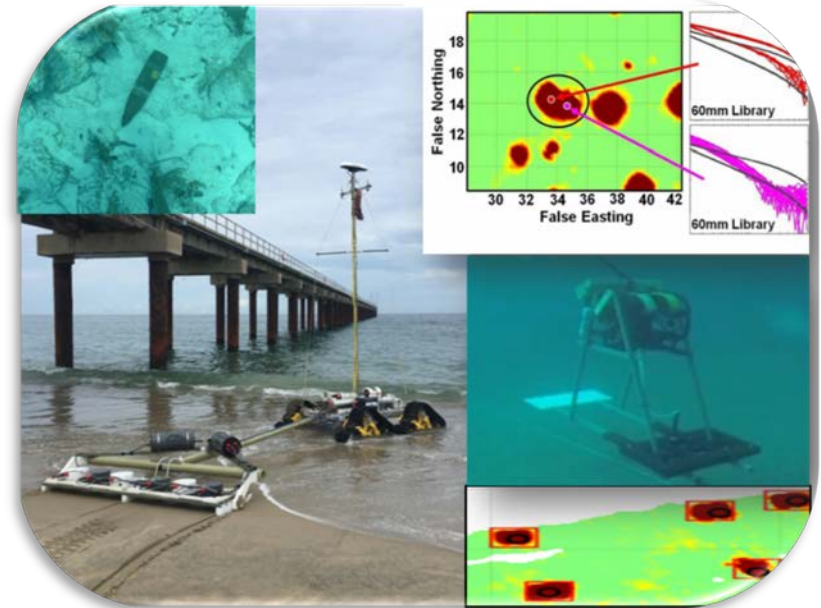# Detection & Classification of UXO Using Unmanned Undersea Electromagnetic Sensing Platforms

Greg Schultz[1], Joe Keranen[1], Jon Miller[1], Jesse McNinch[2]

1. *White River Technologies, Inc.*
2. *USACE ERDC Field Research Facility*

WHITE RIVER TECHNOLOGIES

COASTAL AND HYDRAULICS LABORATORY

Current Manned Approaches

Current geophysical survey technologies are <u>limited to diver-based sensors and towed sensor fish or arrays</u>

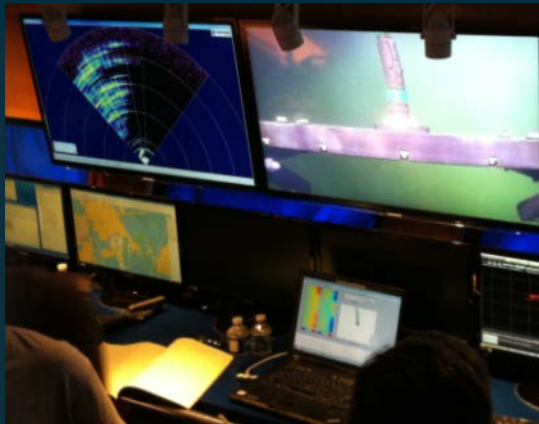➢ *Need for new technologies tailored for addressing <u>localized seabed target mapping & characterization</u>*

- Divers → limited depth & duration
- High **<u>costs</u>** = dive logistics
- Tow fish → limited control
- Single-axis / man methods
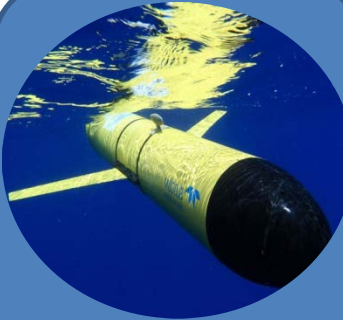- No situational awareness, data sharing, processing, or **<u>characterization</u>** capability

Outline: This Talk

1. Unmanned MAG & EM System Integration
2. Keys for UXO Detection & Classification
   - Operating Close to Seafloor
   - Configuration & Control (Autonomy?)
3. Experiments: A) UUV-MAG, B) ROV-EM, C) Crawlers
4. Synopsis & Future Directions

Anatomy of an AUV

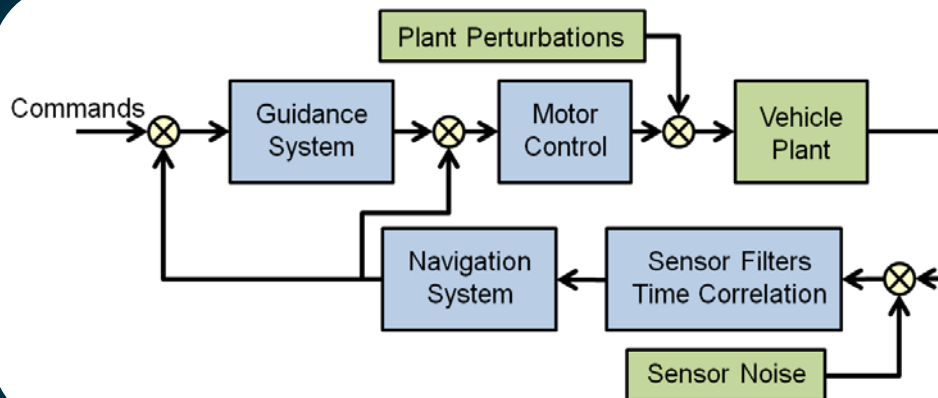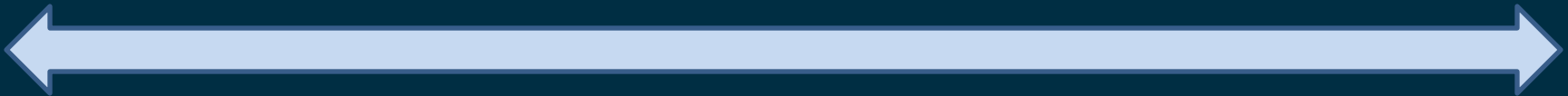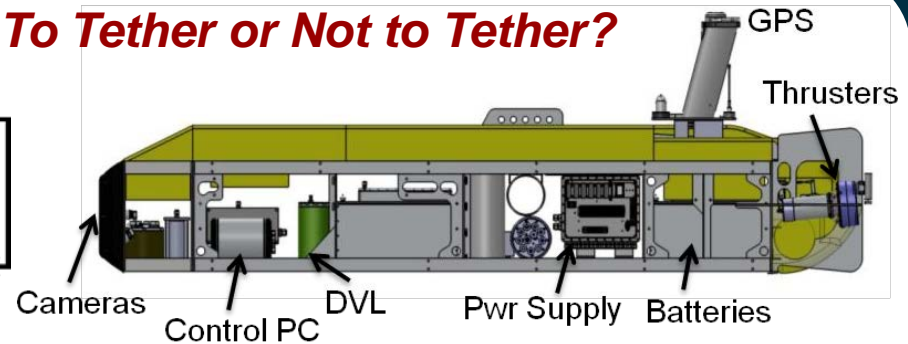**Gliders** | **AUVs** | **Hovering Hybrid AUVs** | **ROVs** | **Crawlers**

Commands → Guidance System → Motor Control → Vehicle Plant

Plant Perturbations

Navigation System ← Sensor Filters Time Correlation

Sensor Noise

To Tether or Not to Tether?

GPS

Thrusters

Cameras — Control PC — DVL — Pwr Supply — Batteries

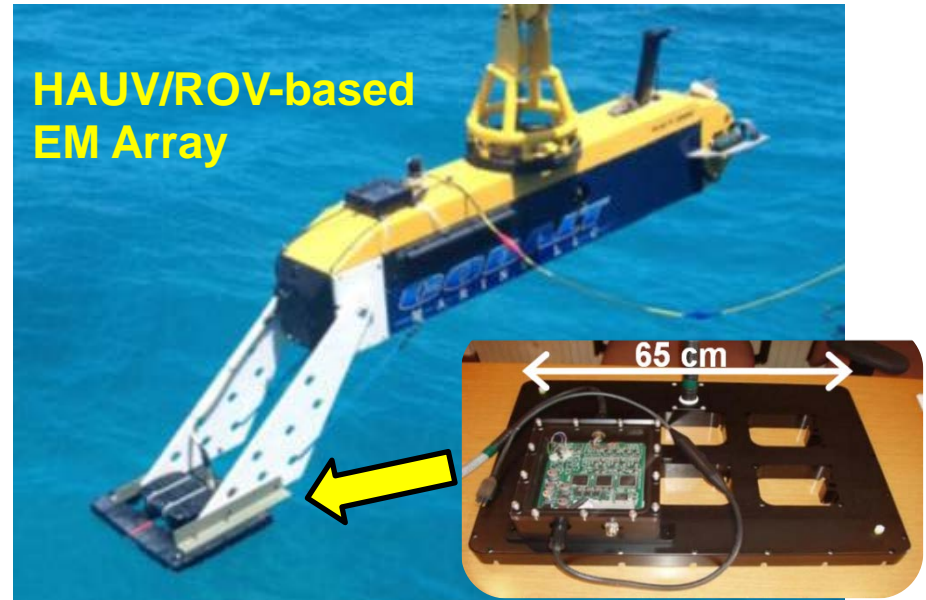*Stability* ⟷ *Coverage* ⟷ *Maneuverability* ⟷ *Endurance* ⟷ *Control*

Integration on Unmanned Platforms

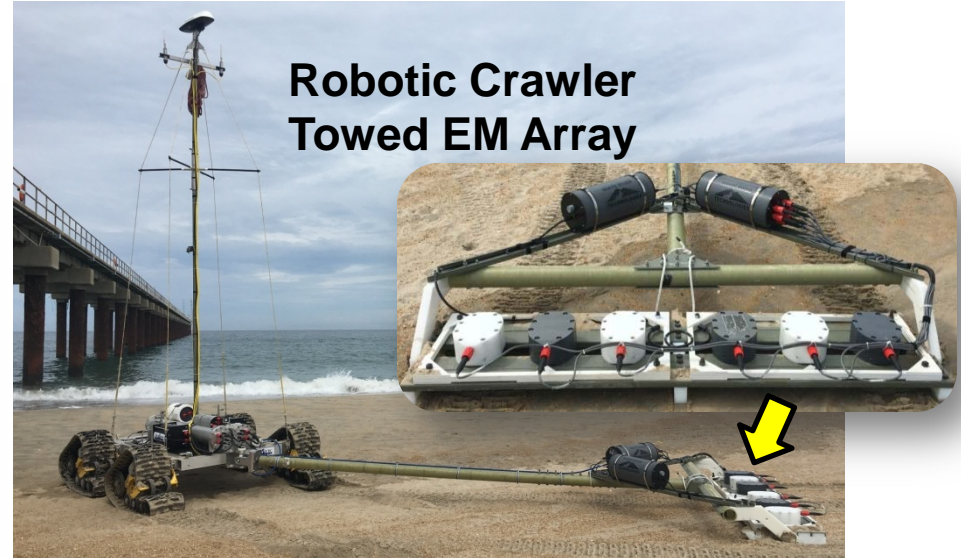UUV (REMUS-100) Mini-MAG Gradiometer Array

HAUV/ROV-based EM Array

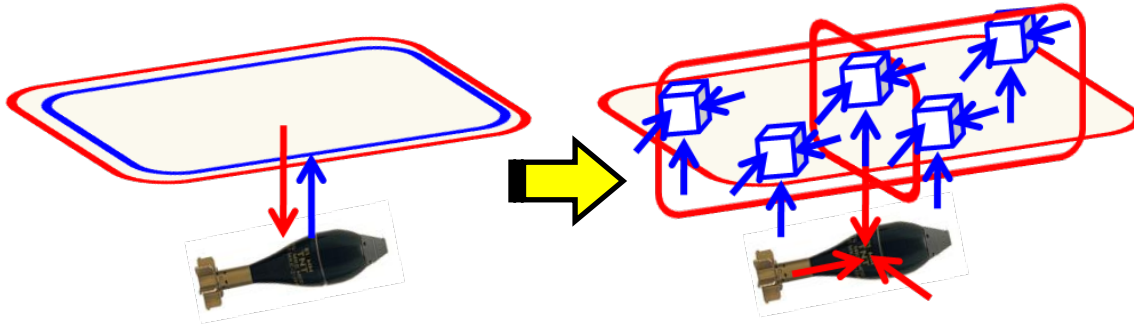65 cm

Man-portable Crawler EM Towed Array

Robotic Crawler Towed EM Array

white river technologies
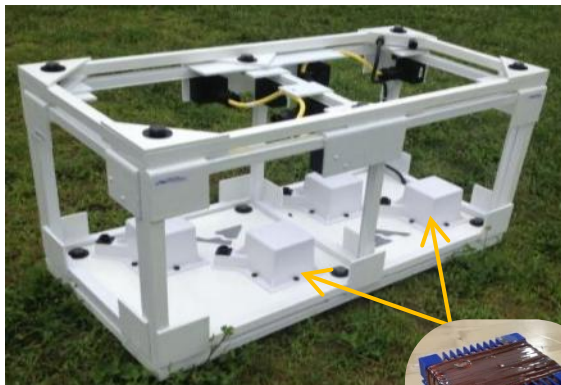
3D Controlled Source EM

OLD (1D) Technology
(Single Sensor, Single Axis)

NEW 3D EM
(Multi-Sensor, Multi-Axis)

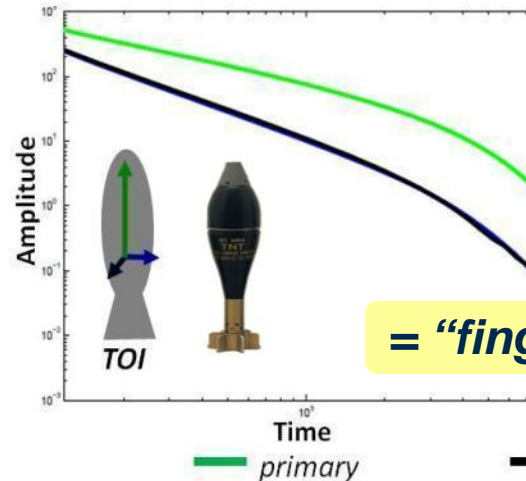- **Spatiotemporal Sampling**
- **Angular Illumination**
- **Inverted Parameters:**
  - *Location*
  - *Orientation*
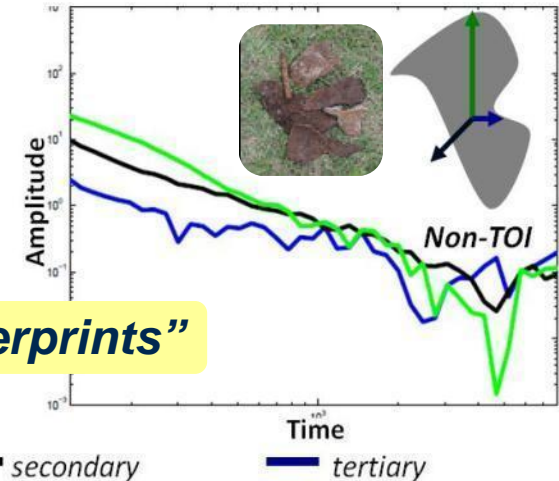 - *Size & Shape*
  - *Composition*
  - *Wall Thickness*

Inverted *Magnetic Polarizabilities* provide *Intrinsic Target (TOI) Parameters*
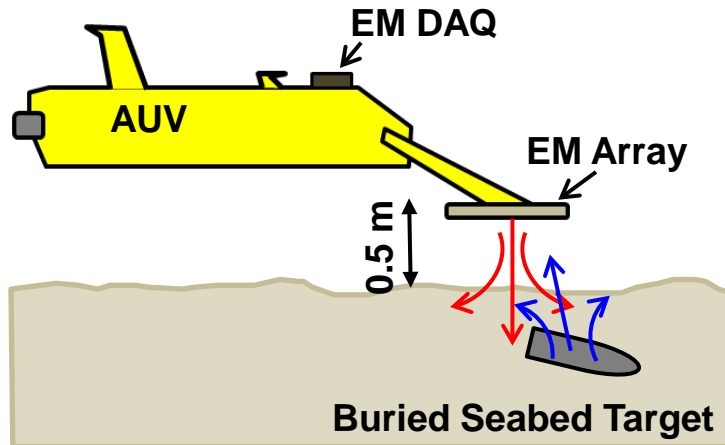*(independent of location, depth, orientation)*
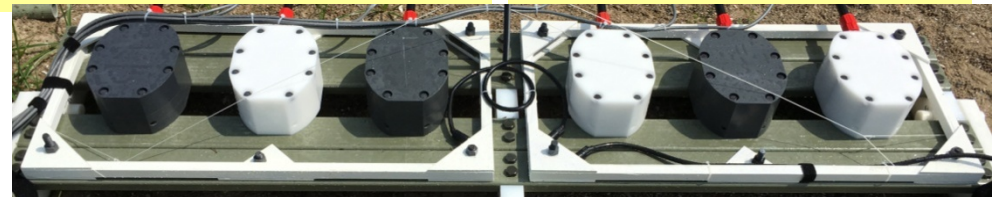
3D EM Receiver
(5cm "mini-cube")

TOI

Non-TOI

= *"fingerprints"*

primary   secondary   tertiary

3D EM: Array Configurations

EM DAQ

AUV

EM Array

0.5 m

Buried Seabed Target

MFDA (FDEM 1x6)

EMPACT 3D (TDEM)

Flex-EM 3D Array (TDEM 2x6)

EM Multi-static / Multi-angle Illumination

$\sigma \sim 0$ air

R_n

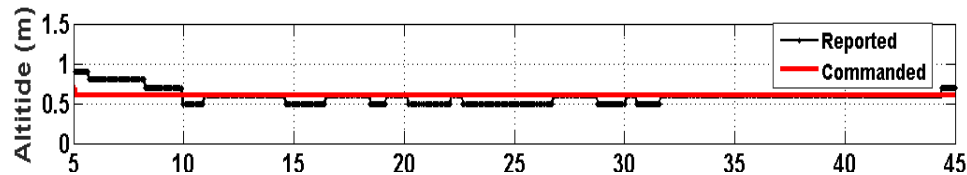$\sigma \sim 4$ S/m

$\sigma \sim 0.1$ S/m   sediments

r_0
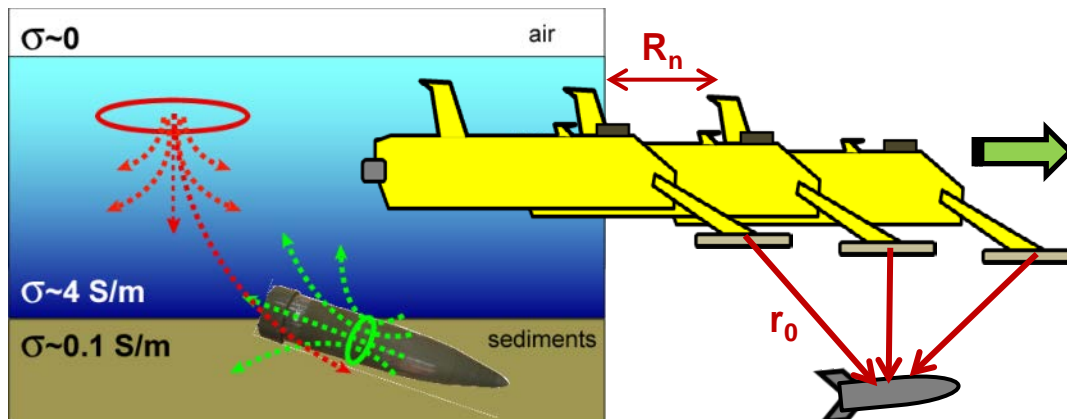
- Compile soundings for each target encounter or "view"
- Use position to determine R_n, r_0 in EM physics model
- Invert concatenated co-registered data for target parameters

white river technologies

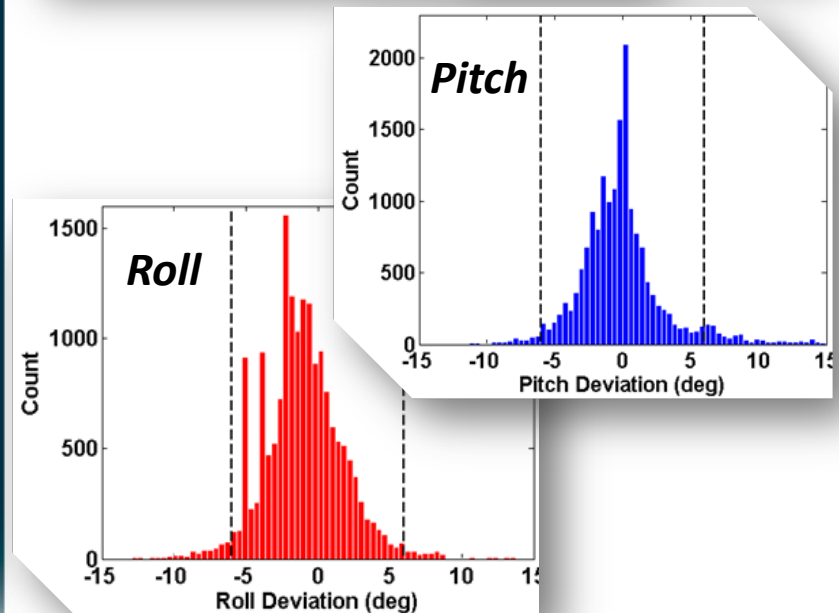# *Mobility / Stability*

ROV-EM
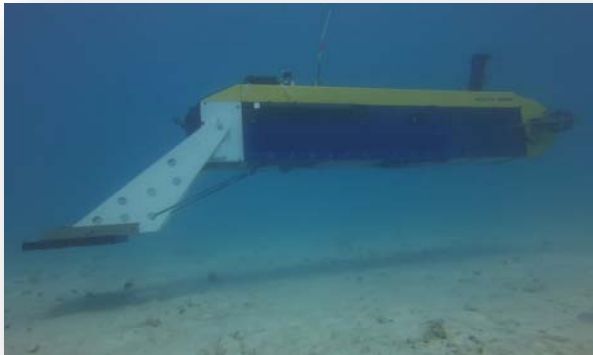
Bottom Following (18 Runs)

ΔAlt = 10 cm
σAlt = 3 cm

ΔRoll = 0.14 deg
σRoll = 0.11 deg

ΔPitch = 0.29 deg
σPitch = 0.20 deg

Station Keeping (5 mins)

ΔE, ΔN = 12 cm, 13 cm
σE, σN = 5.7 cm, 6.7 cm

ΔYaw = 0.86 deg
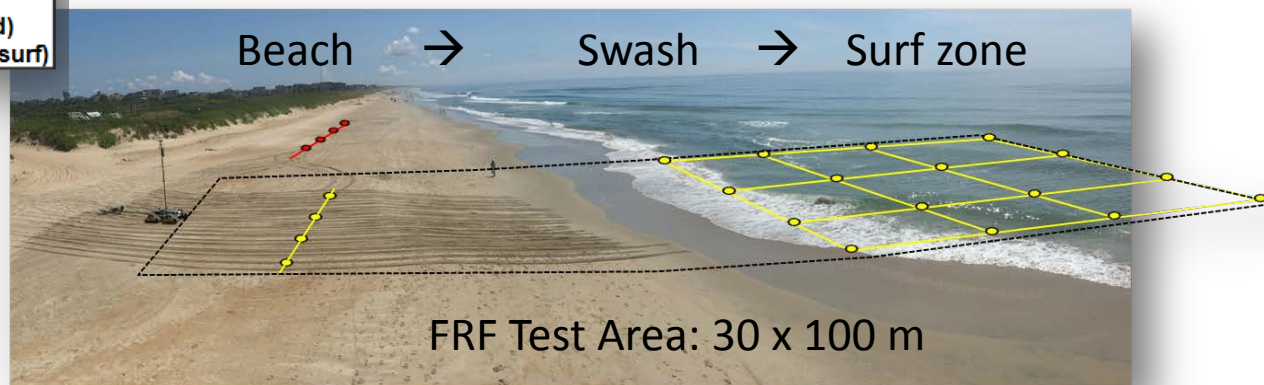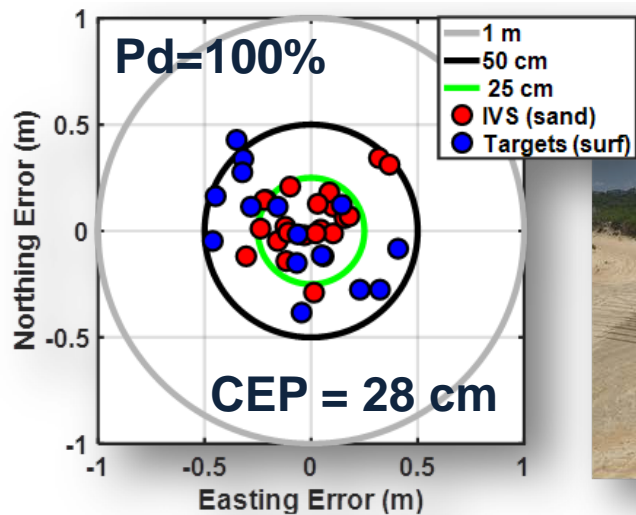ΔRoll = 0.31 deg
ΔPitch = 0.27 deg

Crawler-Towed

Pitch

Roll

ROV-EM: ESTCP Demos (MR-201233)

Pd=100%

POS CEP = 0.35 m

Σ(EM Signal)

100% TOI detected
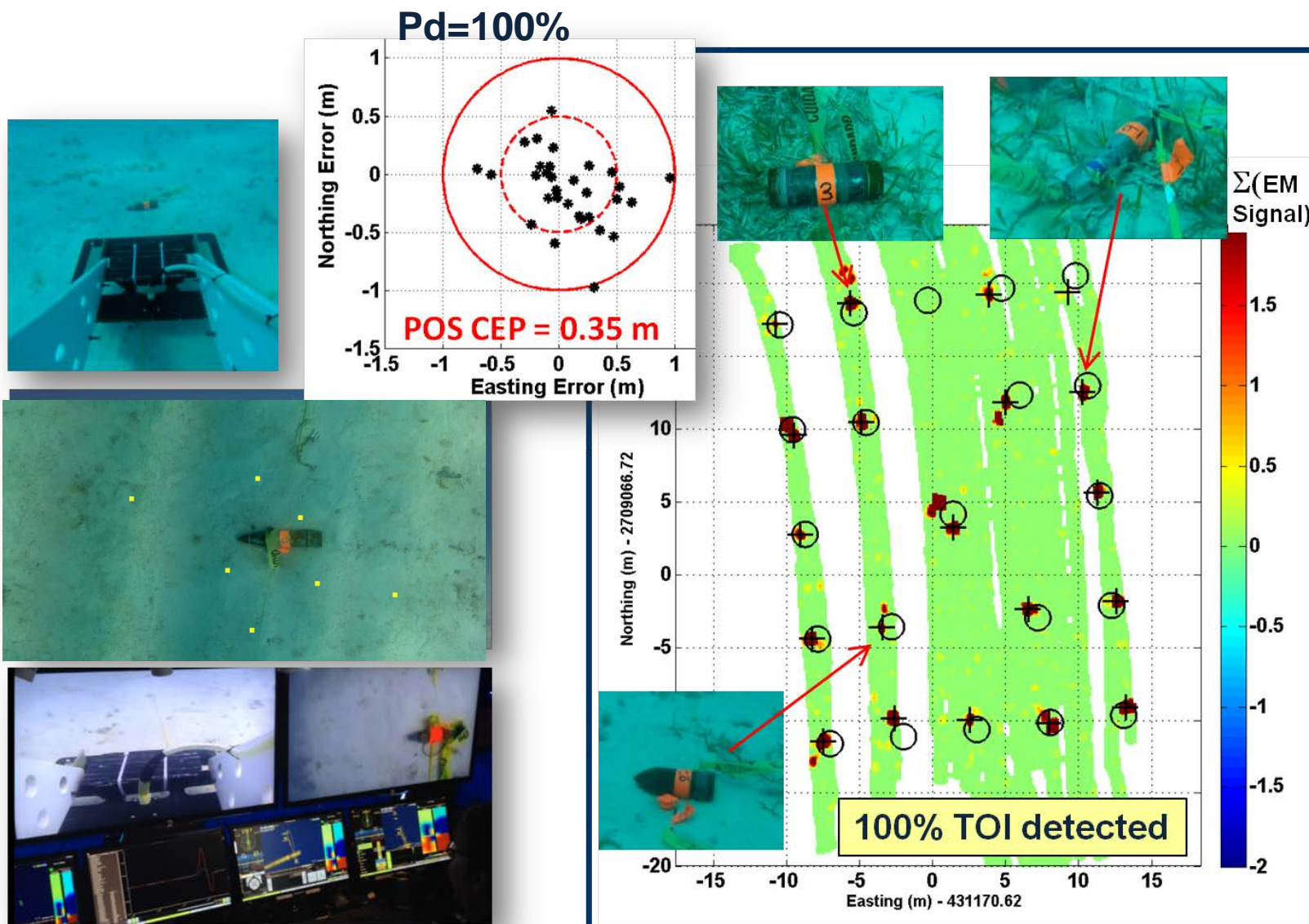
Crawler-EM: ESTCP Demos (MR-201422)

white river technologies

beach swash surf

targets mobilized

Pd=100%

- 1 m
- 50 cm
- 25 cm
- IVS (sand)
- Targets (surf)

CEP = 28 cm

Northing Error (m)

Easting Error (m)

Beach → Swash → Surf zone

FRF Test Area: 30 x 100 m
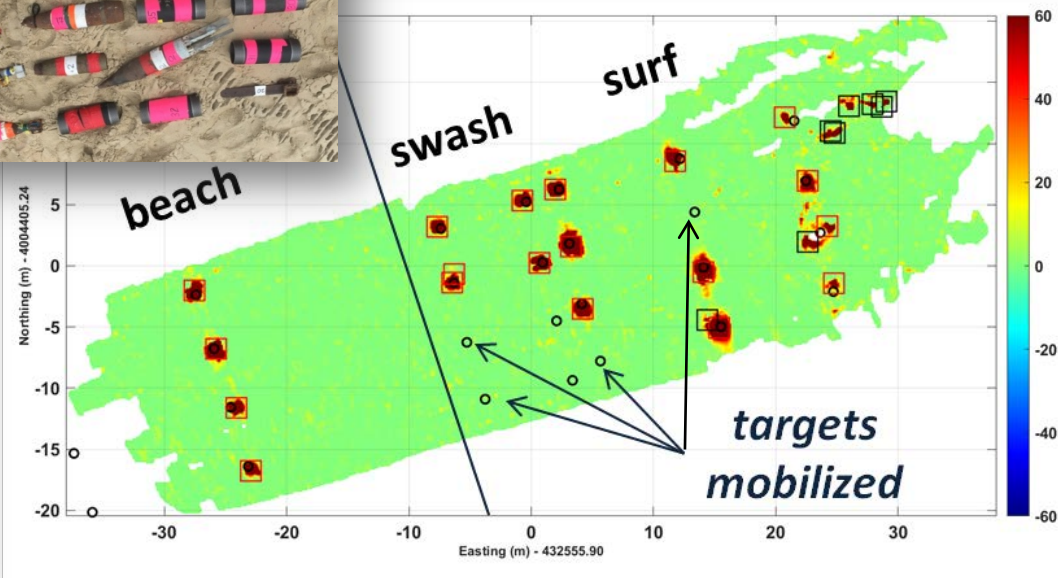
Crawler-EM: UXO Detect & Classify

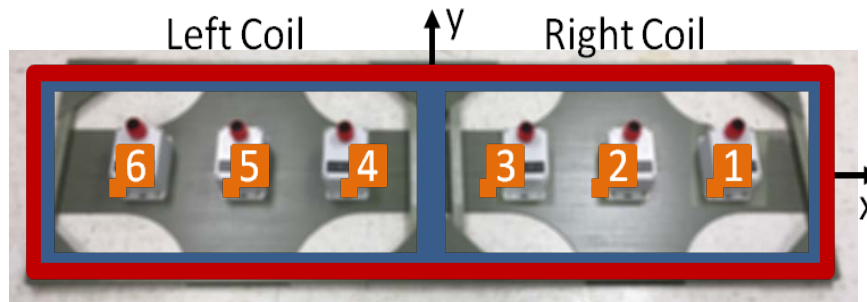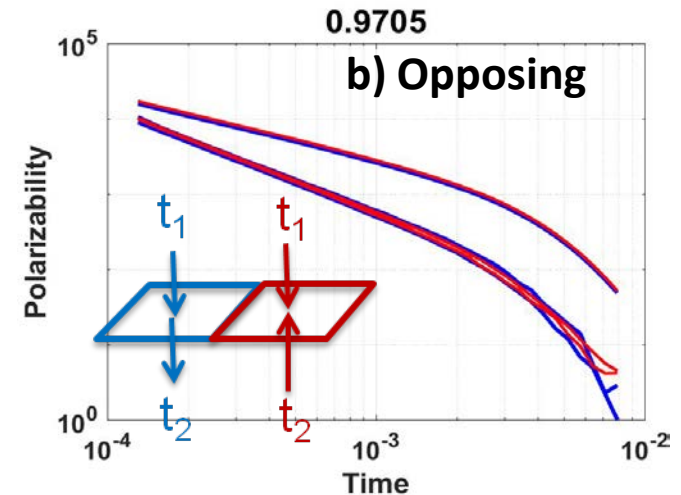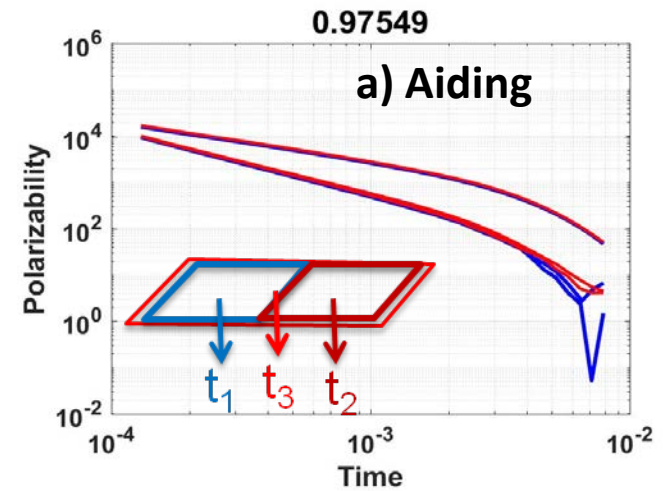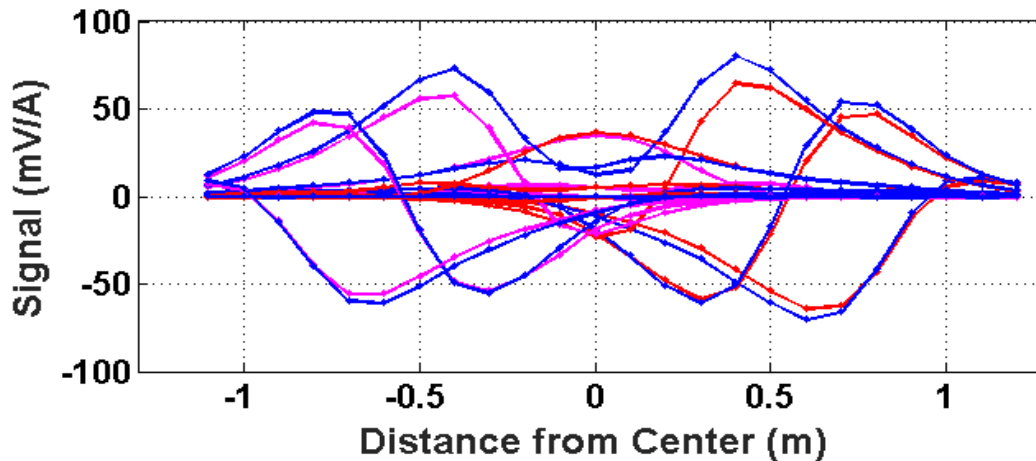**Repeatable Polarizabilities**

60mm: 25 cm depth
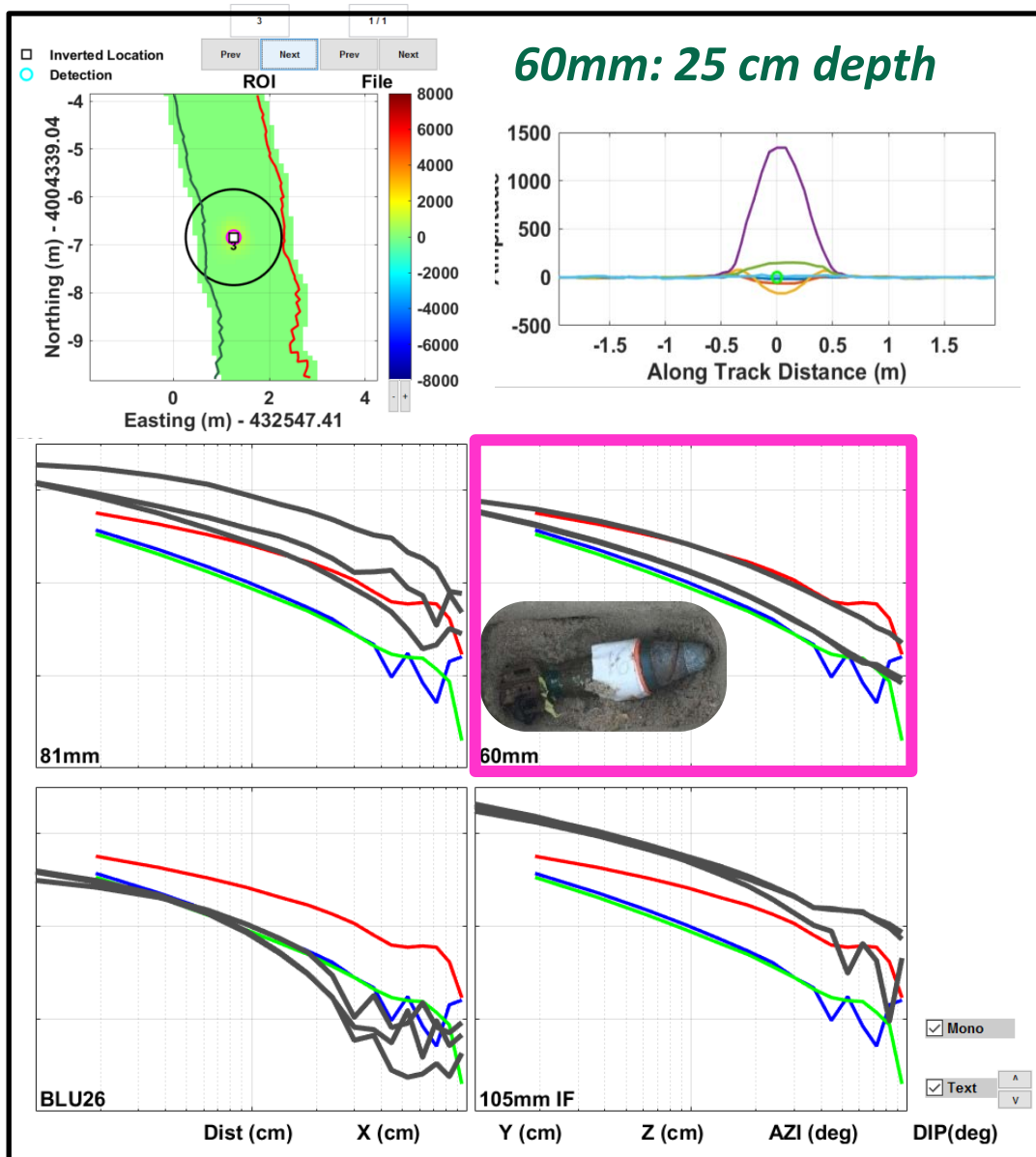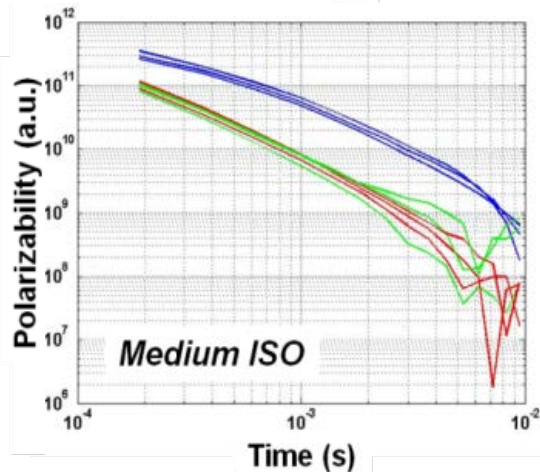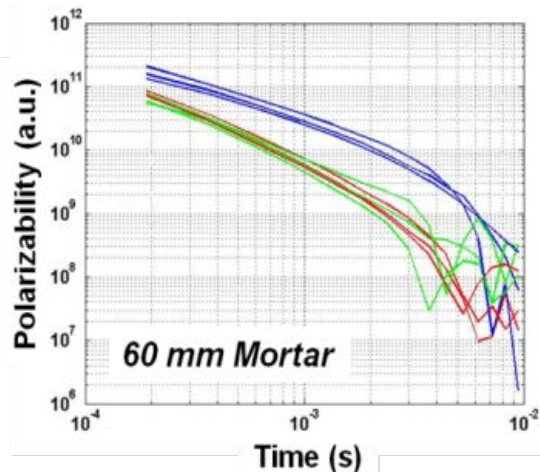
Crawler-EM: UXO Classification

Comparing 2x1 Tx 3D Illumination Configurations

a) Aiding Side-by-Side: 3 Coils, Pol Fit > 0.97
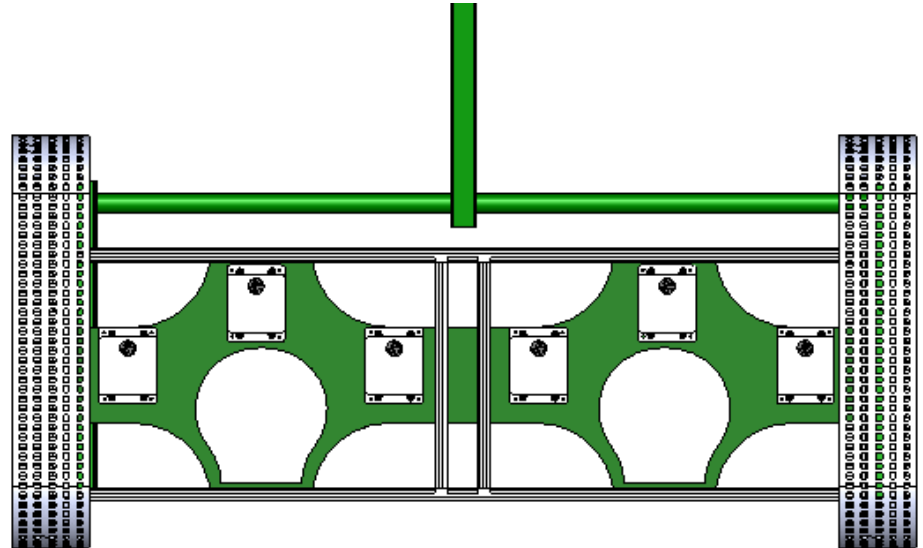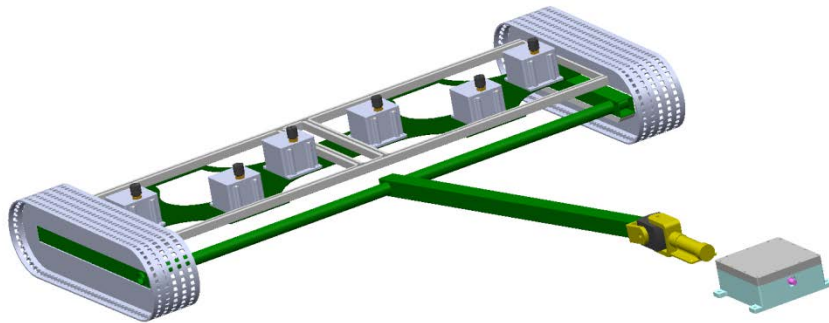b) Opposing Side-by-Side: 2 Coils, Pol Fit > 0.97

Left Coil — Right Coil

6 5 4 3 2 1

Outer 2m Coil, **L&R 1m Coils**, **3x Receivers**
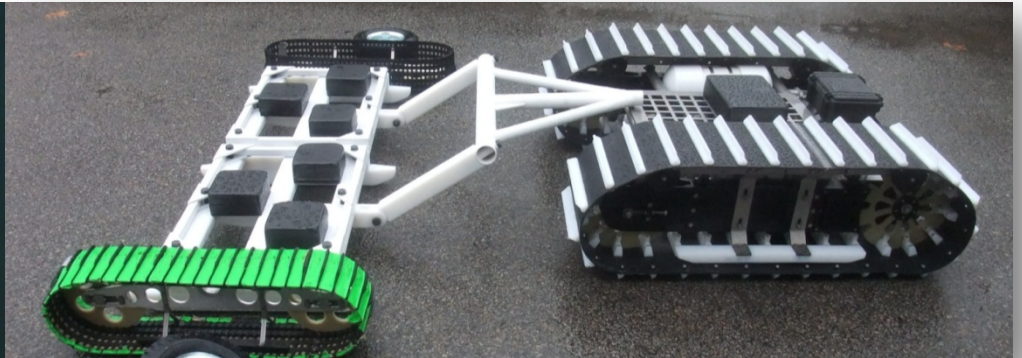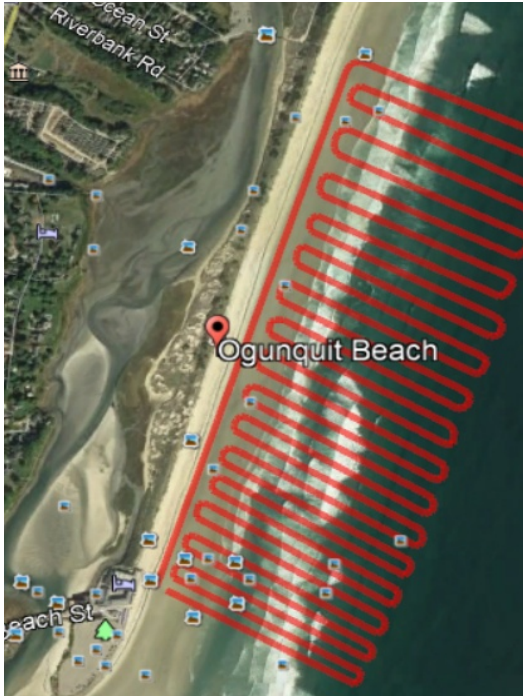

a) Aiding
0.97549

b) Opposing
0.9705
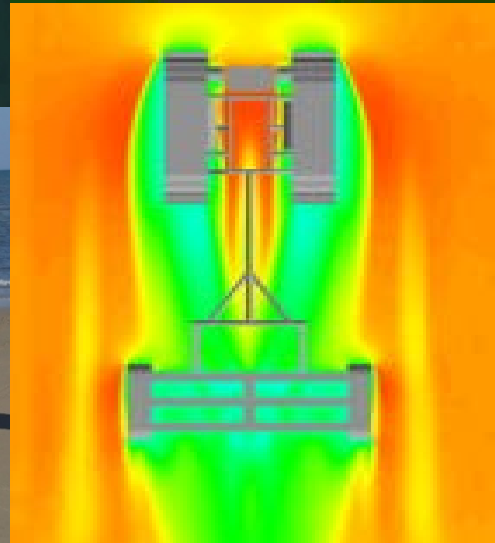
1.6m Wide 3D EMI Array (SeaOx-towed)

- Array: 2 Tx, 6 Rx (triaxial)
- Smaller marine receiver pressure vessels with wet-mateable connectors
- Small overlap between adjacent coils yields null zone for DC sensor

SeaOx Man-portable Crawler-EM System

Ogunquit Beach

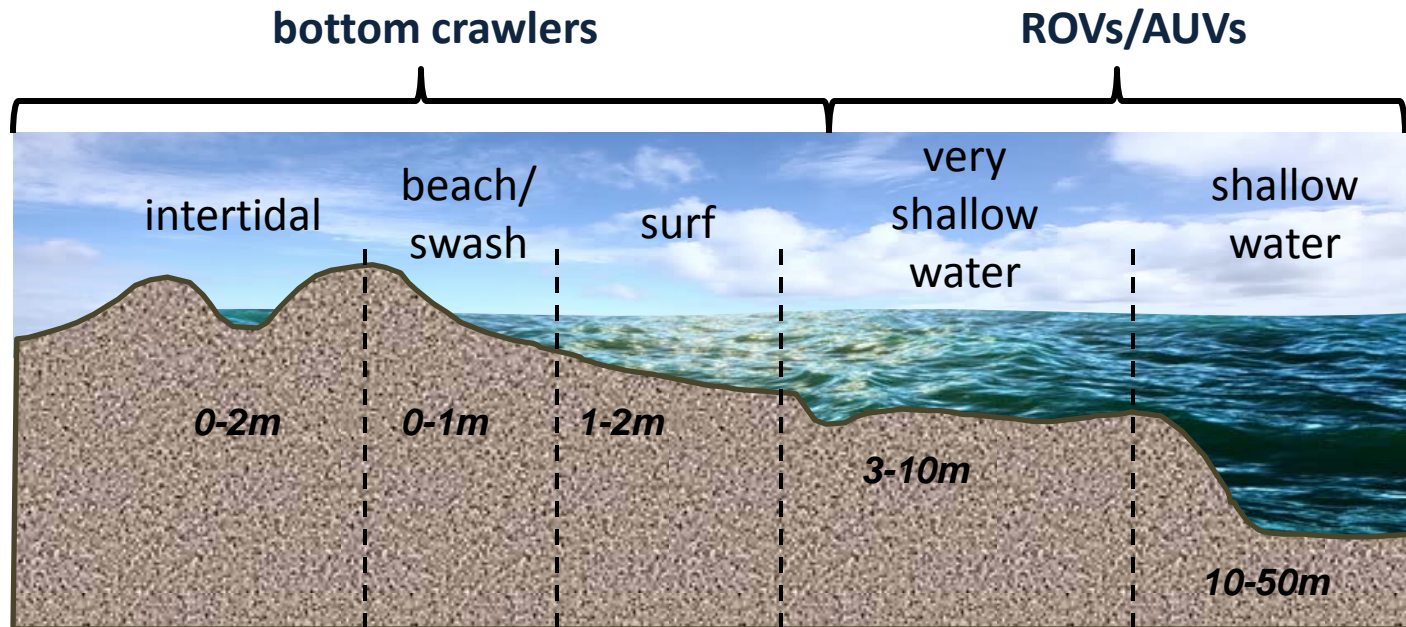C2I SeaOx Crawler: ESTCP MR-201719

SeaOx

SeaOtter

Synthesis: Operating Envelopes

Crawler-Towed EM

- GPS & Radio Link
- Trafficability / Contact
- Maneuverability

ROV-based EM

- USBL / non-GPS
- Local Area Surveys
- Hydrodynamics

UXO applications indicate 50-75% cost reduction using AUVs

Thanks to:

Dr. Rob Evans (WHOI G&G)   Arnis Mangolds (C2I)

Dr. Hendrik Muller (Univ. Bremen)   Dr. Tim Crandle & Team (SeaView)

Gary Randolph (Cobalt Marine)   Mike Purcell (WHOI OSL)

1. ROV-EM & AUV-MAG:
ESTCP Project MR-201233
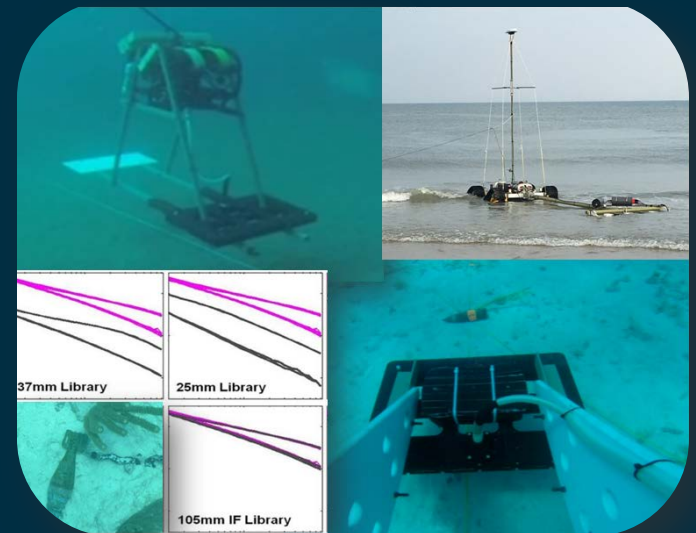*Navy STTR N17A-T015*
Navy SBIR N08-218

2. Crawler-based EM:
ESTCP Project MR-201422
ESTCP Project MR-201712 (C2I)

Contact:
schultz@whiterivertech.com
603 678 8385

white river technologies

www.whiterivertech.com