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APPLICATION OF INSTRUMENTED SURROGATE MUNITIONS FOR MUNITIONS MOBILITY AND BURIAL AT MUNITIONS RESPONSE SITES

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Munitions Mobility & Burial Program
SERDP & ESTCP

Problem: A thorough understanding of the fate of Munitions and Explosives of Concern (MEC) is required for the detection, classification, modeling, monitoring, and mitigation of MEC at Munitions Response Sites (MRS)

Objectives:

- Identify and reduce the parameters necessary to predict MEC mobility and burial in MRS
- Ultimately arrive at a CONOP and tools (both software and hardware) for MRS management

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Synopsis of Munitions Mobility & Burial

Anthropogenic Effects
- Method of emplacement
  - Live-fire vs. disposed
- Bottom disturbances
  - Dredging
  - Commercial fishing
  - Infrastructure installation

Environmental Setting
- Hydrodynamic regime
  - Coastal wave-dominated
  - Tidal estuary
  - Riverine
  - Lacustrine
- Depth
  - Shore break -> deep

Mobility?

Burial?

Bed Characteristics
- Composition
  - Consolidated vs. unconsolidated
- Grain size
- Bulk density
- Stratigraphy

Munitions and Explosives of Concern (MEC) Characteristics
- Density
  - Corrosion/biofouling
  - Integrity
- Diameter
- Shape (?)

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Instrumented Surrogates

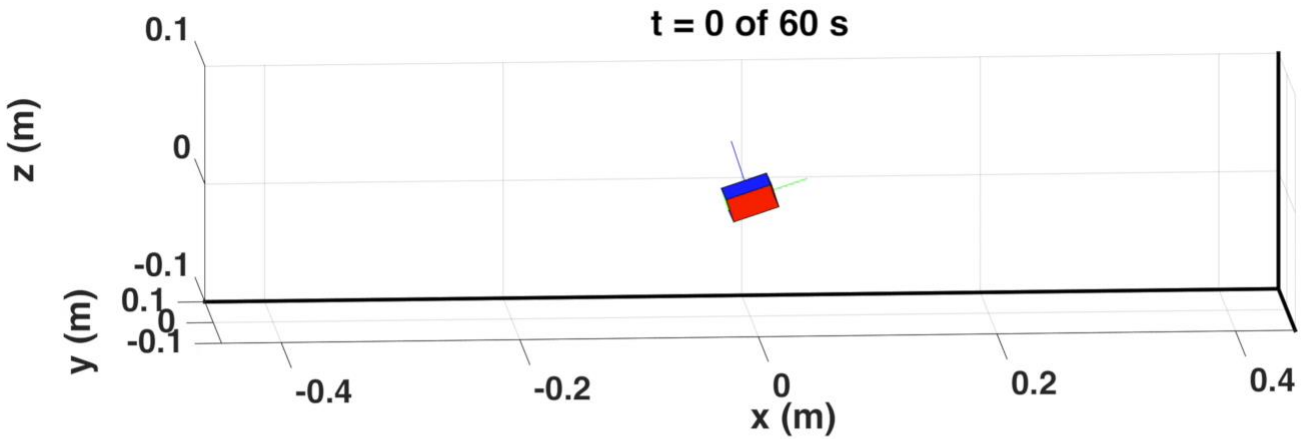
Instrumented surrogates provide much needed observations to quantify physical processes and develop & validate models of munitions mobility and burial

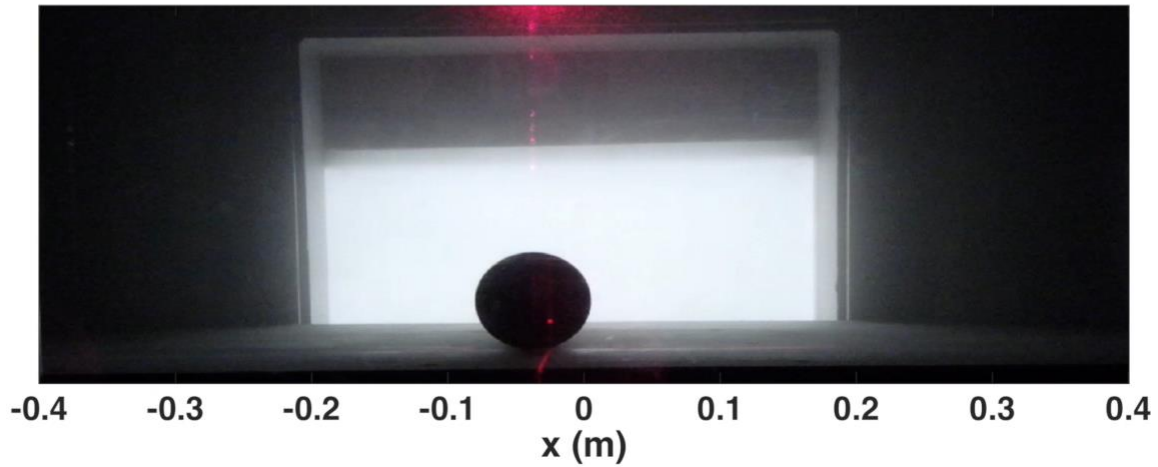
- Equipped with customizable sensor packages tailored to research question
  - ♦ Inertial Motion Units (IMU) – precise movement
  - ♦ Acoustic Tracking – gross movement
  - ♦ Pressure Sensors – burial

Examples:

- Wallops Island Munitions Mobility Experiment (WIMMx)
- California Burial Experiment (ExCaliBur)
- Delaware Bay Munitions Mobility and Burial Study
- Riverine Ammunition Mobility and Burial Live-Site Experiment (RAMBLE)

Integrating IMU – Quantifying Mobility

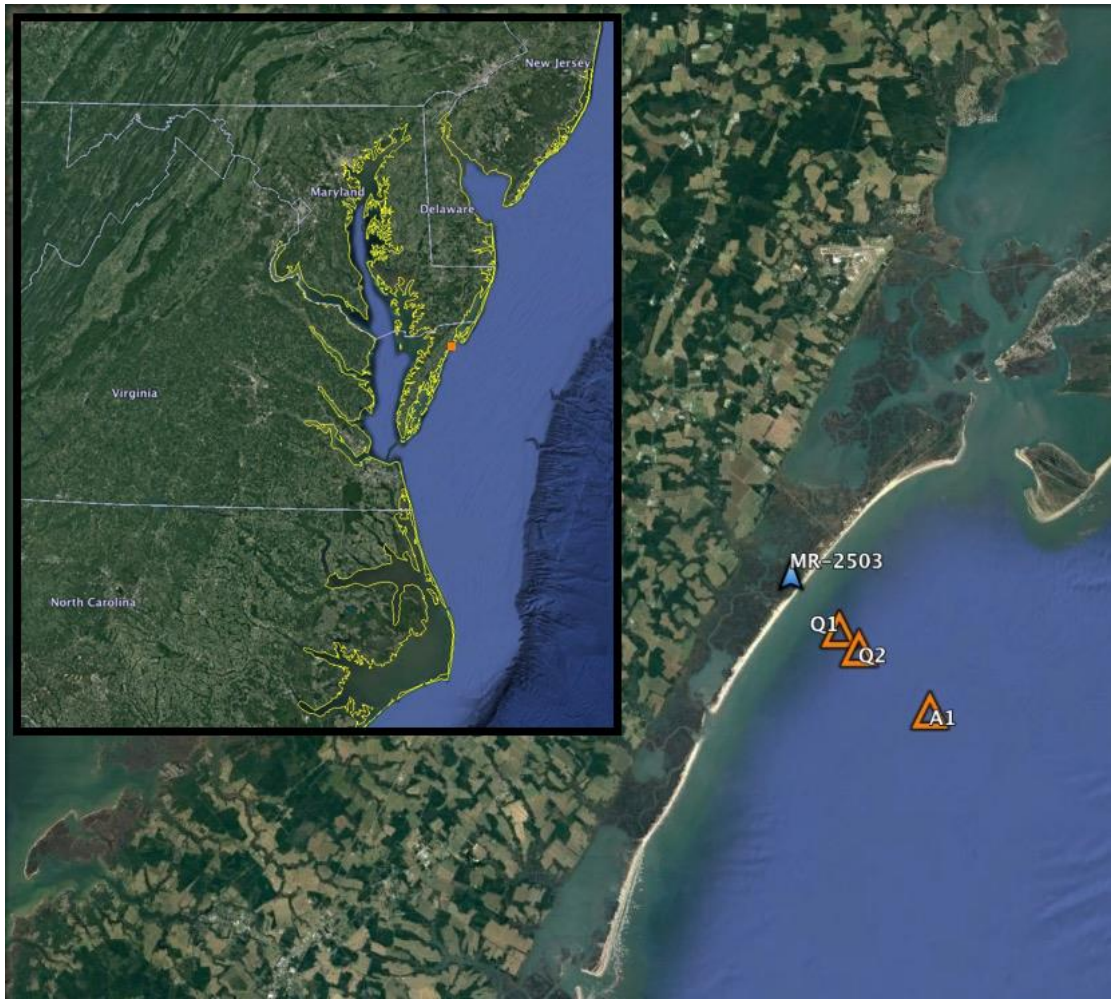




- Collaboration with MR-2410 (Garcia and Landry)
- COTS IMU embedded in nose

Wallops Island Munitions Mobility Experiment (MR-2320)

- Smart munitions with IMUs logging at 16 Hz continuous
  - Three calibers at each location (81 mm, 4.2 inch, and 155 mm)
- Deployed instrumented benthic quadpods Feb – Apr 2017 at 9 m and 11 m water depths



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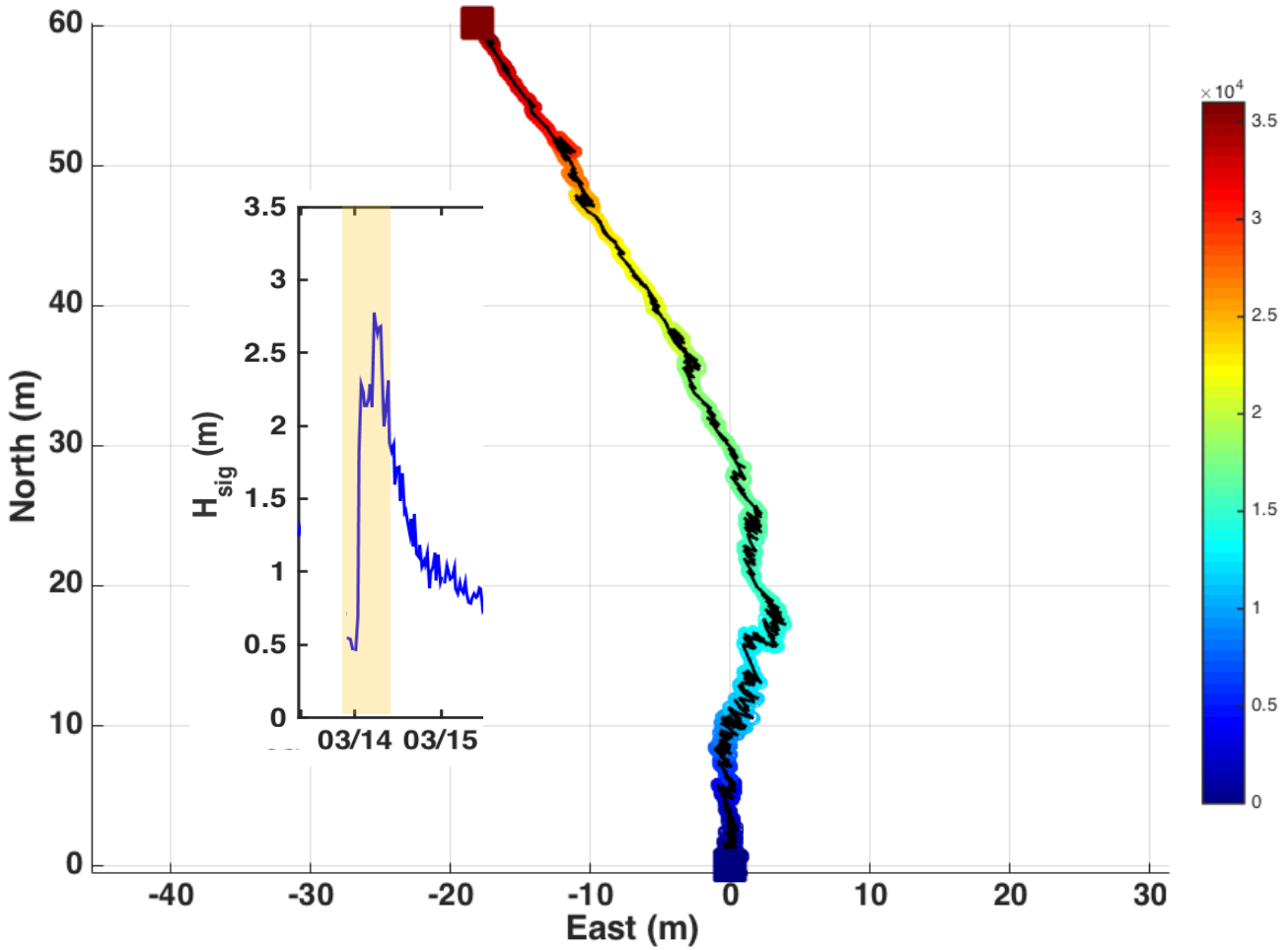
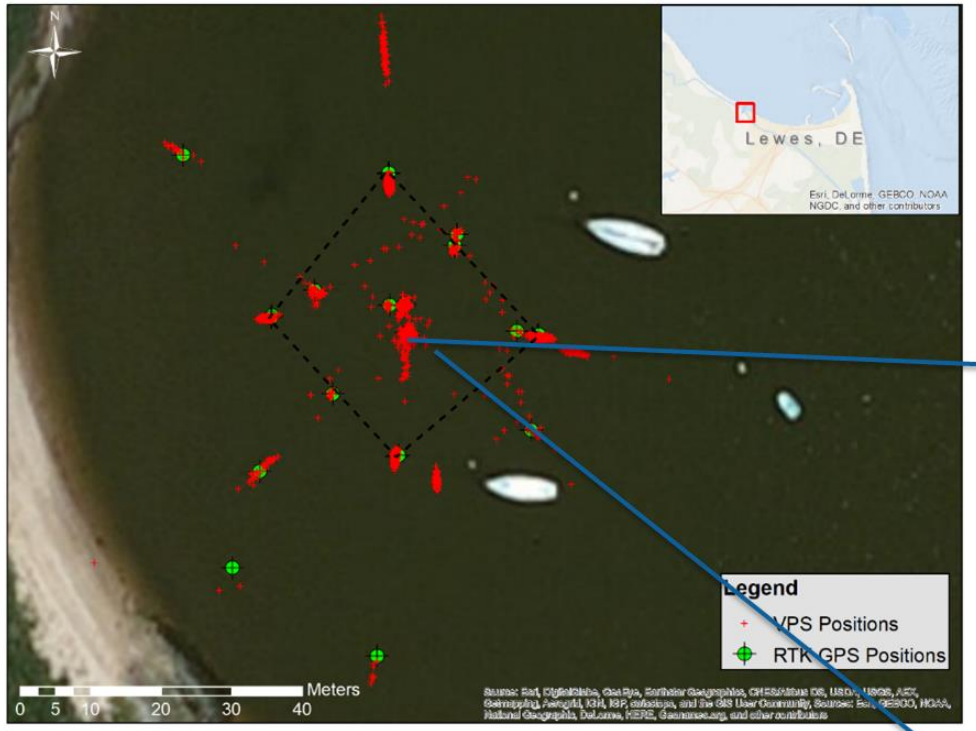
WIMM-X Preliminary Mobility Results



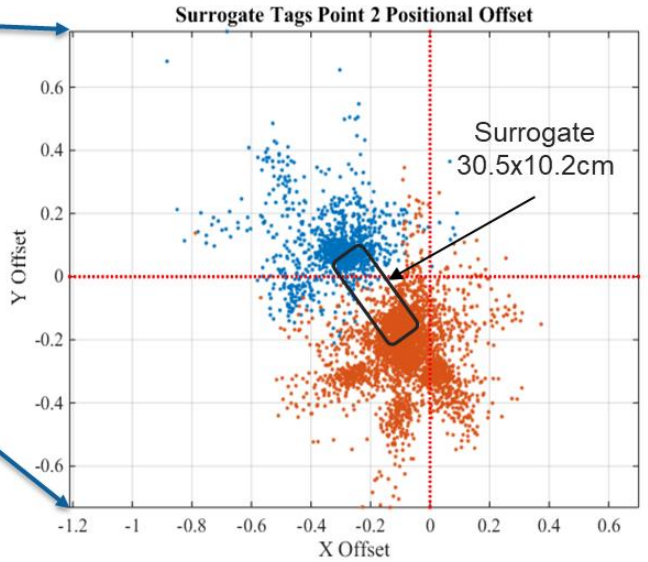
- Start of mobility during storm at 14 March 2017 at 0228
- Integration interval is 9.9 hours (16 Hz continuous)
- **570,240 points**
- Peak significant wave height near 2.8 m during interval
- Total integrated displacement was 206.4 feet with 344 degree heading
- Diver measured displacement was 202.0 feet with 340 degree heading

Integrating Acoustic Tracking Innovasea Vemco Positioning System (VPS)

- Acoustic tracking system (180kHz) – positional accuracies down to 10cm
  - Conducted field trial Fall 2016 to establish baseline performance



- Surrogate GPS to VPS positional offset < 20cm
  - VEMCO estimated surrogate size at 13” from data alone (surrogate 12” long)



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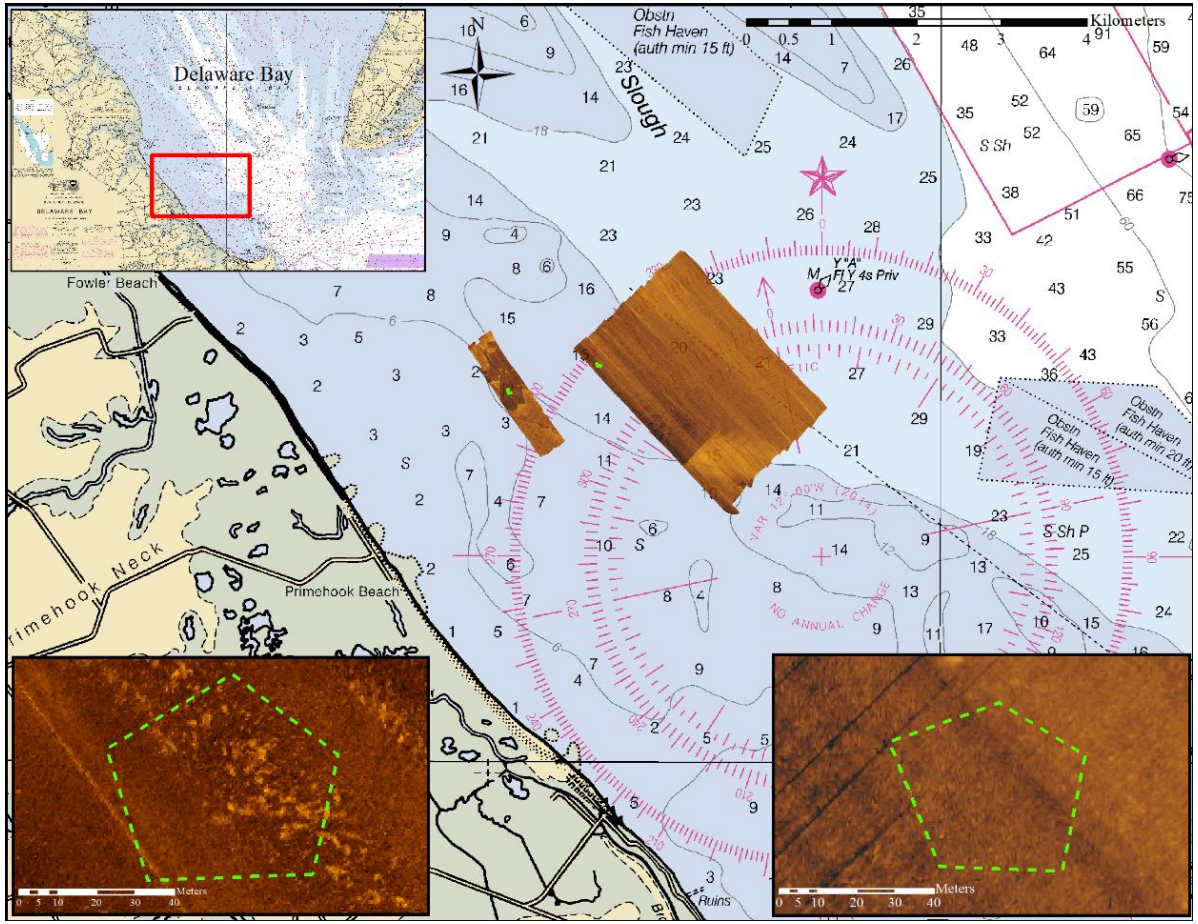
Unexploded Ordnance Characterization in Muddy Estuarine Environments (MR-2730)

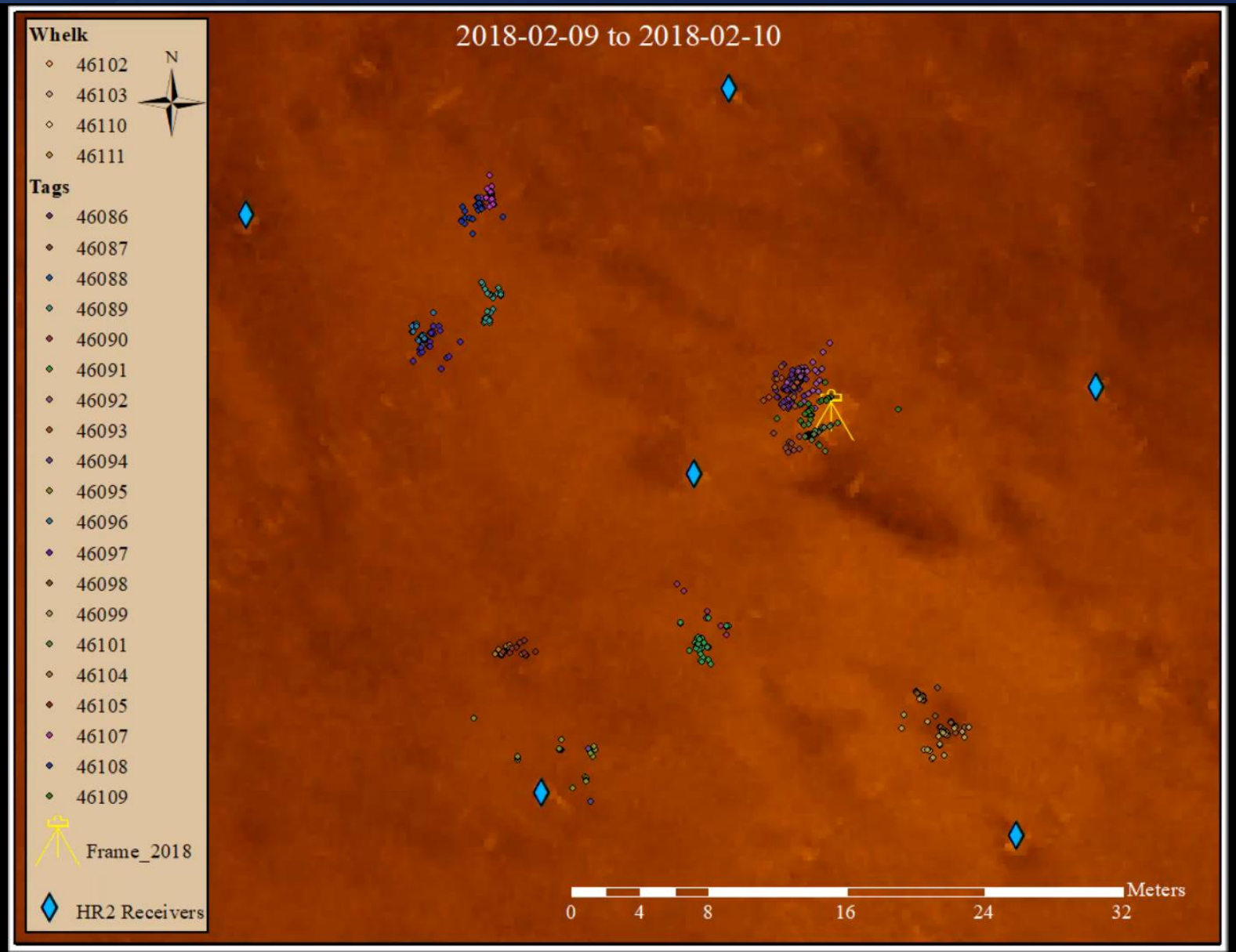
- *Trembanis (University of Delaware) and DuVal*
- Objective: to test and characterize munition mobility and burial in shallow, muddy environments.
  - Monitor the mobility and behavior of sensor-integrated surrogate munitions in muddy environments using a high-accuracy acoustic positioning system
- Four deployments at two sites Oct 2017 - May 2019
  - 60mm, 81mm, 4.2”, 155mm surrogates



Spring 2018 VPS Animation

Four Nor'easters

- *Riley (Mar 2)*
- *Quinn (Mar 7)*
- *Skyler (Mar 12)*
- *Toby (Mar 20)*



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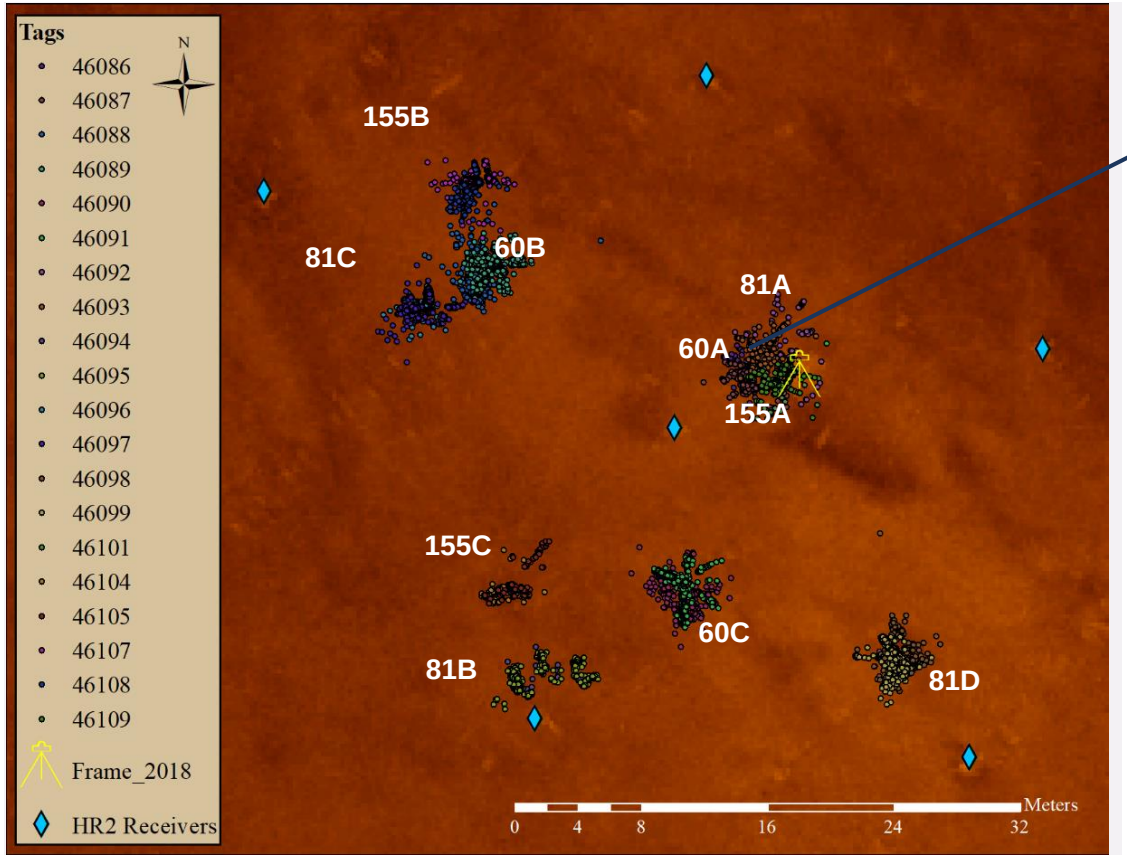
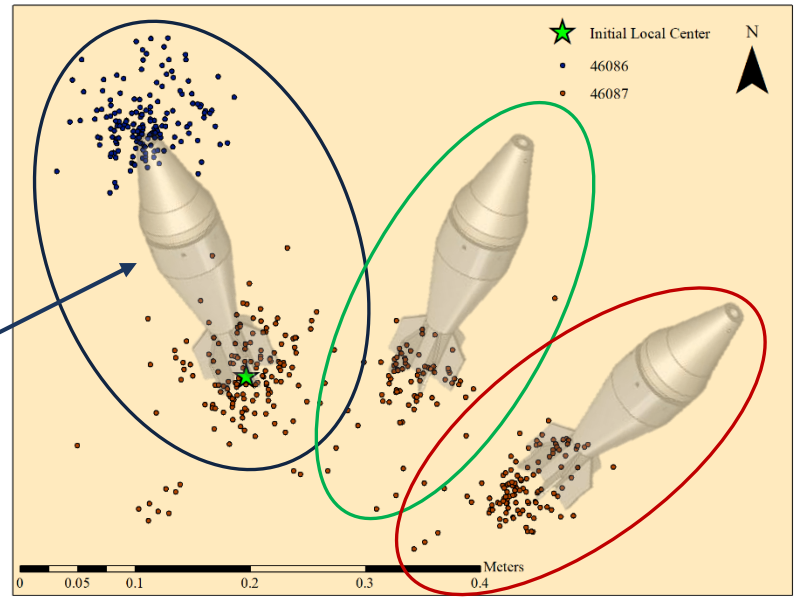
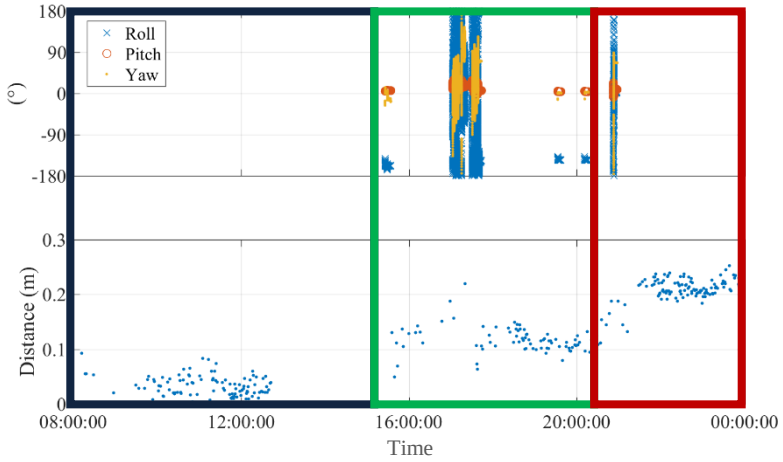
Surrogate Mobility?

Nor'easter "Toby"
March 20, 2018

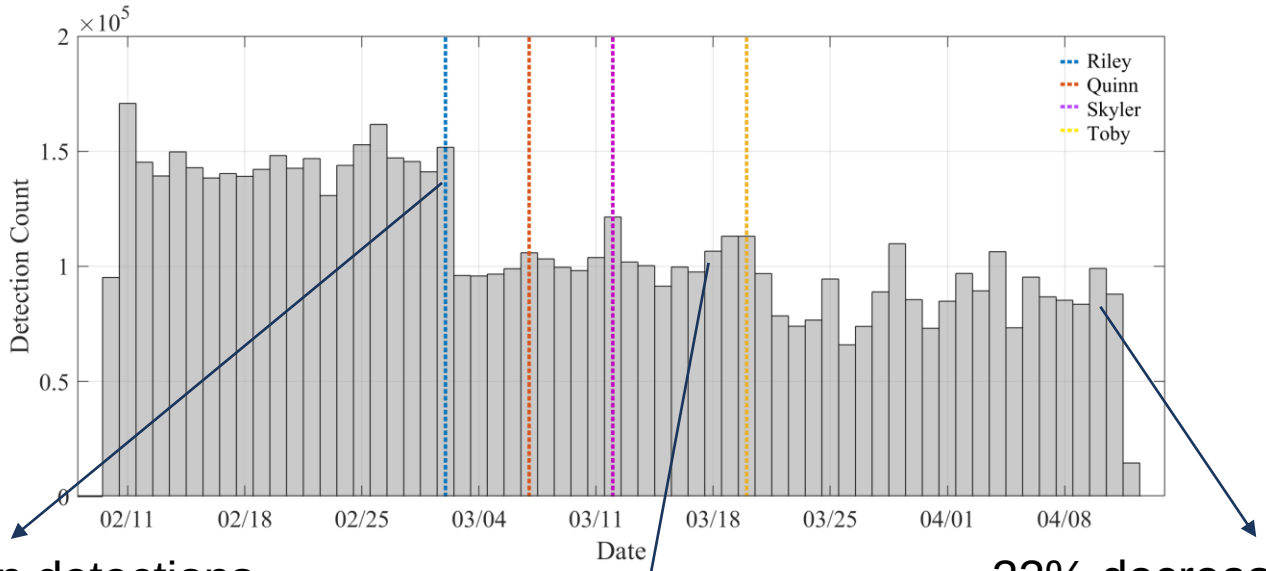




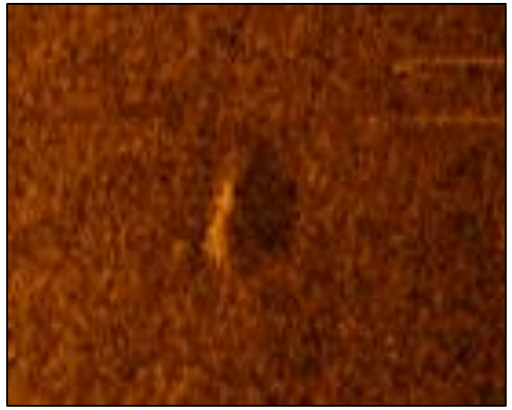


Burial and Exposure

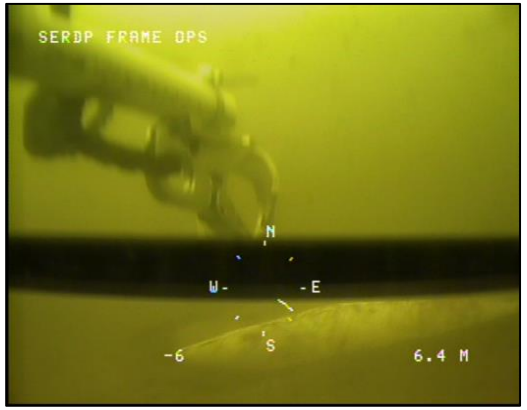
- Field test demonstrated VPS unable to detect buried tags.
  - ♦ If daily tag detections decrease w/ no mobility = burial



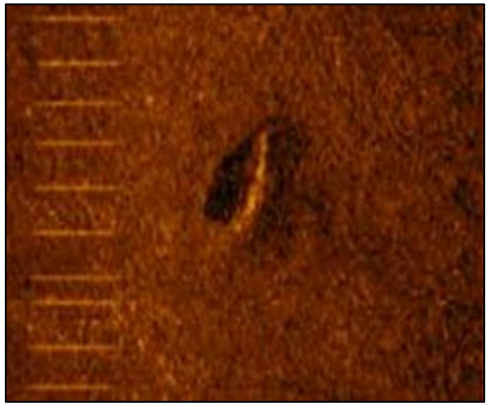
35% drop in detections
Only 155mm visible in sonar



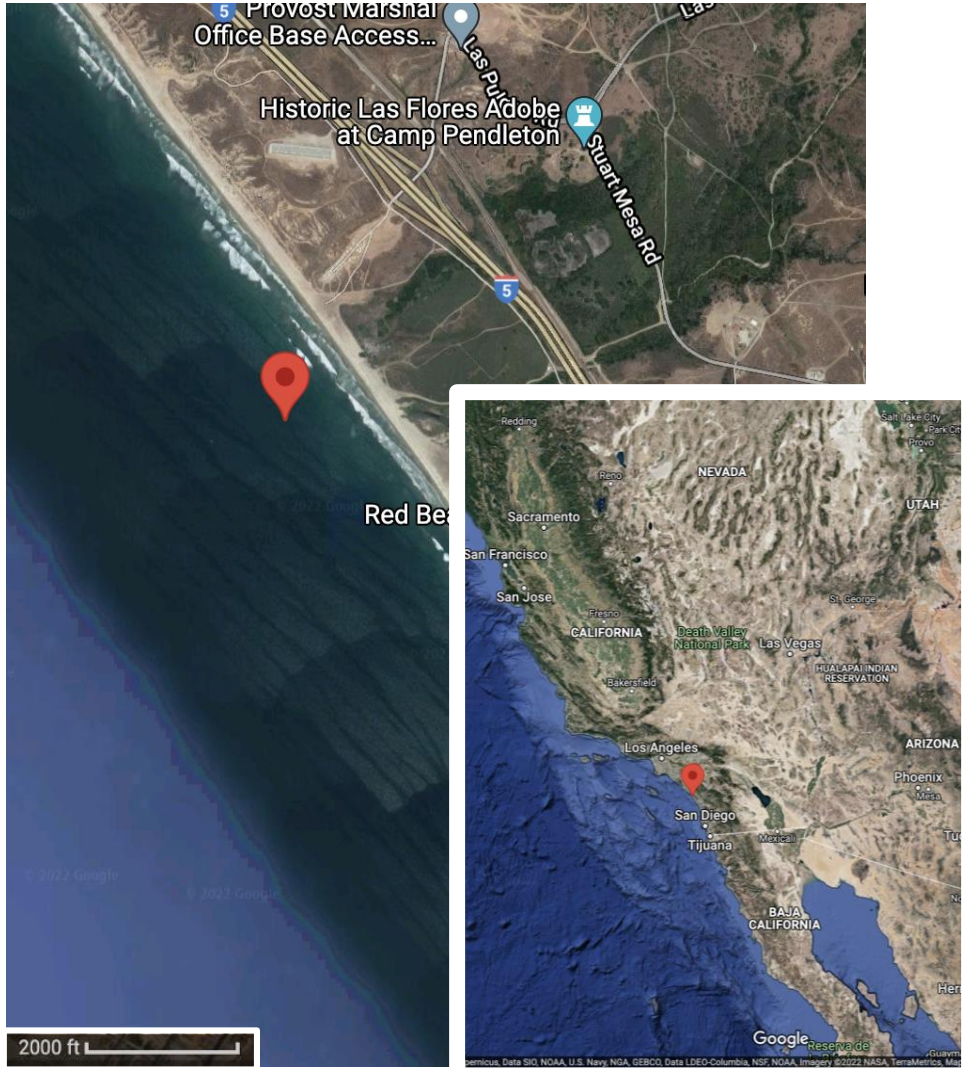
81mm ~50% buried in ROV video



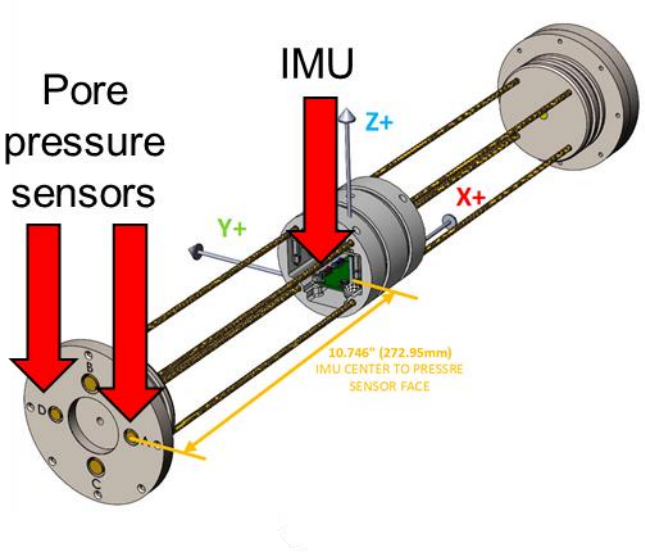
22% decrease from Toby to retrieval
155mm in open scour pits



Integrating Pressure Sensors Quantifying Burial Depth



- California Burial Experiment (MR19-1317)
  - To determine effects of surrogate parameters on burial depth from *in-situ* data
  - Experiments at Camp Pendleton, CA in 2021 & 2022 at a depth of 20 feet (~ 6.1 meters)
  - Each surrogate carried:
    - 2 pore pressure sensors
    - 2 total pressure sensors
    - Inertial motion unit (IMU)



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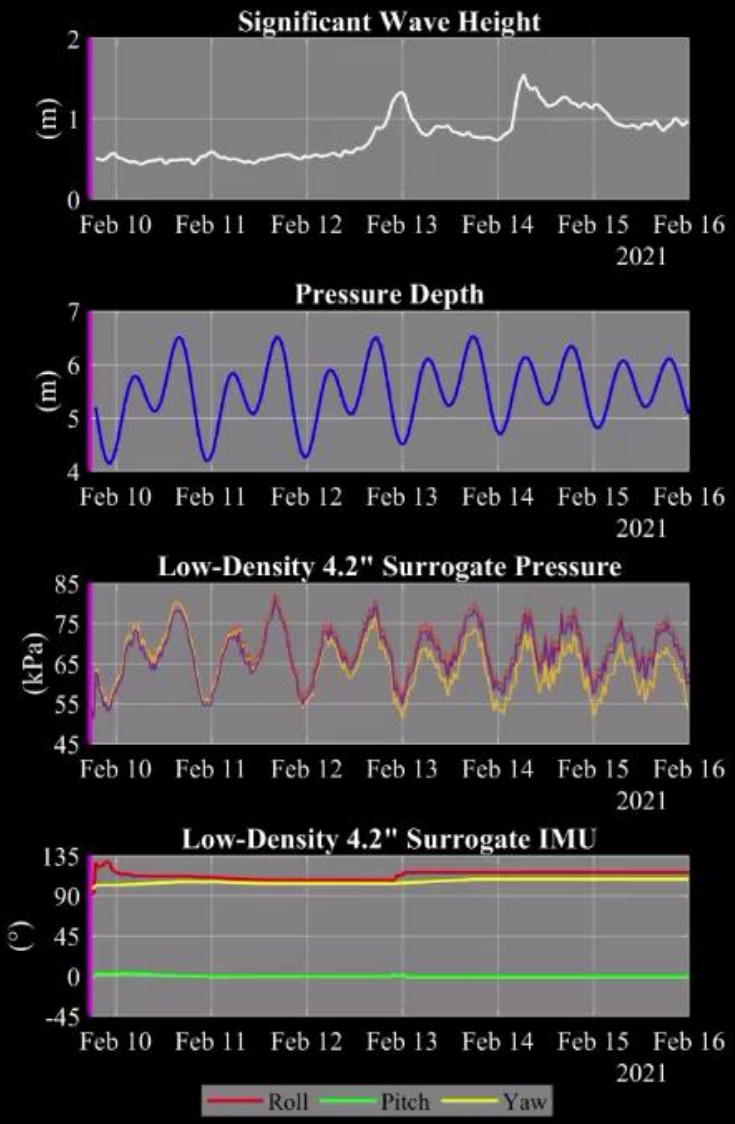
Field Experiment



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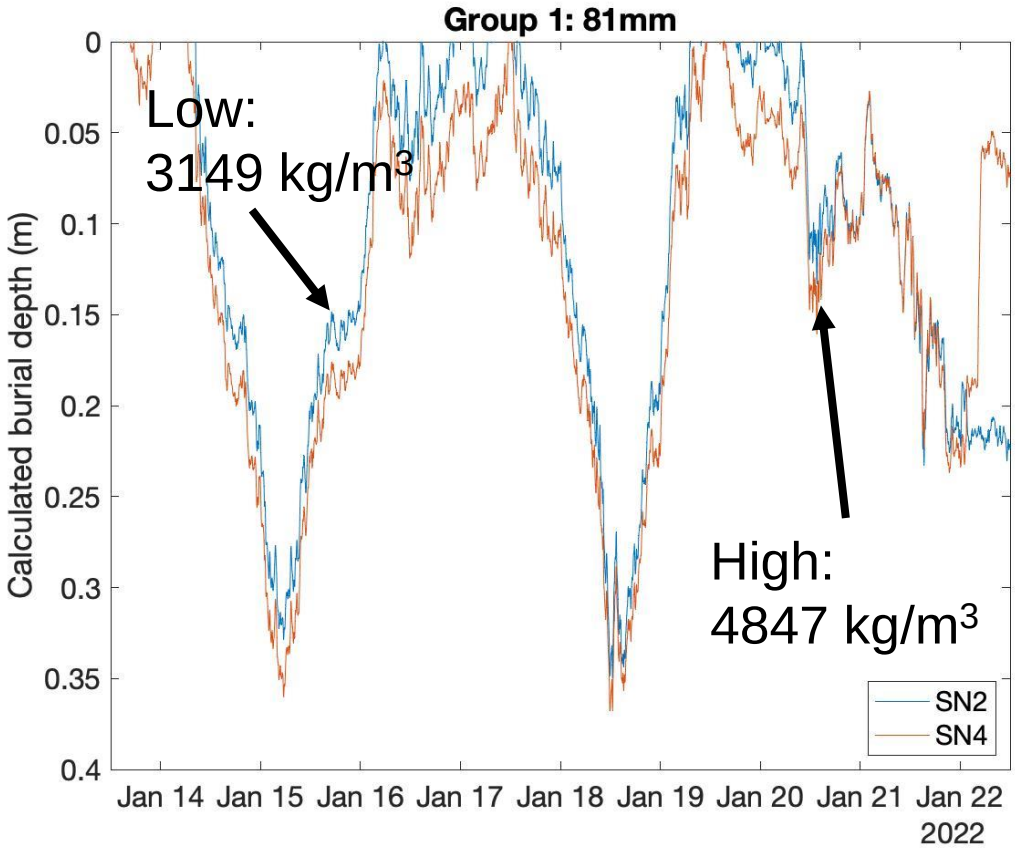
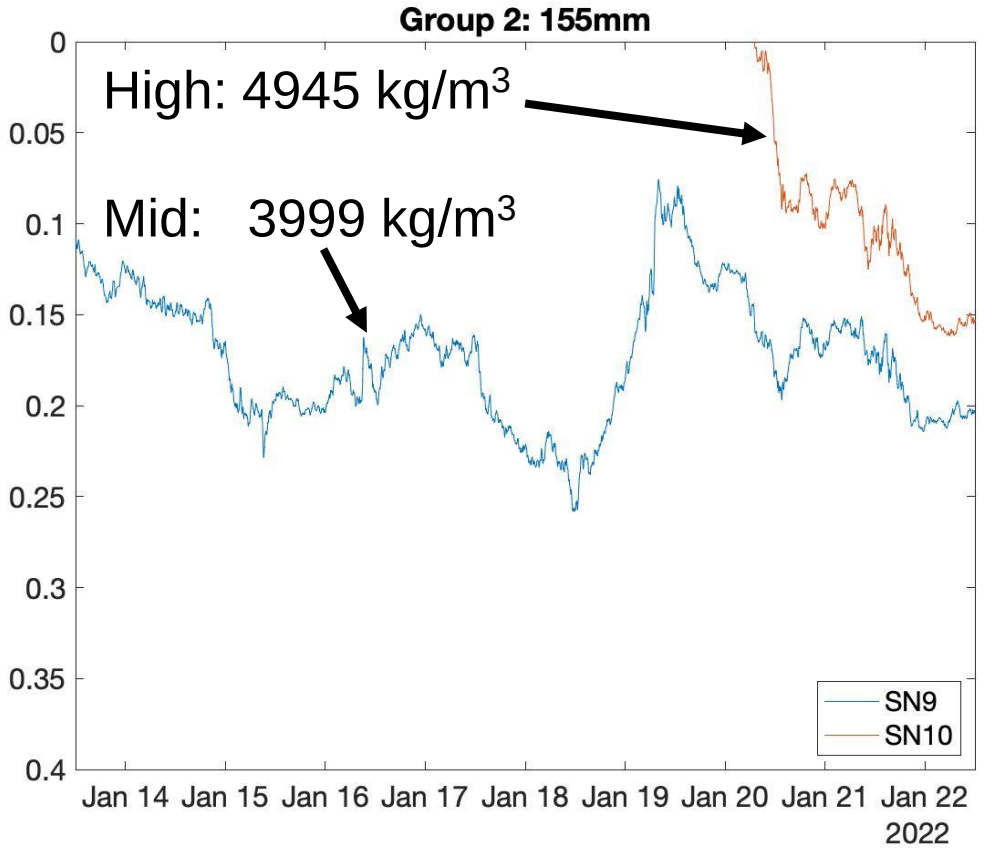
Burial Depth by Surrogate Type & Density





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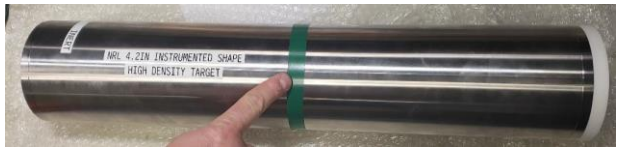
Inferred depths: Orientation

	SN8	SN3	SN10	SN4	SN2	SN9
Orientation of long axis rel. to Mean wave dir.	9.0	13.4	18.1	22.8	32.8	38.1
Behavior	No burial	Unburied/ Reburied	Partial burial	Full burial	Full burial	Full burial
	Light density 155mm		High density 155mm		Light density 81mm	Mid density 155mm

Orientation is a primary factor in burial variability

~20° from the mean wave direction is the cut-off between partial and immediate full burial

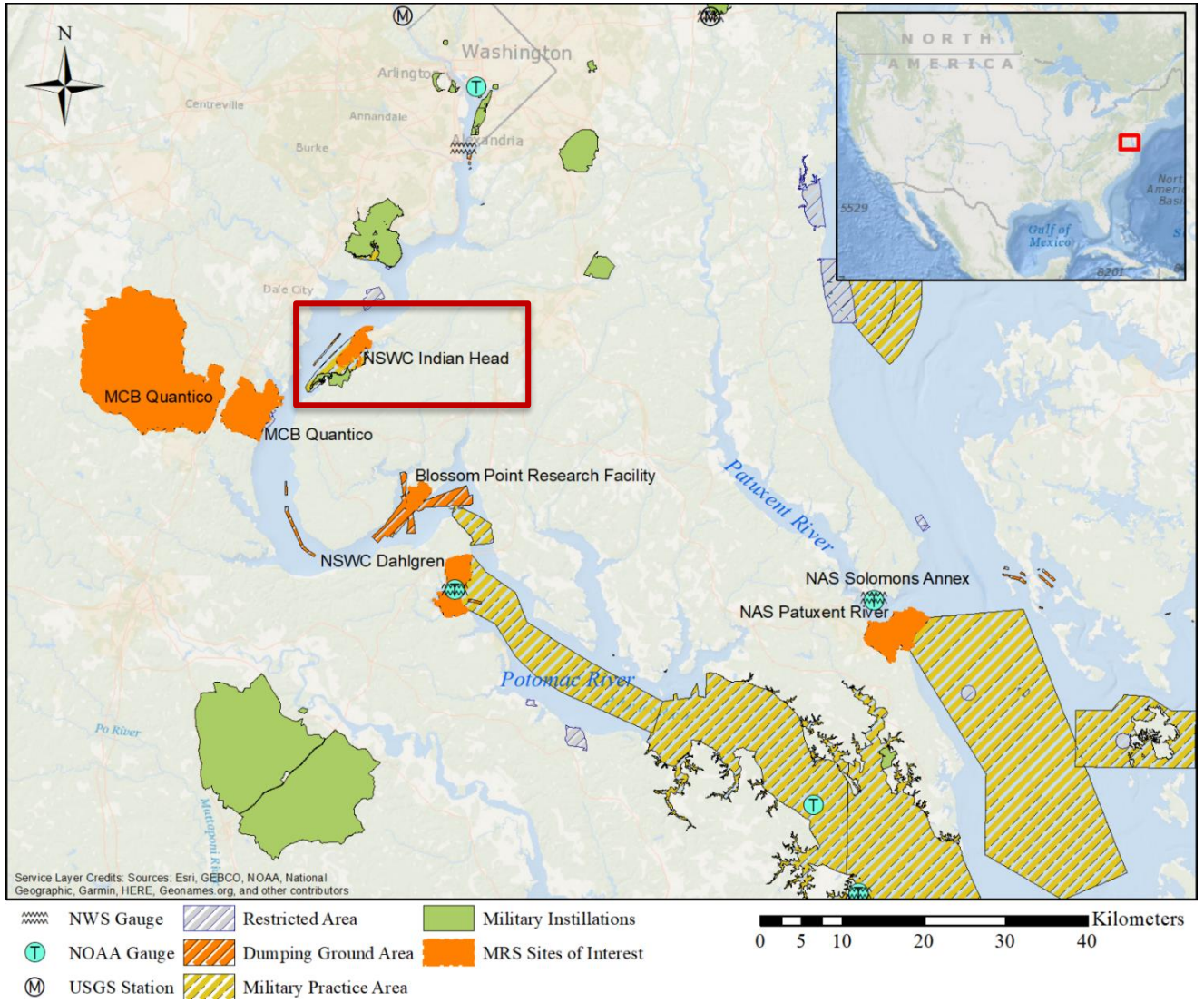
Wave Direction



Wave Direction

Riverine Ammunition Mobility and Burial Live-Site Experiment (RAMBLE)

- **Objective:** Quantify mobility and burial of munitions and explosives of concern (MEC) in dynamic riverine environments using a Munitions Response Site (MRS)
- NSF Indian Head, MD
  - 12000 Acres
  - Sediments:
    - 36% Clay, 27% Silt, 37% Sand
    - Median grain size (0.01mm – Silt)
- Battleship Gun test 1891-1921
  - 1-in to 16-in AP & HE projectiles
- Rockets 1946-1947



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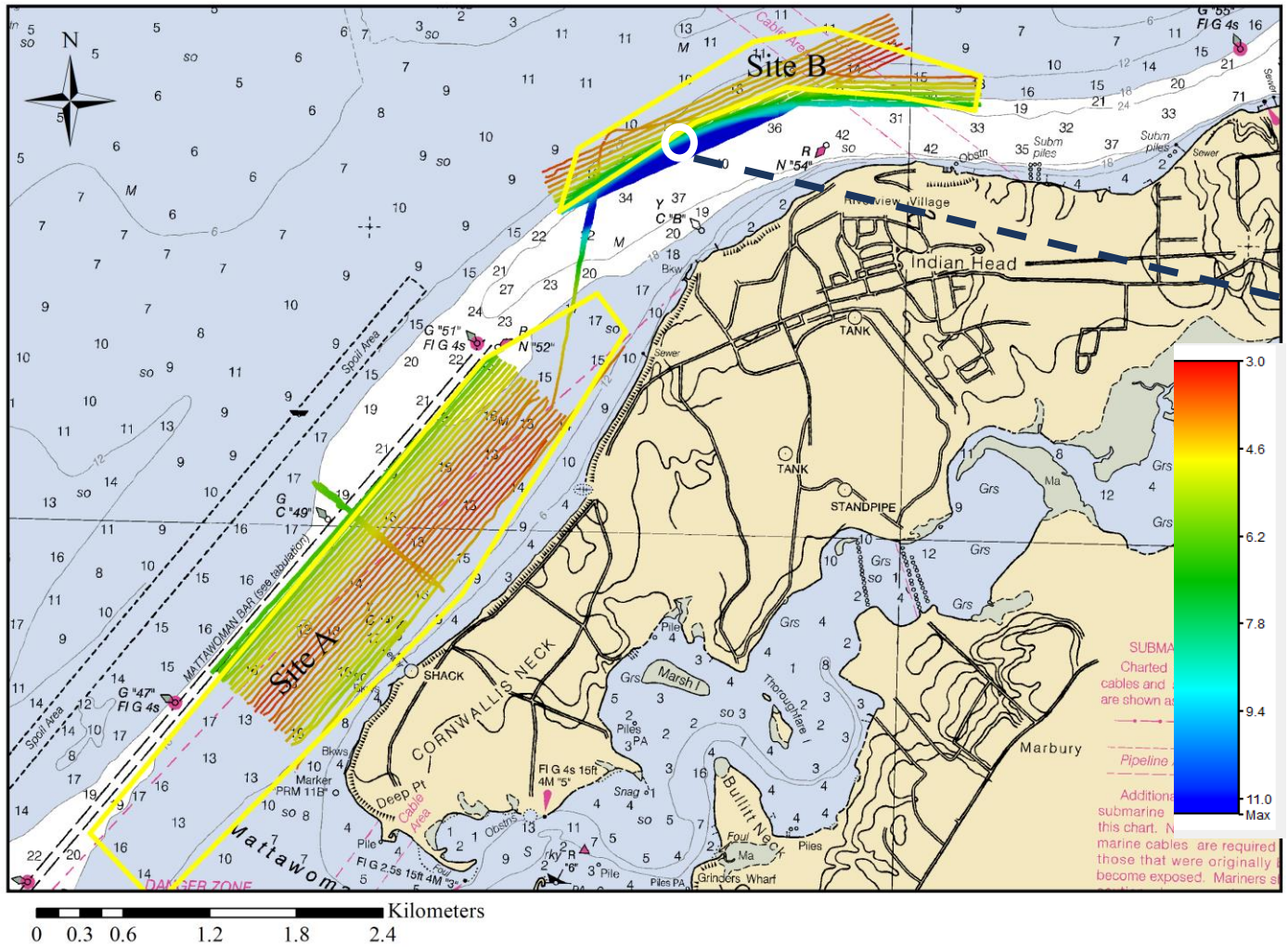
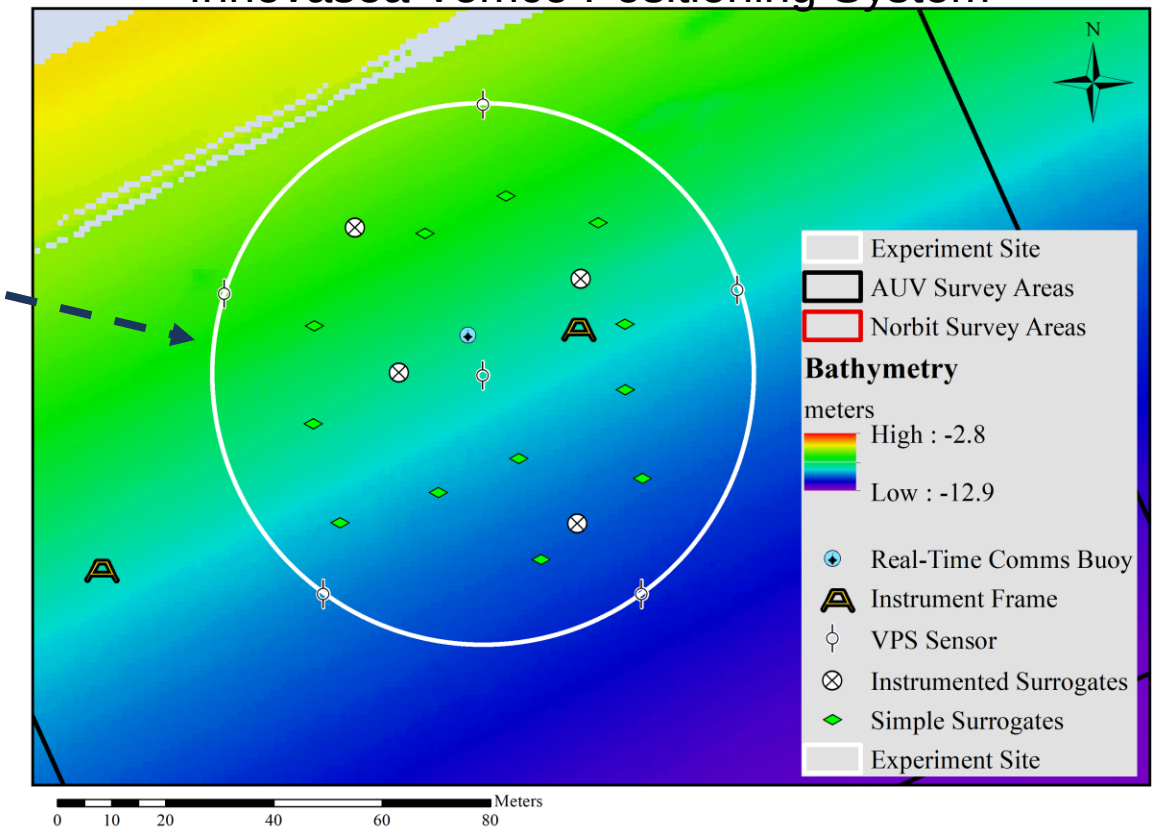
Spring 2023 Field Experiment

27 Feb – 28 April, 2023



Innovasea Vemco Positioning System



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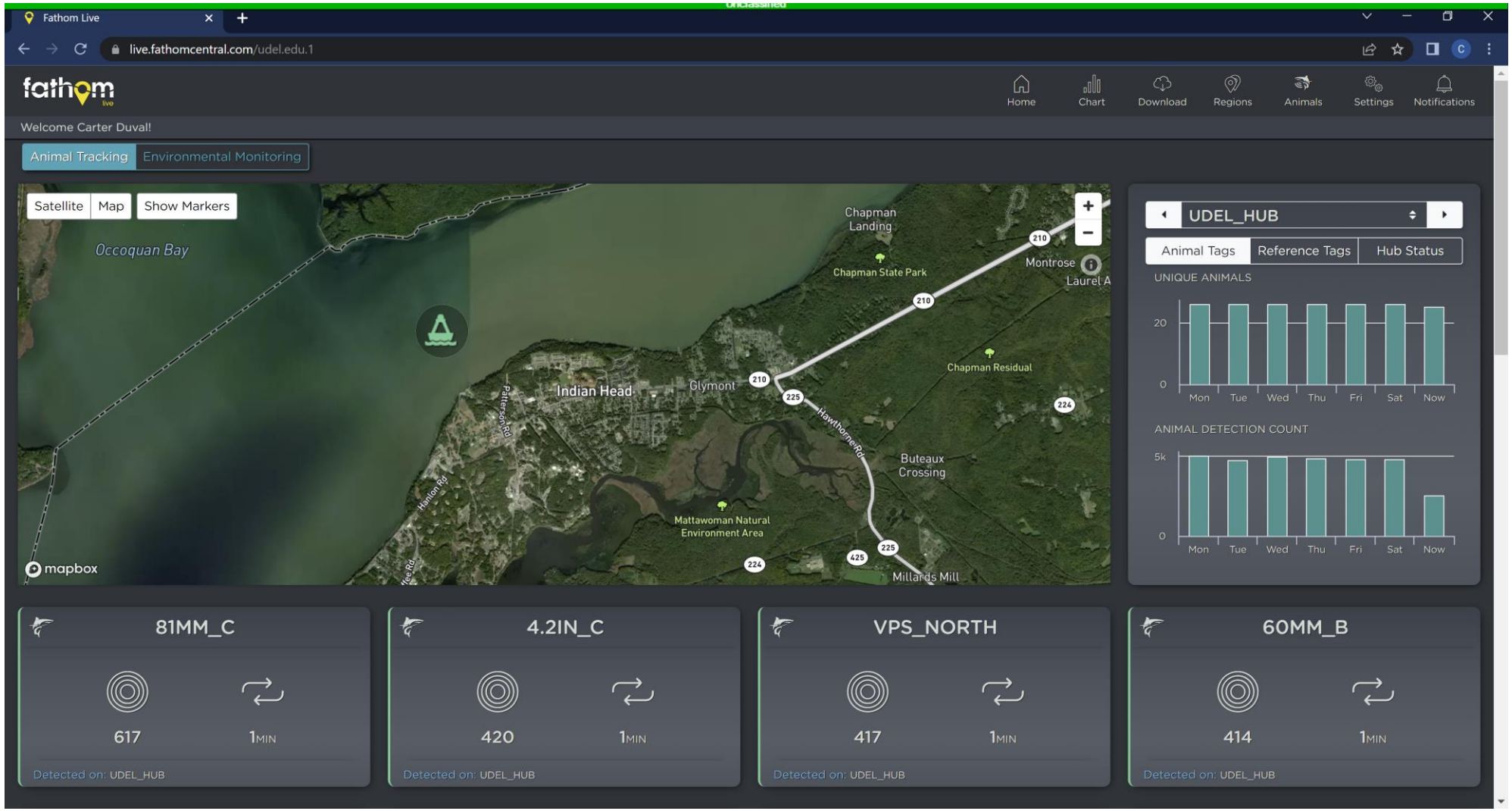
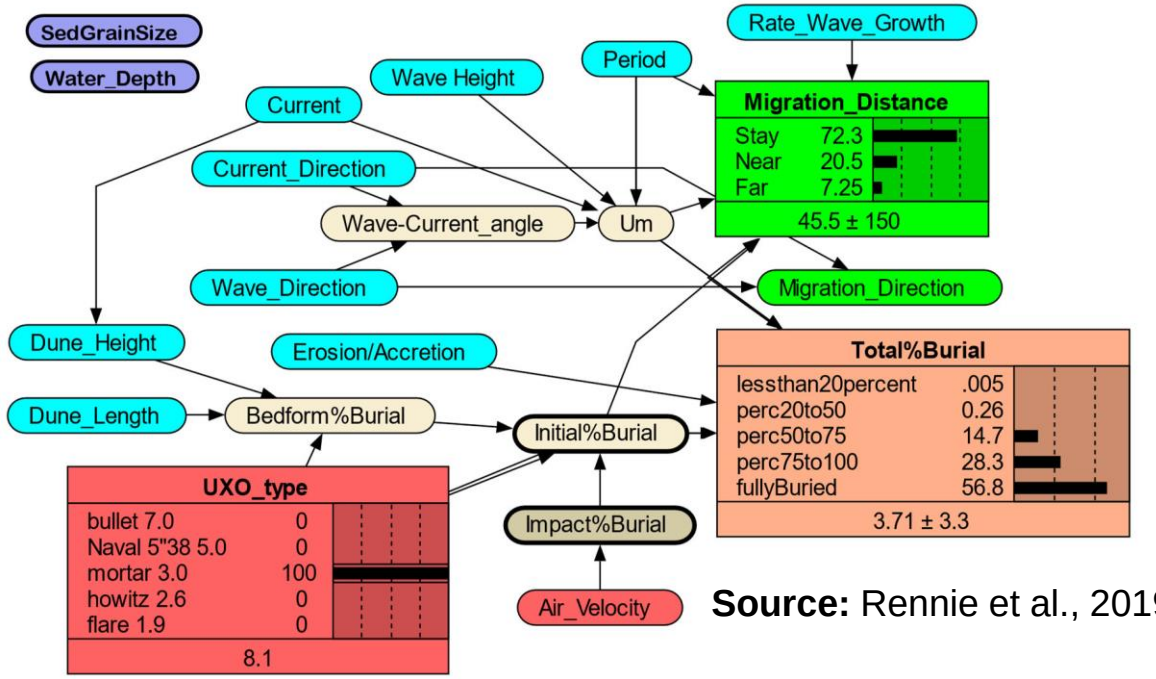
Innovasea Vemco Fathom Live

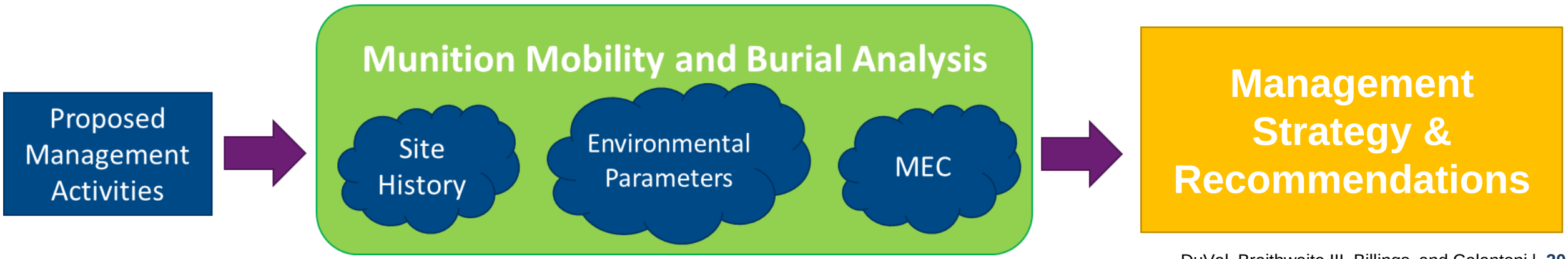


Transitioning from Field to Forecasting

- Objective
  - Provide tools for MRS management
    - Ex: Underwater Munitions Expert System Model (UnMES) – Rennie et al., 2019
  - Determine fate of munitions at MRS



Source: Rennie et al., 2019



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Summary

- Basic and applied research needs drove the development and application of prototype instrumented surrogates to characterize the physics necessary for modeling munitions mobility and burial in underwater environments
- Wide application of instrumented surrogates to varying environmental types and underwater sites provide much needed observations for predicting munitions mobility and burial at MRS
- Long-term site management that includes predicting munitions phenomenology represents a future mission critical technology

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