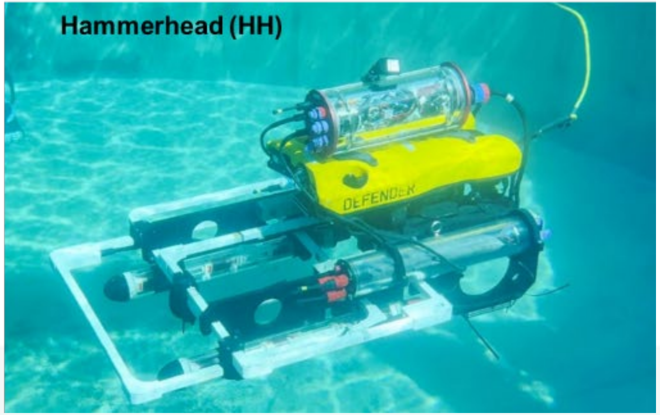
In-Water Demonstrations

A) Helmholtz “HS-Config.”
MAY 2025 Demo

B) Hammerhead “HH-Config.”
OCT 2025 Demo

- Fall ‘23 — BlueROV Test Stand
- Winter 23/24 — UNH Test Basin
- May ‘24 — Lake Mascoma NAV tests
- Oct ‘24 — Defender ROV Test Stand
- Nov ‘24 — Lake Pinneo NAV tests
- Mar ‘25 — Lake Pinneo Proveout
- May ‘25 — Waquoit Bay Demo (HS)
- Aug ‘25 — WHOI Tank NAV tests
- Sep ‘25 — Waquoit Bay Demo (HH)





Helmholtz-style Configuration
- ➢ *Compact, frontal drag*

Hammerhead Co-Planar Config.
- ➢ *Greater yaw stability*
- ➢ *Enables bolt-on skid*

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Performance Objectives

Objective	Metric	Success Criteria
Survey Coverage	Point-to-point cross-track spacing derived from N, E	100% cross-track spacing ≤ 1.5m
Coverage Rate	Estimated Acres / day	1 acre/day; full coverage
Detection of UXO	$SNR > 5 \times RMS_{noise}$	Detection of LG-ISO-40 up to 80cm standoff range
Location Accuracy	ΔN & ΔE = $\lVert est\_XY - true\_XY \rVert$ $CEP = \sigma_{xy}\sqrt{-2\ln(0.5)}$	ΔN & ΔE < 100 cm σN & σE < 50 cm
Data Usability for Classification	Quality of Inverted Polarizabilities	Model Coherence/Fit > 0.85 Library Match > 0.80

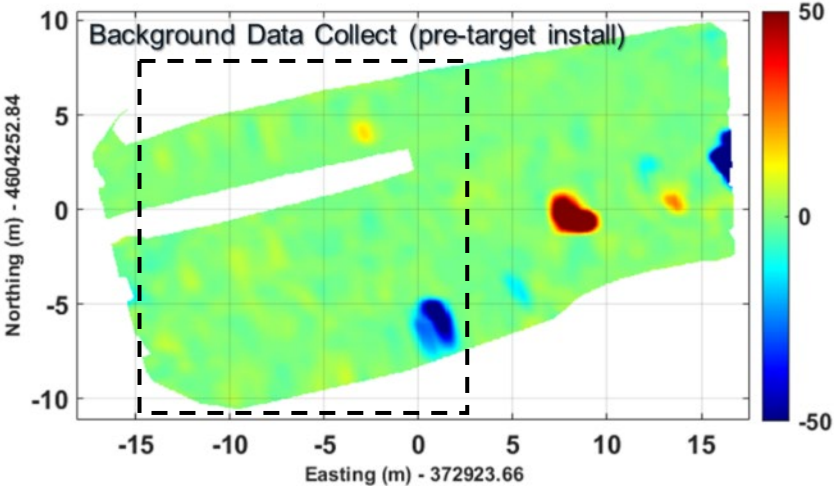
Classification Accuracy	P_{class} = (#True Labels / #TOI)x100
	CR = (#Rejected / #Clutter)x100
		100% TOI Classification
		Clutter Rejection > 65%

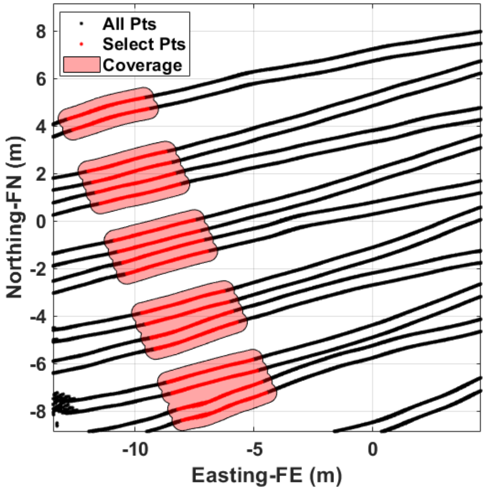
Ease of Use & Stability	Operator Observations	Compared to other Ops/ROVs

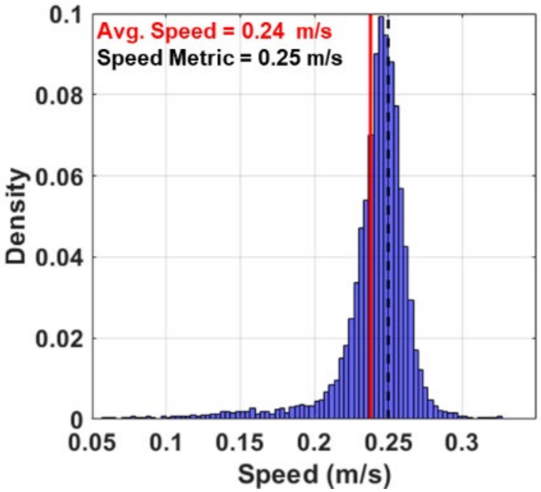
Survey Coverage

Coverage Rate projected using segmented area coverage and average advance rate

HS Config: 0.86 line-km/hr, 0.28 ac/hr
HH Config: 0.88 line-km/hr, 0.29 ac/hr







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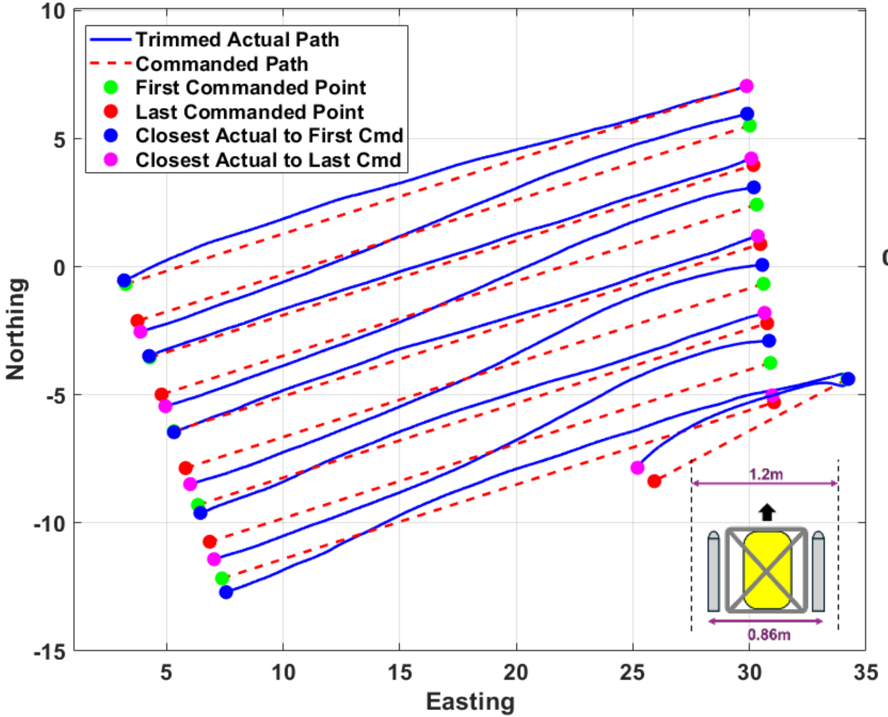
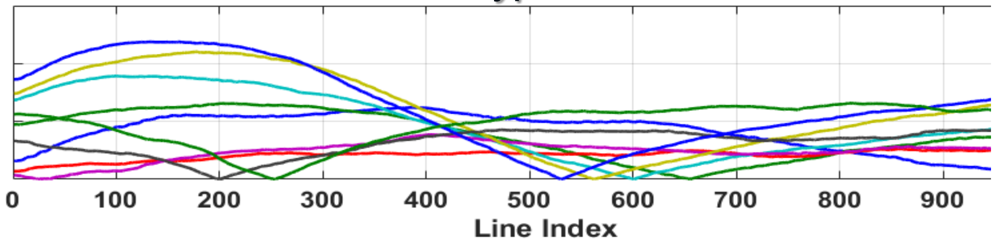
Survey Coverage



waypoint line deviations



- Waypoint line deviations from commanded
- Line spacing 1.2m
- Mean ΔR=0.38m, Max ΔR = 1.24m
- Tether catenary affects waypoint line track
- Analyzing heading drift influence on errors

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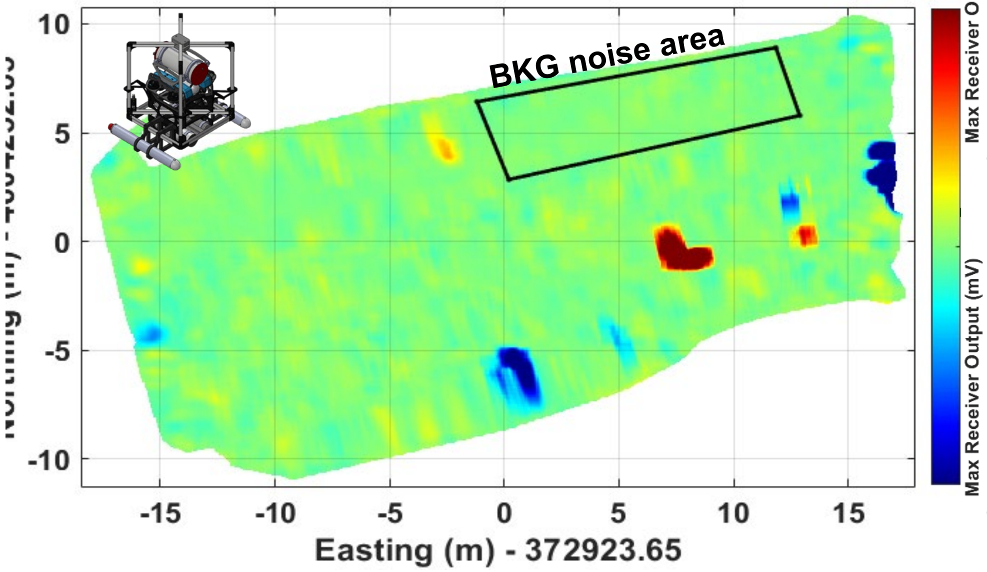
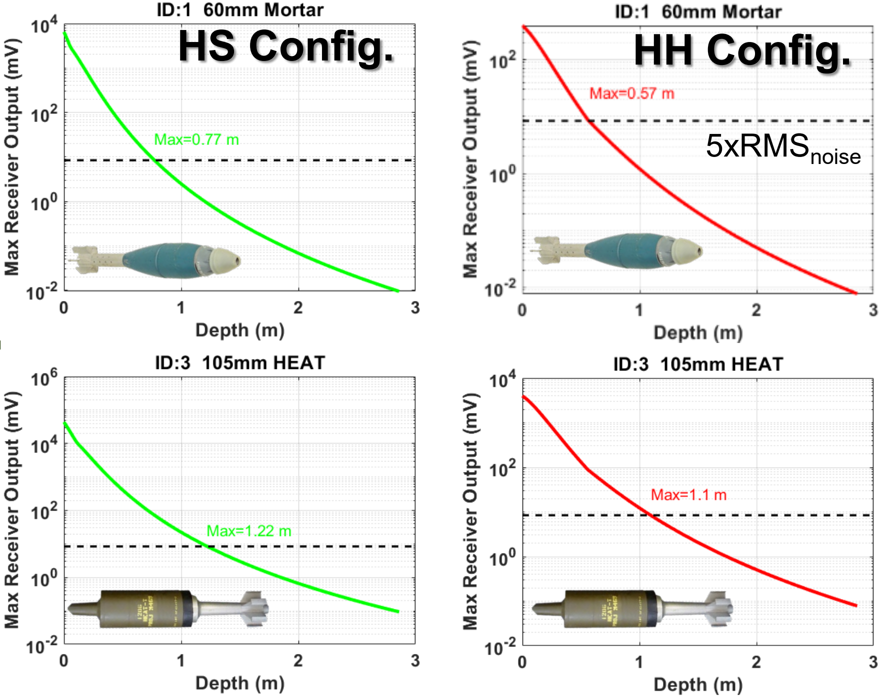
Detection/Classification Depth Response

Maximum reliable classification depth at the 5x RMS noise





Max. Reliable Classification Depth Estimates

Emplaced Item	Approx. Diameter (cm [in])	Approx. Length (cm [in])	HS Max Depth* (cm [in])	HH Max Depth* (cm [in])	11x Diam. Depth* (cm [in])
Small ISO-80	2.5 [1.0]	10.2 [4.0]	55.0 [21.7]	29.0 [11.4]	27.9 [11.0]
Medium-ISO-40	5.1 [2.0]	20.3 [8.0]	85.0 [33.5]	64.0 [25.2]	55.9 [22.0]
Large-ISO-40	10.1 [4.0]	30.5 [12.0]	125.0 [49.2]	112.0 [44.1]	111.8 [44.0]
XL-ISO-40	15.2 [6.0]	60.9 [24.0]	179.0 [70.5]	168.0 [66.1]	167.6 [66.0]
60mm Mortar	6.0 [2.4]	29.5 [11.6]	77.0 [30.3]	57.0 [22.4]	66.0 [26.0]
81mm Mortar	8.1 [3.2]	33.8 [13.3]	93.0 [36.6]	76.0 [29.9]	89.1 [35.1]
105mm HEAT	10.5 [4.1]	49.5 [19.5]	122.0 [48.0]	110.0 [43.3]	115.5 [45.5]
155mm Projectile	15.5 [6.1]	67.6 [26.6]	176.0 [69.3]	165.0 [64.9]	170.5 [67.1]

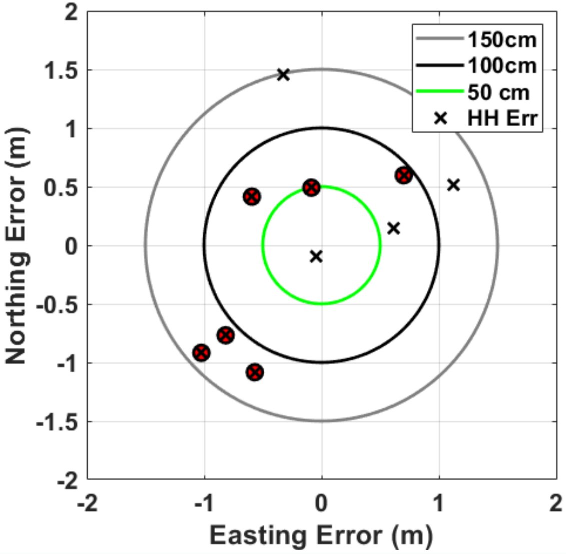
**Estimated using worst case orientation*

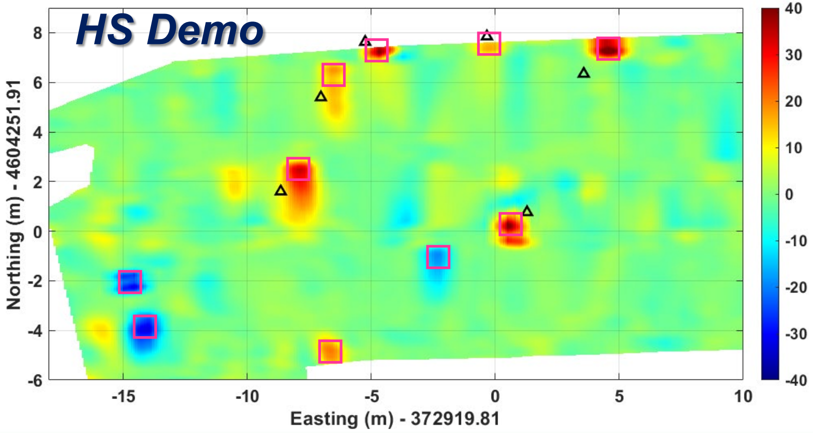
Localization Error

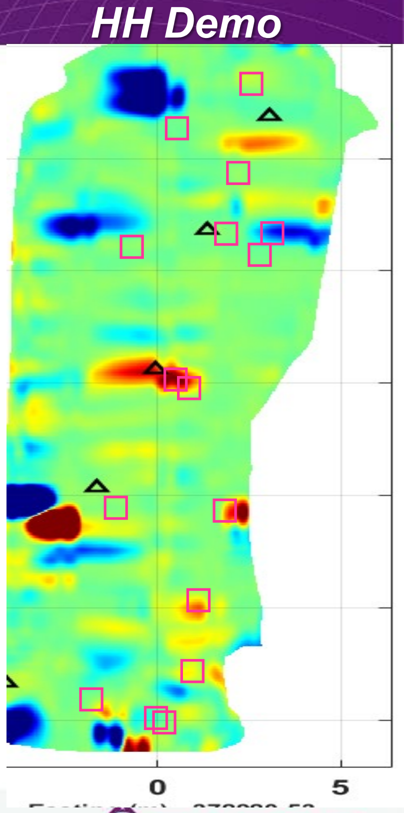
All locations <1.5m
80% locs <1.0m

Composite: μ=0.93m, σ=0.44m, max=1.49m
CEP = 0.52m, DRMS=0.62m

HS : μ=0.98m, σ=0.33m, max=1.37m
HH: μ=0.87m, σ=0.62m, max=1.49m







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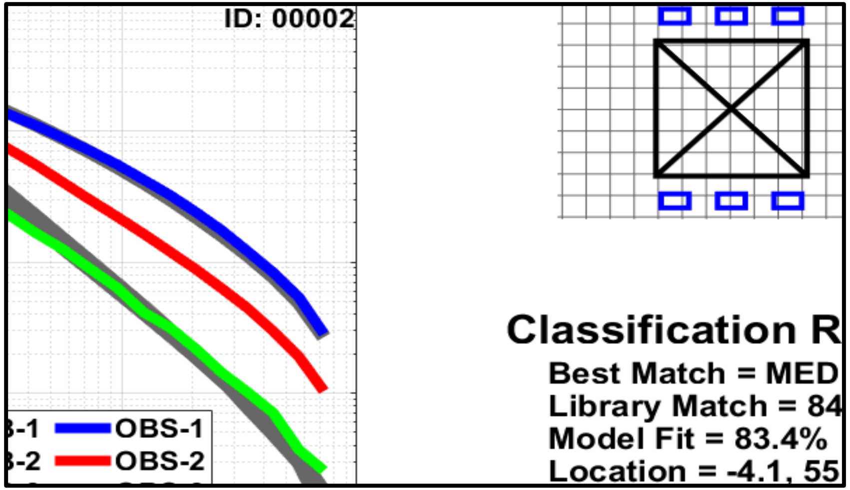
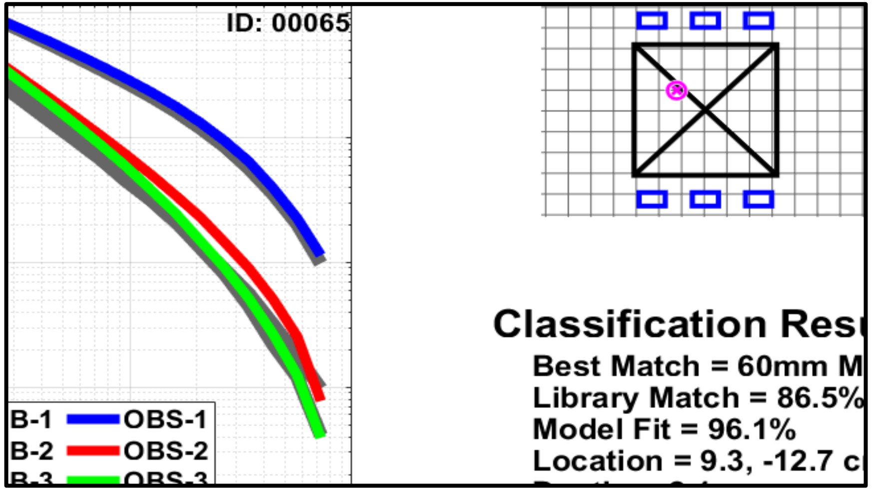
Classification: Inverted Polarizabilities

MED-ISO

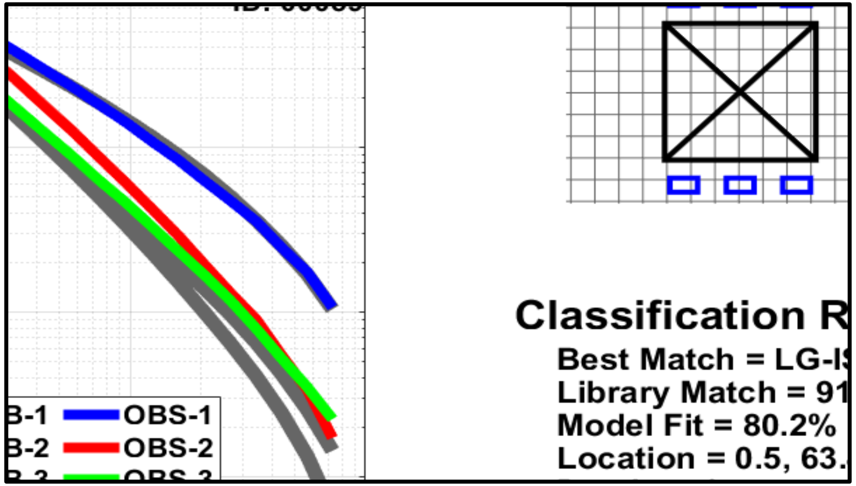


60mm Mortar

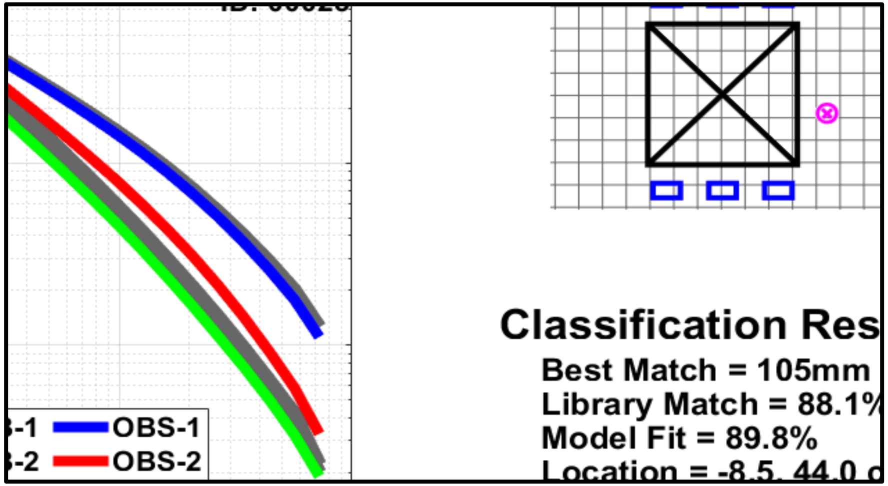


In-Water Full Scale Testing

LG-ISO



105mm HEAT

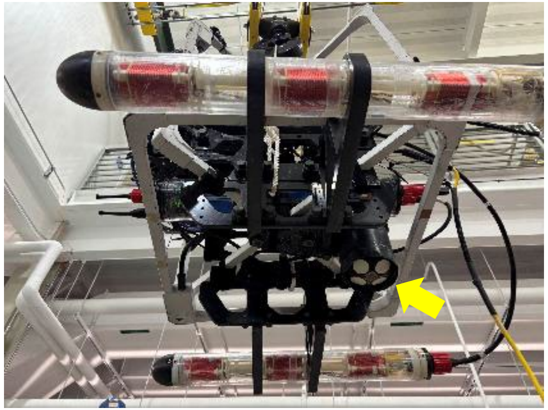


Performance Objectives

Objective	Target Metric	Observed Result
Survey Coverage	100% cross-track spacing ≤ 1.5m	Data not sufficient to assess
Coverage Rate	1 acre/day; full coverage	0.25 acre/hour (>1 acre/day)
Detection of UXO	Detection of LG-ISO-40 up to 80cm standoff range	100% Detection (6/6): HS config. 100% Detection (5/5): HH config.
Location Accuracy	ΔN & ΔE < 100 cm σN & σE < 50 cm	HS Demo: CEP = 92 cm HH Demo: CEP = 124 cm
Data Usability for Classification	Model Coherence/Fit > 0.85 Library Match > 0.80	All TOI inversions meeting data usability correctly classified TOI
Classification Accuracy	100% TOI Classification Clutter Rejection >65%	100% TOI Classified Correctly Unable to assess Clutter Rejection
Ease of Use & Stability	Compared to other Ops/ROVs	LAR effective; OCS effective; Mission Planning requires standards

Issues

- UGPS SBL positioning not stable enough for autonomous surveying
- MEMS INS-aided DVL (Nortek) heading errors observed when APEX Transmitters are ON prior to sufficient DVL lock – working with VideoRay and GSSIQ (EODWorkspace) on alternate DVL-INS tests



Unit	INS Tech.	DT Mfg.	DT Est.	BT Mfg.	BT Est.
WaterLinked A50	MEMS*	1%	1.6%	0.1 cm/s	±2 cm/s
Nortek DVL 500	MEMS*	0.1%	0.9%	0.8 cm/s	±2 cm/s
GSQI IQNS	FOG	0.3%	Unk	Unk	Unk
Sonardyne SprintNAV-U	FOG	0.1%	0.45%	1 cm/s	1 cm/s

** MEMS IMU separate from DVL unit; IQNS&SprintNAV integrate DVL+INS*

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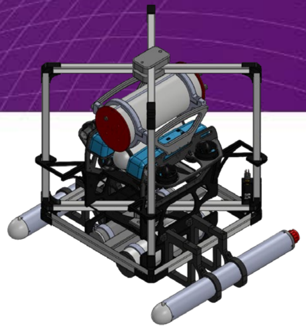
Scale Up



- Full-scale demonstration or pilot study still needed
- Custom APEXCOM <> EOD-Workspace streamlined UI
- Improve waypoint navigation for dynamic ROV-EM AGC
- Implement INS-aided DVL calibration to improve NAV/POS
- Pursue direct mount on VRR Wraith and/or Saab SeaEye Falcon
- Implement new electronics bottle (77% smaller) & modular MAG payload (via NAVSEA MESR program)

Technology Transfer

1. **Role/utility in CERCLA process / MR Site Management**
   - Supports local-scale RI/RA studies where other tech denied (sensitive bottom)
   - Locates individual items / AGC-level information; can combine w/ EO or Acoustics
2. **Identified Limitations**
   - Dynamic (map) surveying over large area challenged by positioning and efficiency/range
   - Small (Low SWAP-C) inspection-class ROVs limited in currents (<2 kts)
   - Highly-integrated system less capable wrt detection due to ROV noise influence
3. **Quality Considerations**
   - Generally amenable to typical DGM/AGC QC procedures (SFT, IVS, MQOs)
   - Underwater positioning degradation relative to GPS considerations for MQOs
   - QC and QA seeds augmented with synthetic seeds to evaluate depth performance

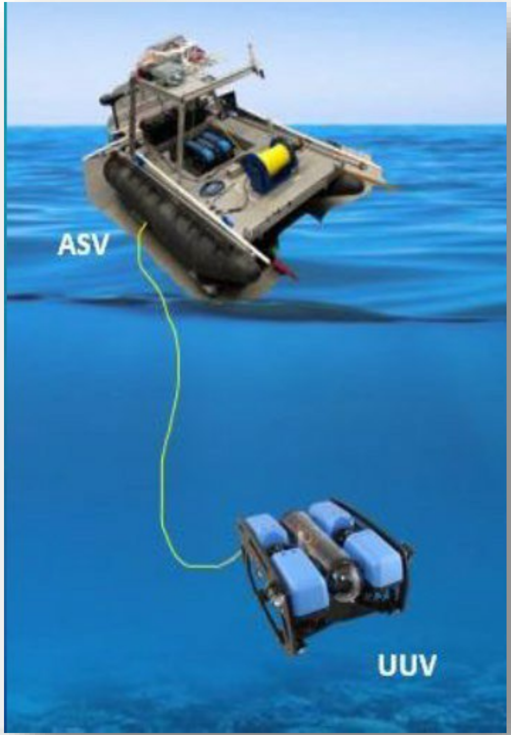
Technology Transfer

1. **Production Transition Assessment**
   - Operating envelope for full-scale implementation / operational concepts
   - Cost models: 1) “wet” lease option, 2) lease/contract option
2. **Outreach Products & Information Dissemination**
   - *SERDP Webinar (NOV 2024), MARELEC & SAGEEP Presentations (APR 2025)*
   - Kanjiken Conference (NOV 2025)
   - Complexities of ROV-based AGC White Paper (submitted to SEMS)
   - Training and information sessions (e.g., NAOC, M2S2, SAGEEP)
3. **Govt/Commercial Demonstrations**
   - Demonstrations with interested prime contractors → direct transition
   - Collaboration with NAVFAC & USACE on Demonstrations / Live Site Transition Pilots

BACKUP MATERIAL

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

Demonstration System Technology

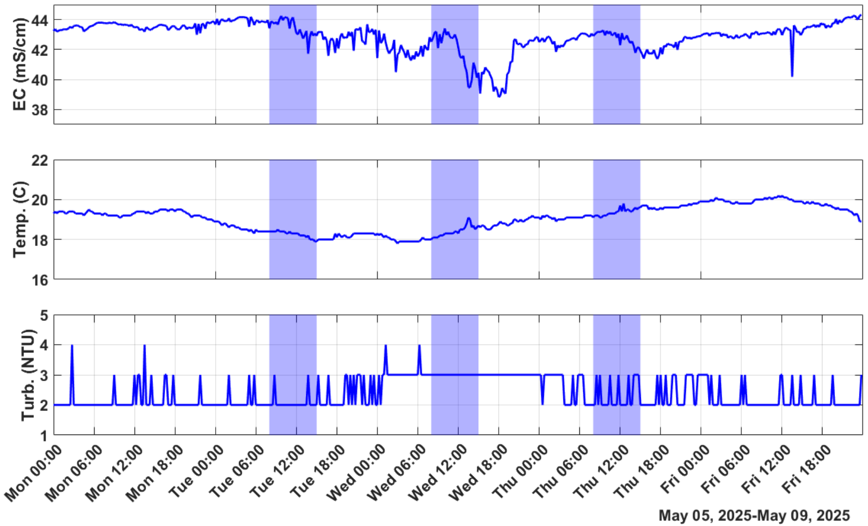


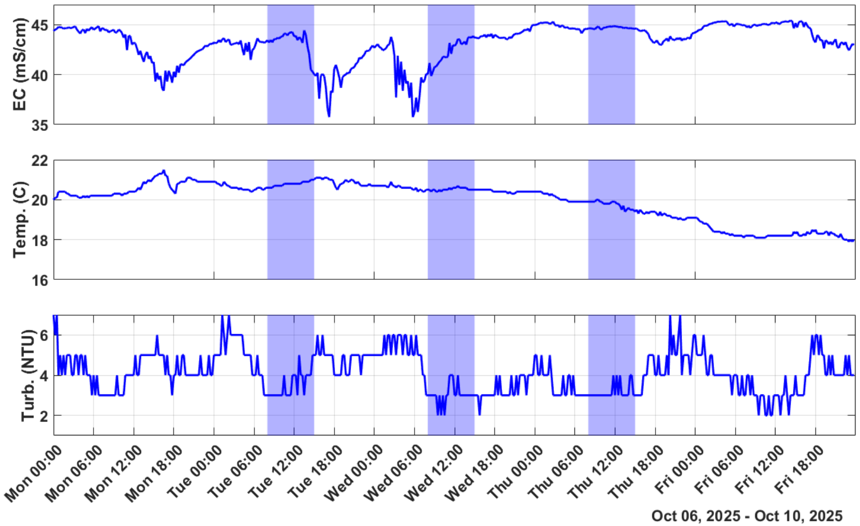
- **GPS:** Use when **Vehicle on the surface**
  - Constant GPS updates
  - Minimal navigation error build up
- **USBL:** Use when **Vehicle is below surface, no bottom lock**
  - Topside GPS combined with USBL establishes vehicle location.
  - Less precise navigation
- **DVL:** Use when **Vehicle has bottom lock**
  - No GPS update
  - Navigation error builds up over time

Plain Language Summary

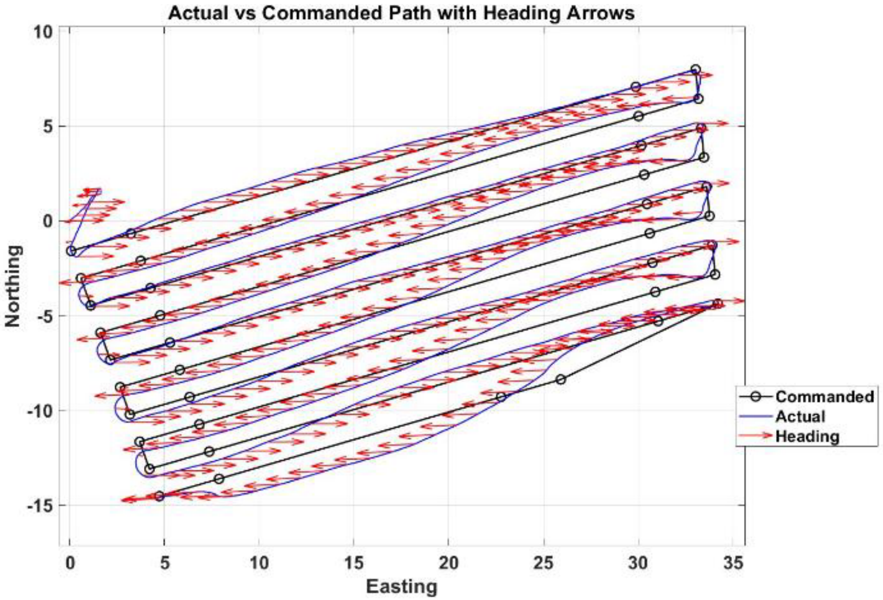
- **Shallow water UXO sites (<5-10m water depth) lack effective methods to detect and classify individual munitions, especially where bottom conditions challenge acoustics**
- **Previous ROV-based classification techniques suffered from hydrodynamic maneuverability and efficient mobilization, positioning, and survey control**
- **Cost-effective methods that apply to a wide range of nearshore, riverine, and lacustrine sites needed to fill gap between land-based AGC and offshore surveying methods**

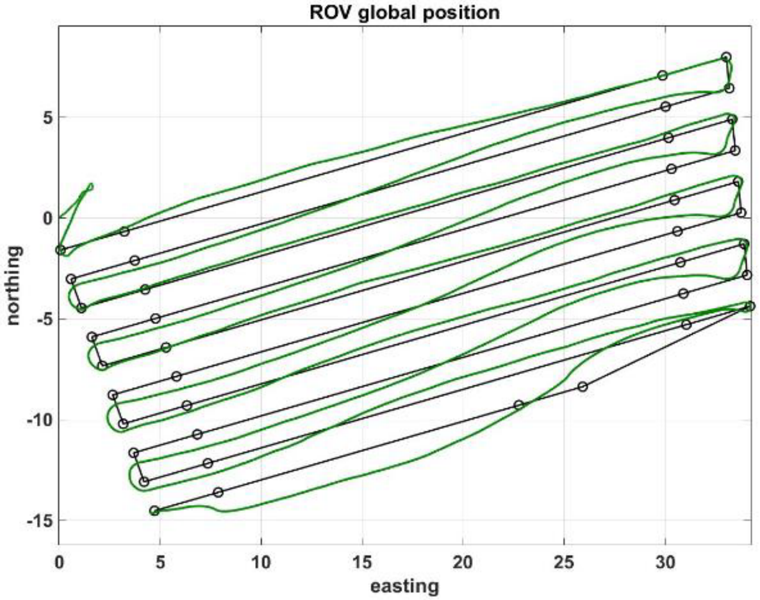
Waquoit Bay: Water Conditions





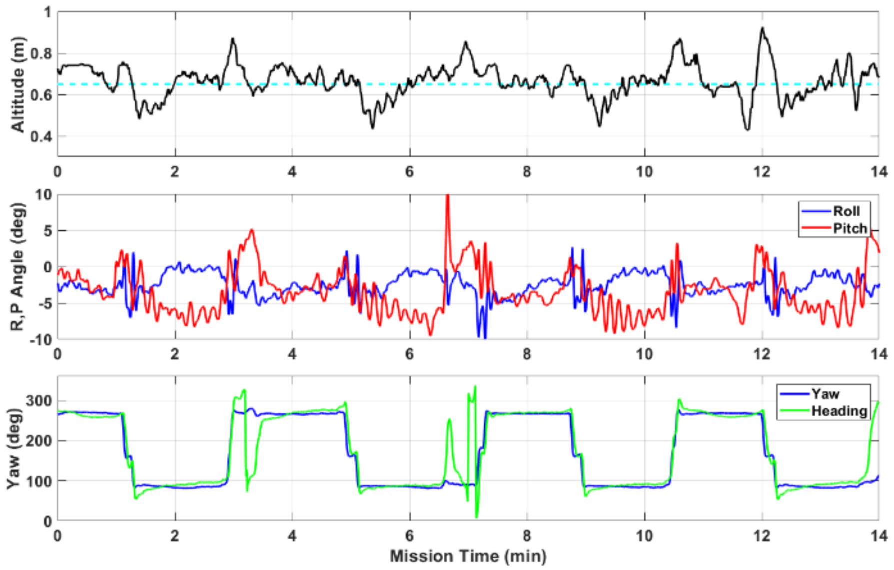
Waquoit Bay: Waypoint NAV

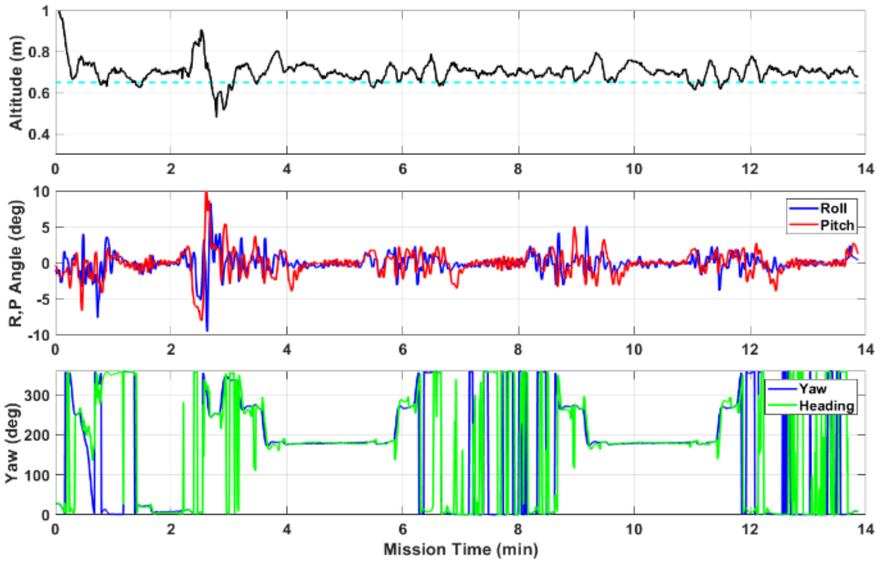




ESTCP

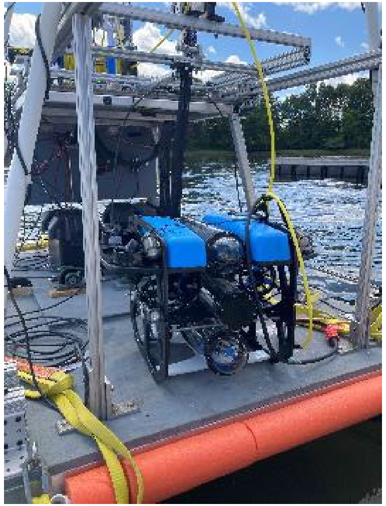
Waquoit Bay: Waypoint Control





ASV Design & Testing

- Propulsion Control
- Station Keeping
- Autonomous Path-planning
- Tether Tensioning System
- ROV Positioning System
- ROV Launch & Recovery



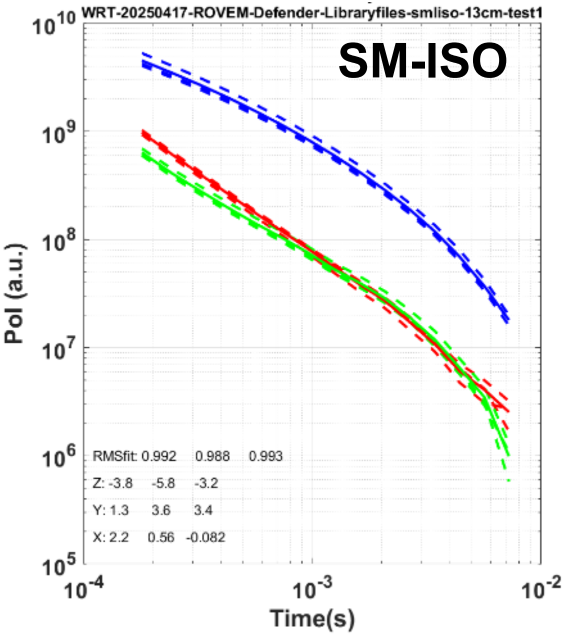
ESTCP

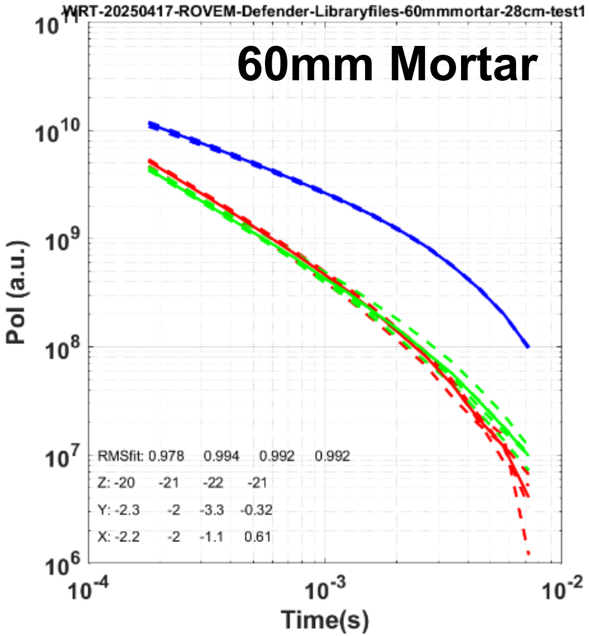
ASV Integration Design

- Tether Tensioning system:
  - Winch and spool assembly
  - Integrated linear encoder
  - Spring assembly
- Linear encoder
  - Measures force applied to tether
  - Controls amount of spool released
- Rotary encoder - used to monitor length of released tether (assuming no slipping)

ESTCP

Defender ROV-EM Validation



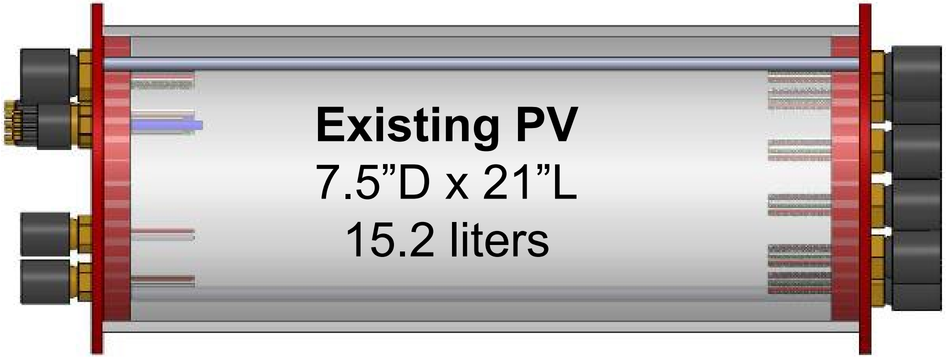


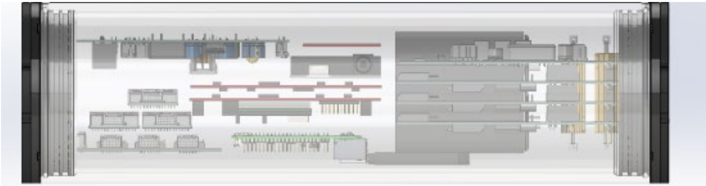
VRR Wraith Integration

Depth	1,000 m standard (expandable to 4,000 m)
Thrusters	4 horizontal / 6 vertical
Max Speed	4.2 kts forward; 0.9 kts lateral; 1.5 m/s vertical
Max Lift	36.3 kg (80 lbs)
Payload Bay	67.3 × 33 × 33 cm (26.5 × 13 × 13 in)
Power	Subsea batteries
Dimensions	131.2 × 77.6 × 34.3 cm (51.7 × 30.6 × 13.5 in)
Dry Weight	99.8 kg (220 lbs)

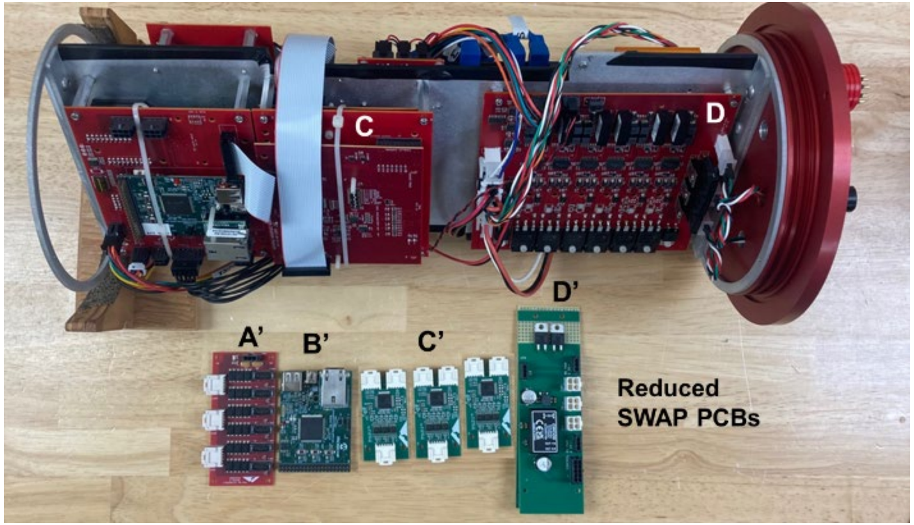
ESTCP

Electronics Upgrade (SWAP Reduction)





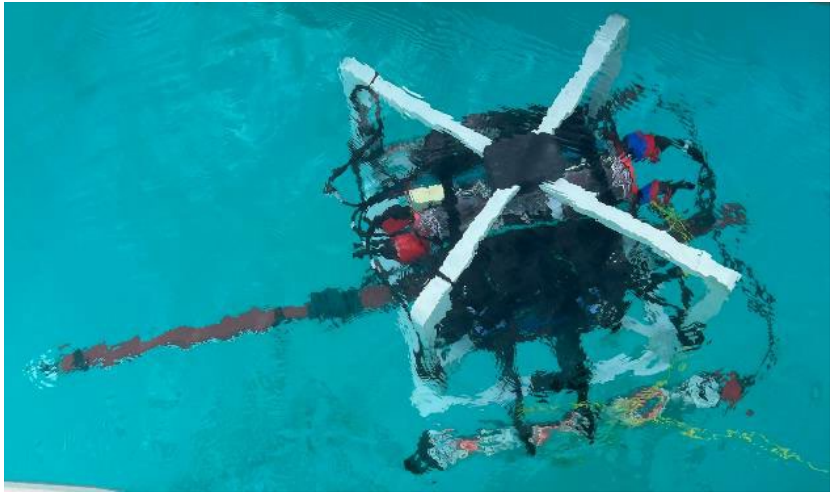
New PV
4"D x 16.5"L
3.4 liters

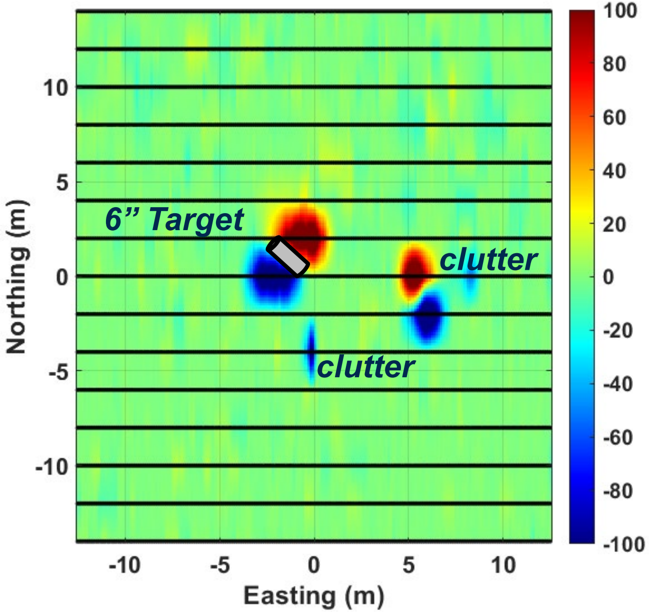


- ***>77% decrease in size (vol.)***
- ***Validated on APEX cart unit***

ESTCP

ROV-MAG Mapping System





ESTCP

ROV-EM Integration