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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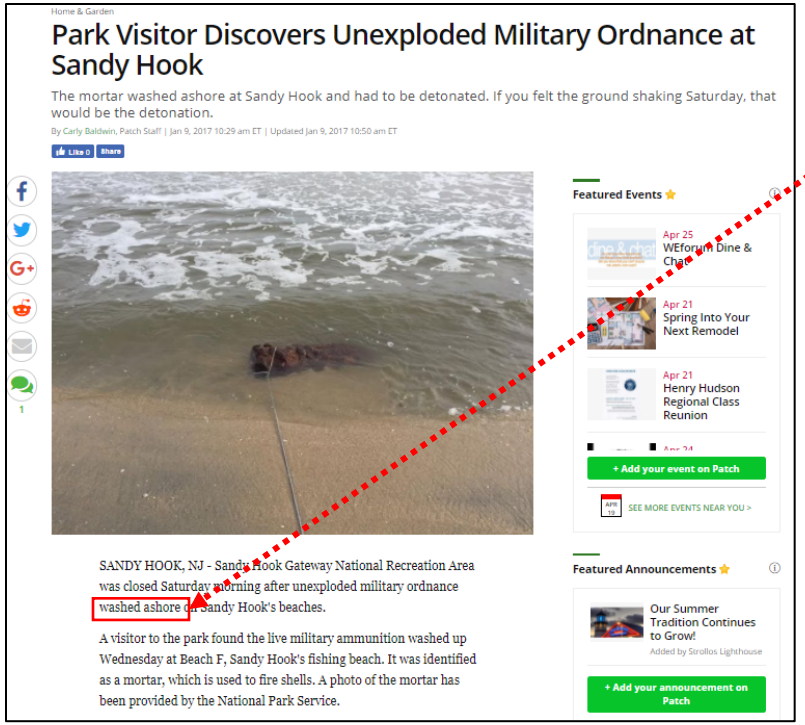
Why Study Munitions Mobility and Burial?



Home & Garden

Park Visitor Discovers Unexploded Military Ordnance at Sandy Hook

The mortar washed ashore at Sandy Hook and had to be detonated. If you felt the ground shaking Saturday, that would be the detonation.

By Carly Baldwin, Patch Staff | Jan 9, 2017 10:29 am ET | Updated Jan 9, 2017 10:50 am ET

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SANDY HOOK, NJ - Sandy Hook Gateway National Recreation Area was closed Saturday morning after unexploded military ordnance washed ashore on Sandy Hook's beaches.

A visitor to the park found the live military ammunition washed up Wednesday at Beach F, Sandy Hook's fishing beach. It was identified as a mortar, which is used to fire shells. A photo of the mortar has been provided by the National Park Service.

Featured Events

Apr 25
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Apr 21
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Apr 21
Henry Hudson Regional Class Reunion

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Our Summer Tradition Continues to Grow!
Added by Strollos Lighthouse

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- "…washed ashore…"
- But did it really?
- Was it there the whole time?

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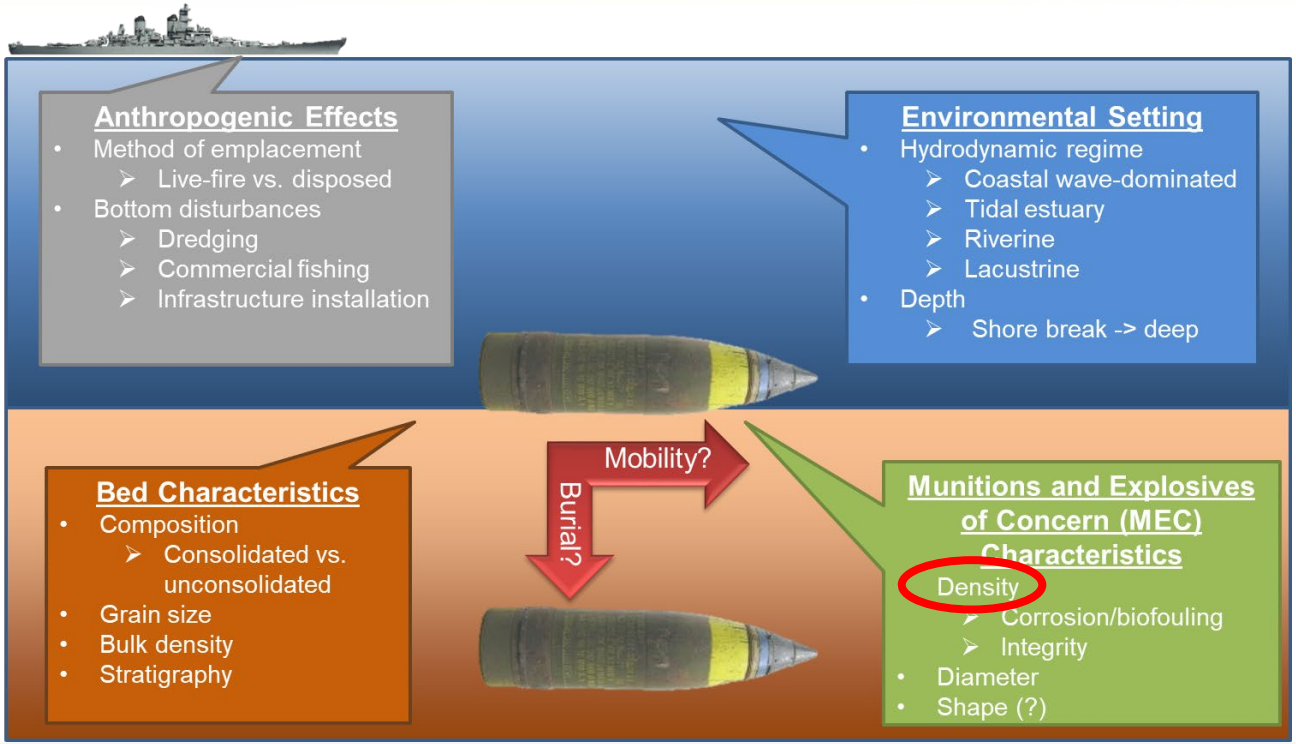
Synopsis of Munitions Mobility & Burial



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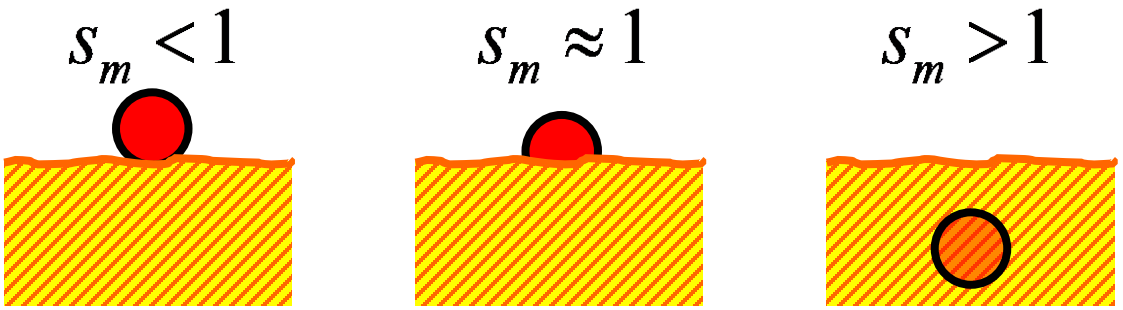
Importance of Density

relative density, s_m, is the ratio of density of munitions to the density of sediment

$$s_m = \frac{\rho_m}{\rho_s}$$



(see "Why the Brazil Nuts are on Top…", Rosato et al., Physical Review Letters, 1987; "Reverse Brazil Nut Problem…", Hong et al., Physical Review Letters, 2001)

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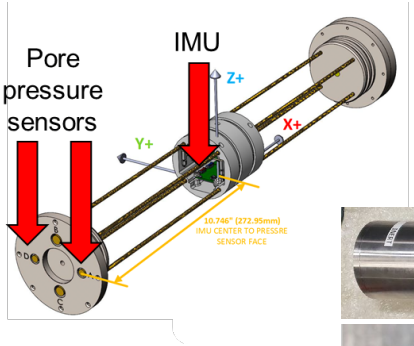
Instrumented Surrogates: "Mobility Monitoring Units"

Mobility Monitoring Units (MMU) 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)

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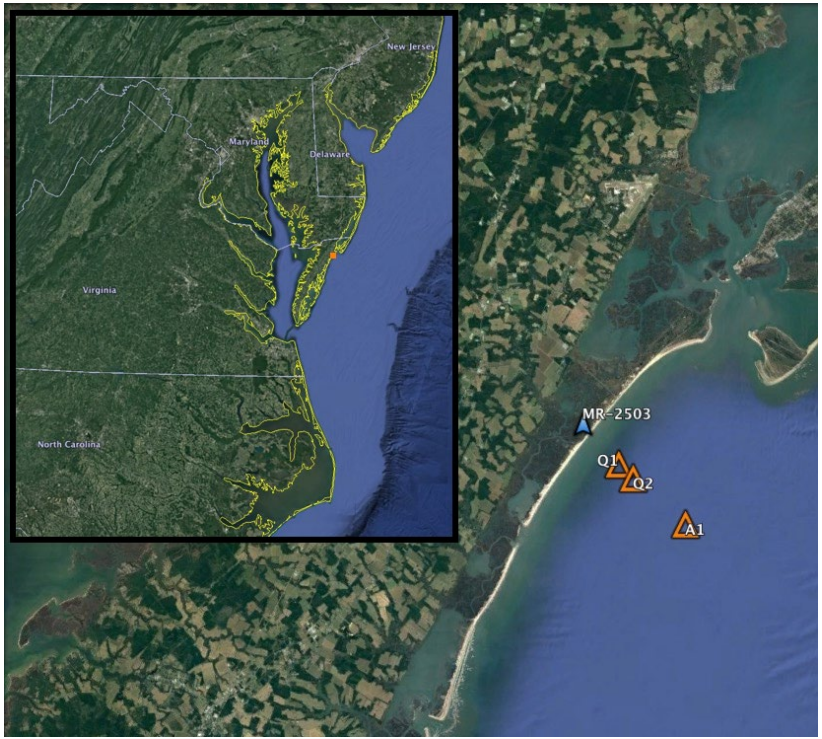
Integrating IMU – Quantifying Mobility

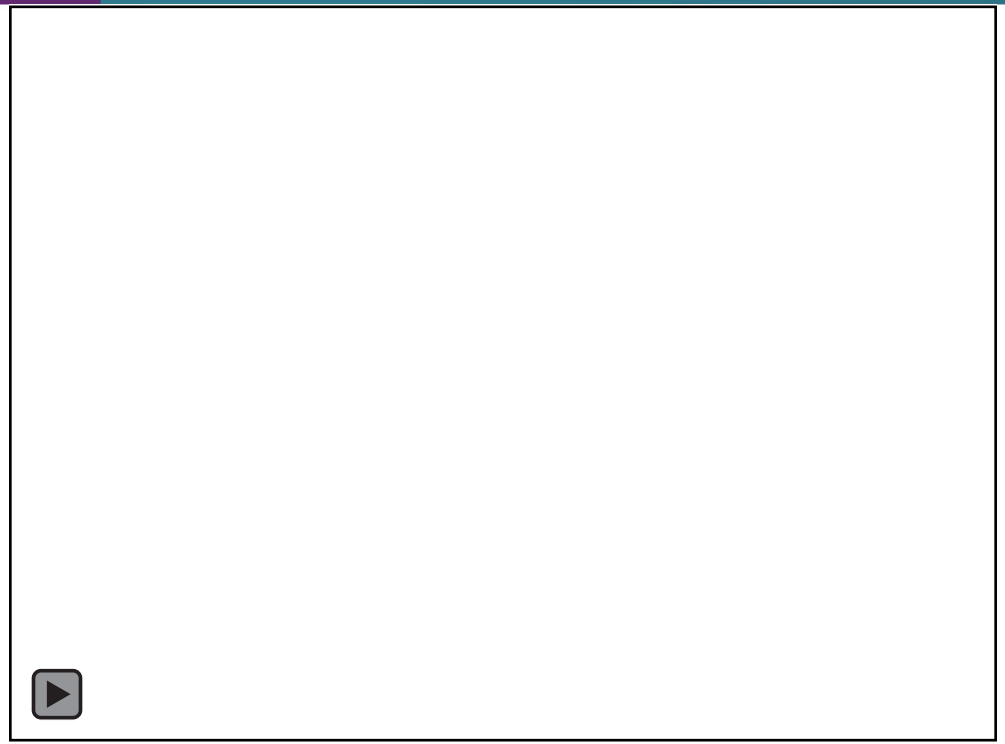
- Collaboration with MR-2410 (Garcia and Landry)
- COTS IMU embedded in nose

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



WIMM-X Mobility Results



- Start of mobility during storm at 14 March 2017 at 0228
- 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

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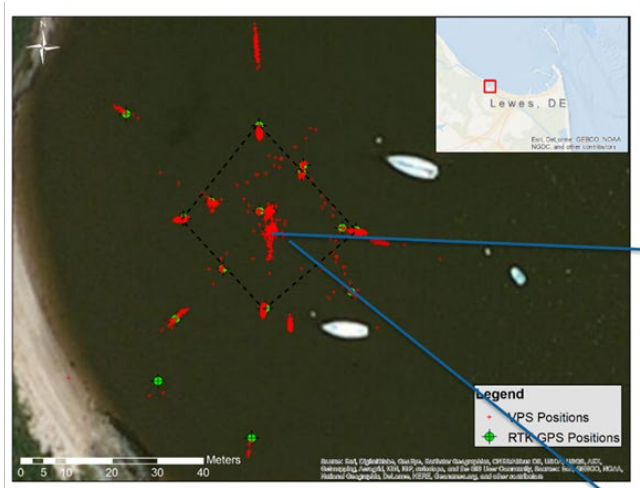
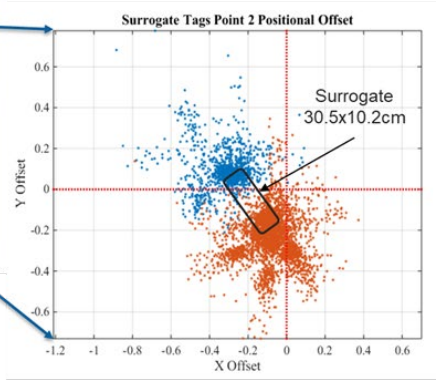
Integrating Acoustic Tracking Innovasea Vemco Positioning System (VPS)

- Acoustic tracking system (180kHz) – positional accuracies down to 10cm



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



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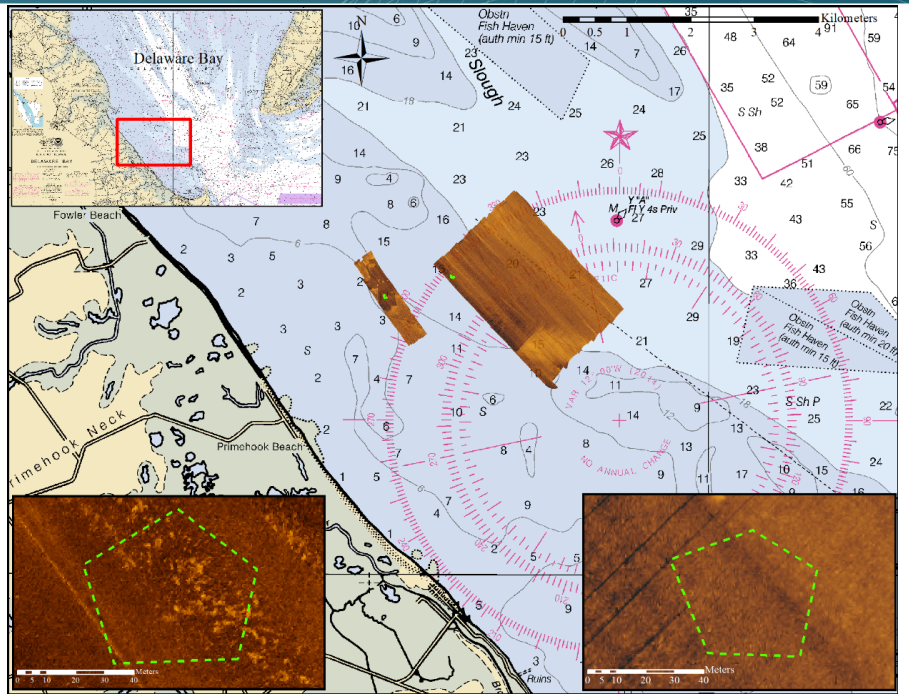
Unexploded Ordnance Characterization in Muddy Estuarine Environments (MR-2730)

- *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



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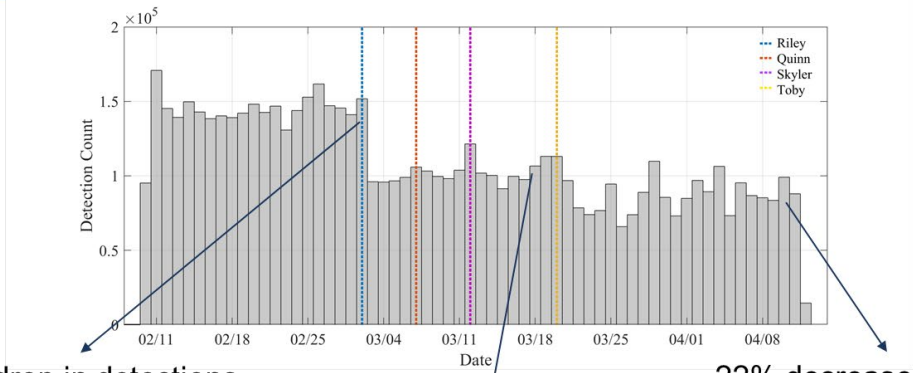
Spring 2018 VPS Animation

Four Nor'easters

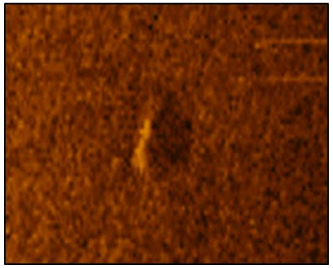
- *Riley (Mar 2)*
- *Quinn (Mar 7)*
- *Skyler (Mar 12)*
- *Toby (Mar 20)*

Burial and Exposure

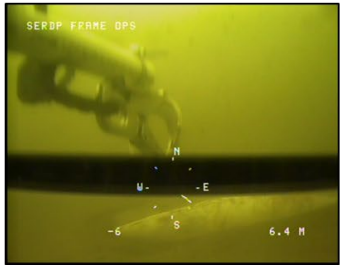
- Field test demonstrated VPS unable to detect buried 180kHz tags.
  - If daily tag detections decrease w/ no mobility = burial



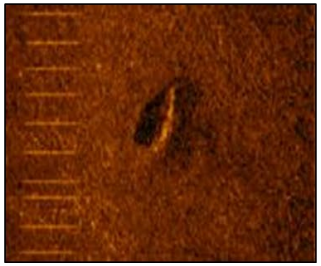
35% drop in detections
Only 155mm visible in sonar



81mm ~50% buried in ROV video



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



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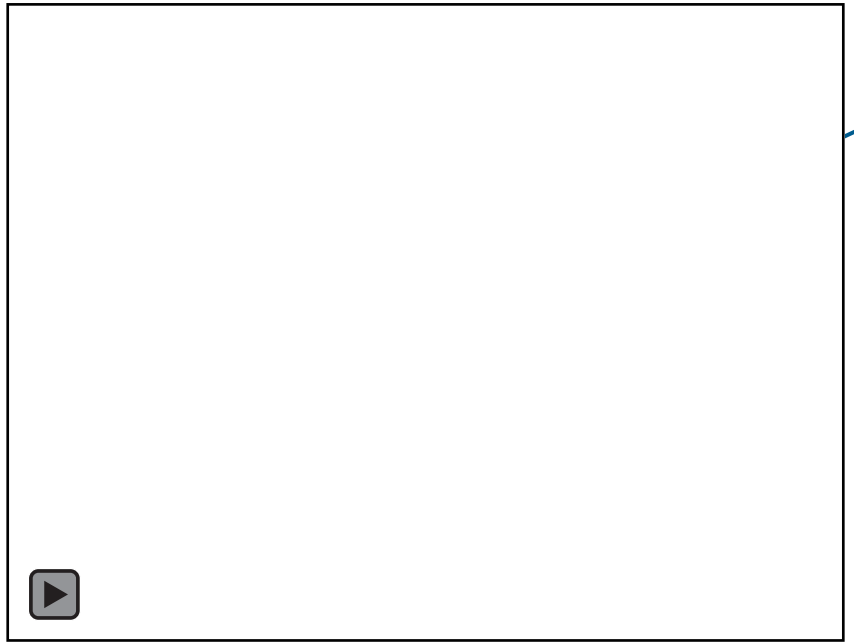
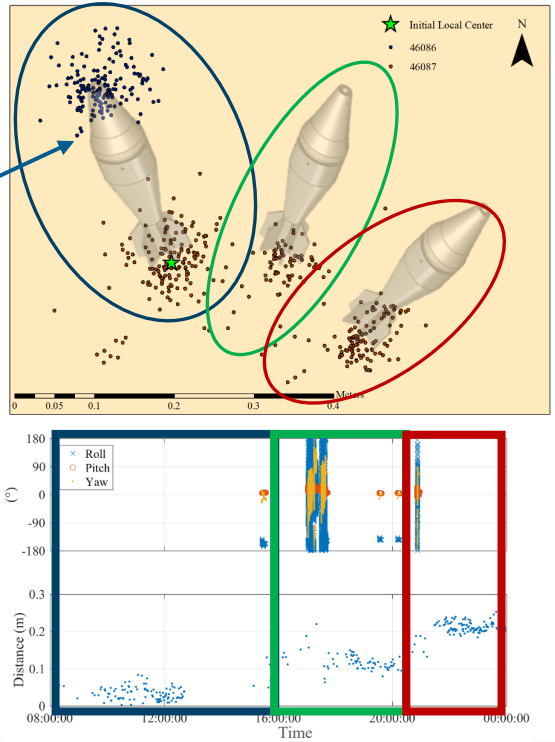
Surrogate Mobility?

Nor'easter "Toby" March 20, 2018





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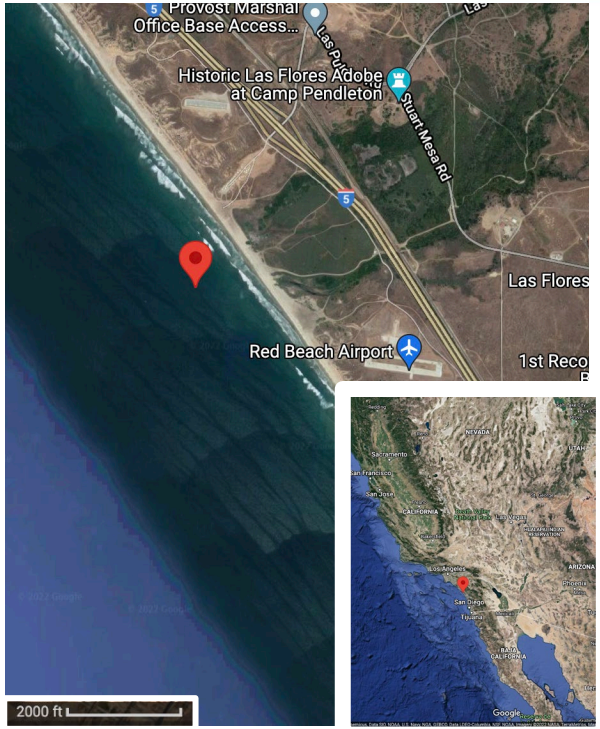
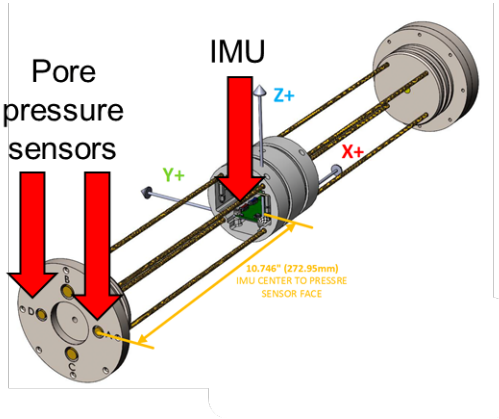
Integrating Pressure Sensors Quantifying Burial Depth



- 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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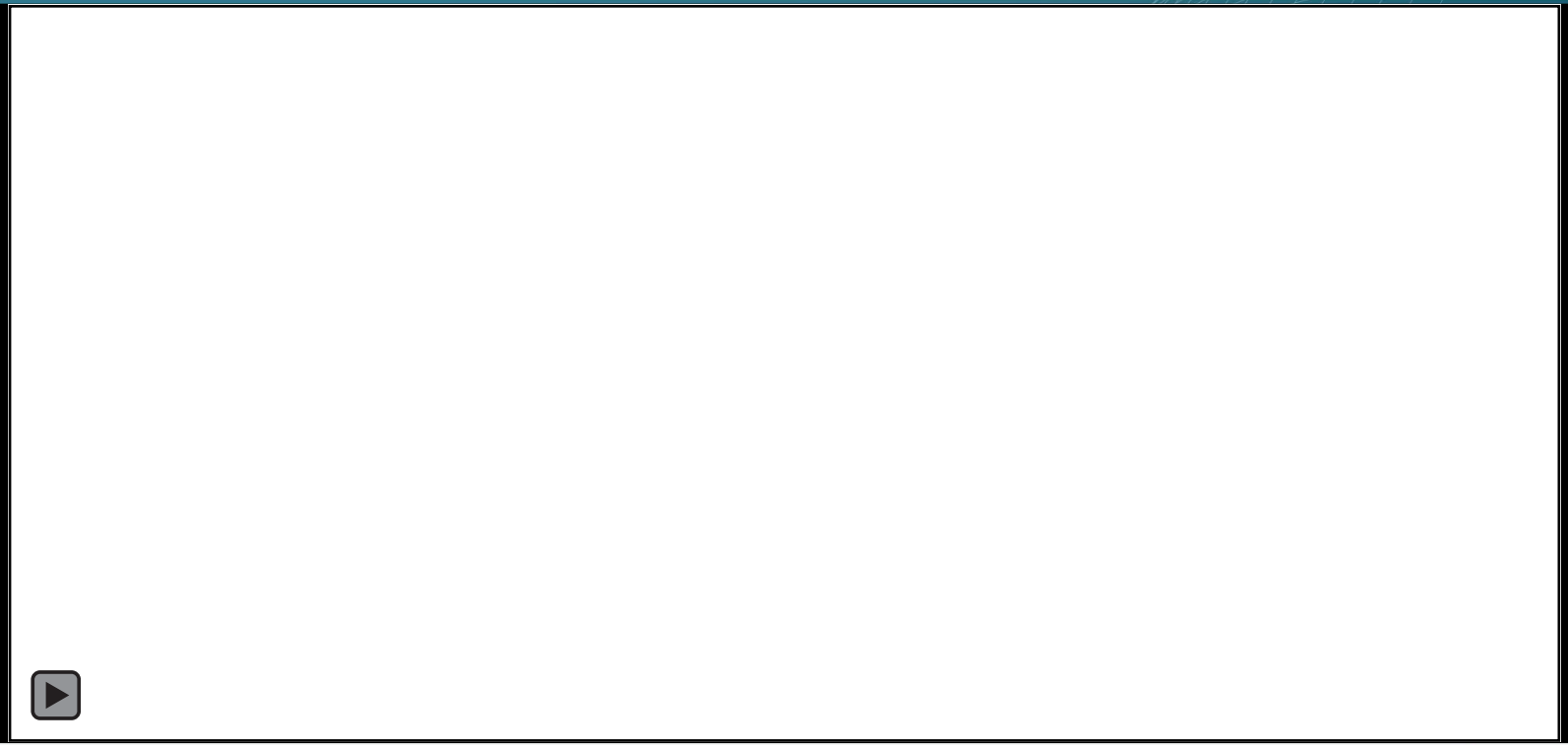
Field Experiment



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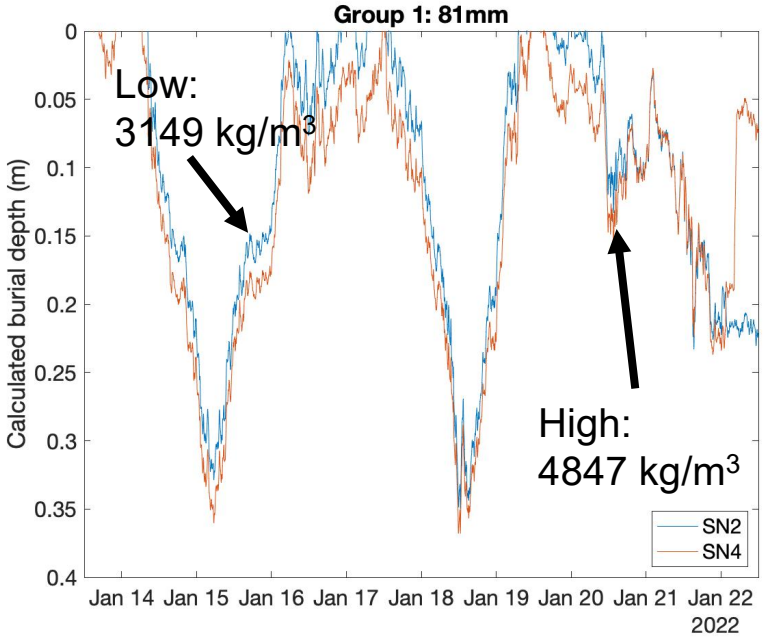
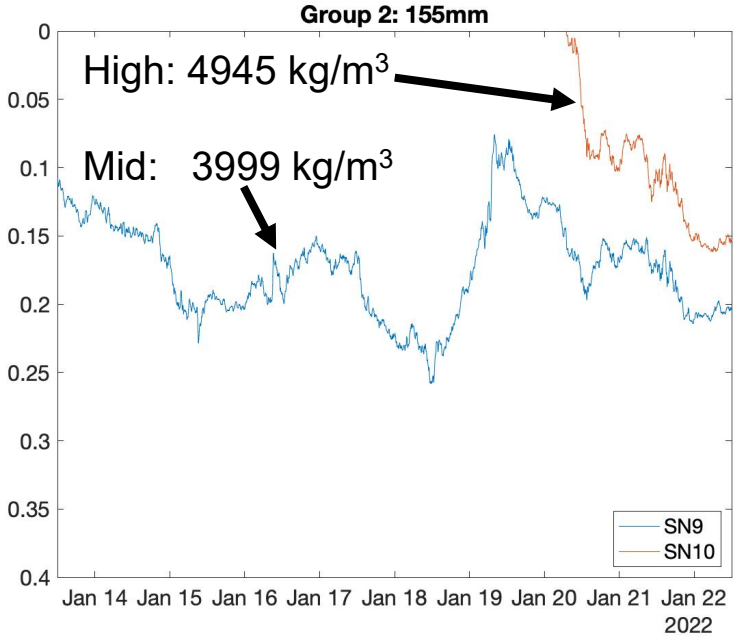
Burial Depth by Surrogate Type & Density





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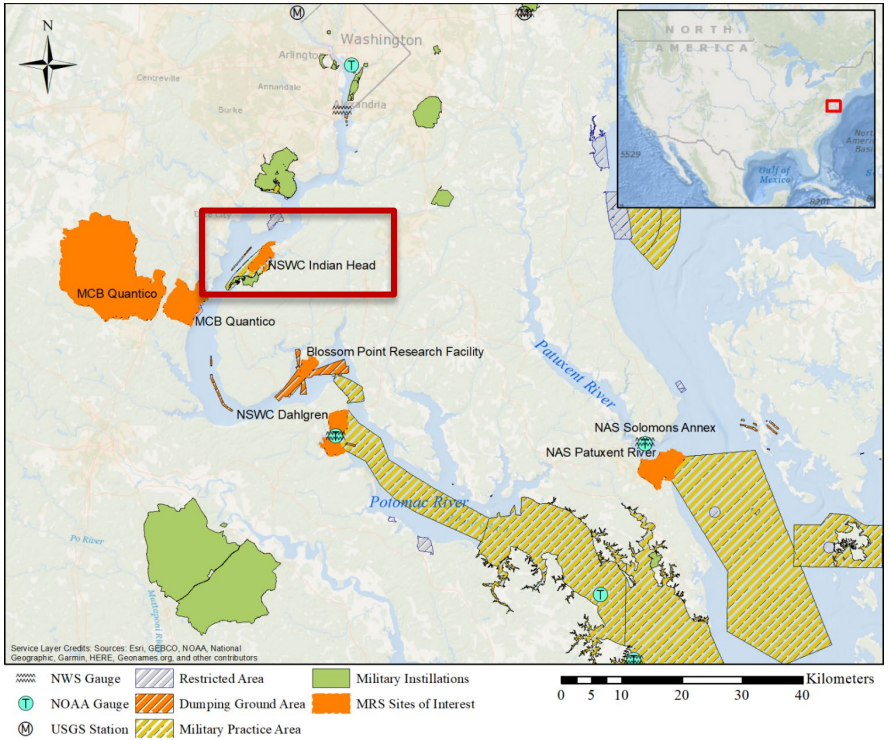
Riverine Ammunition Mobility and Burial Live-Site Experiment (RAMBLE)

- **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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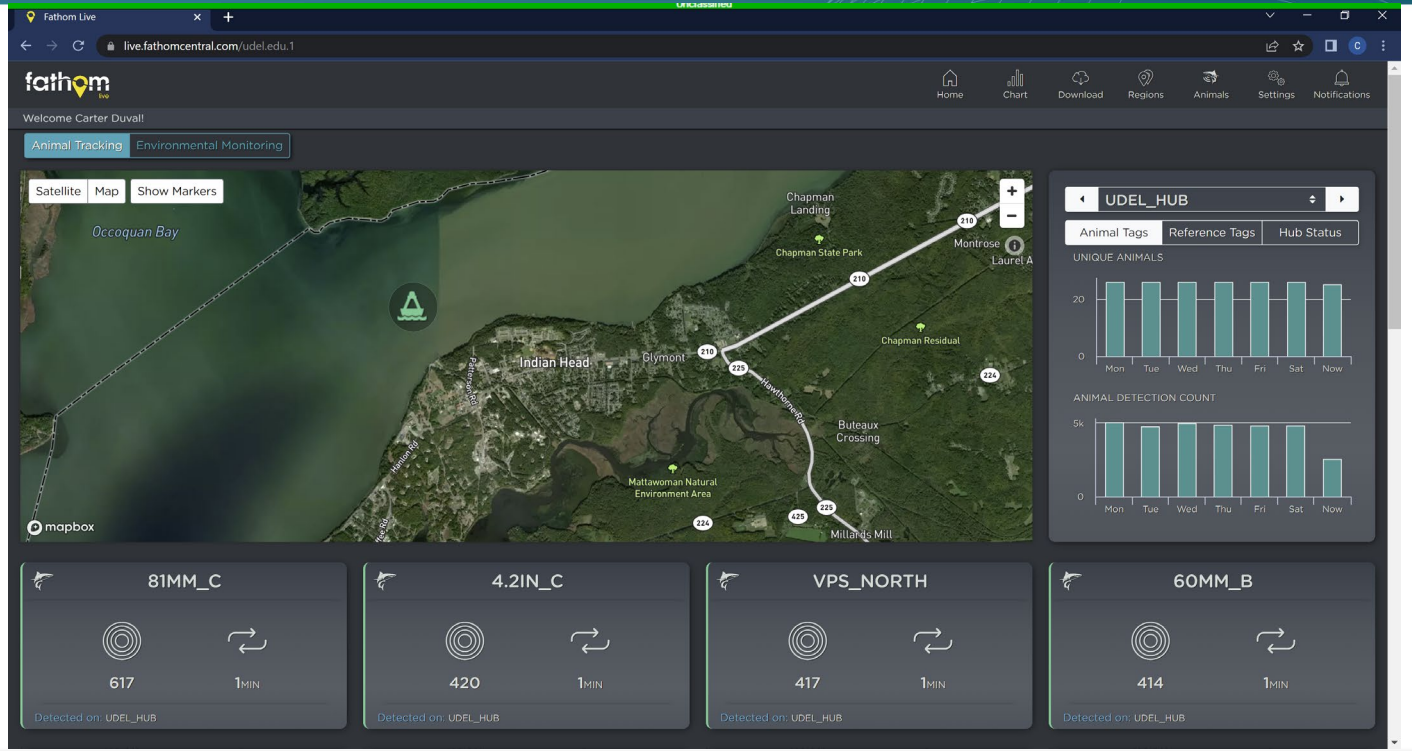
Innovasea Vemco Fathom Live



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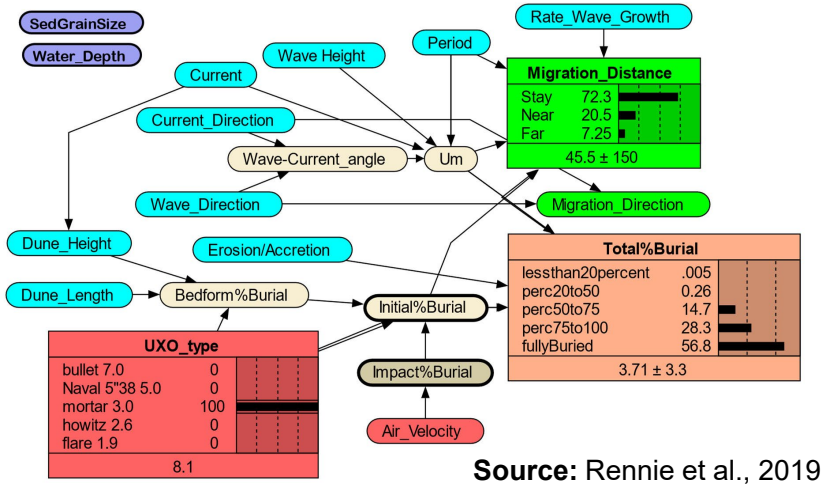
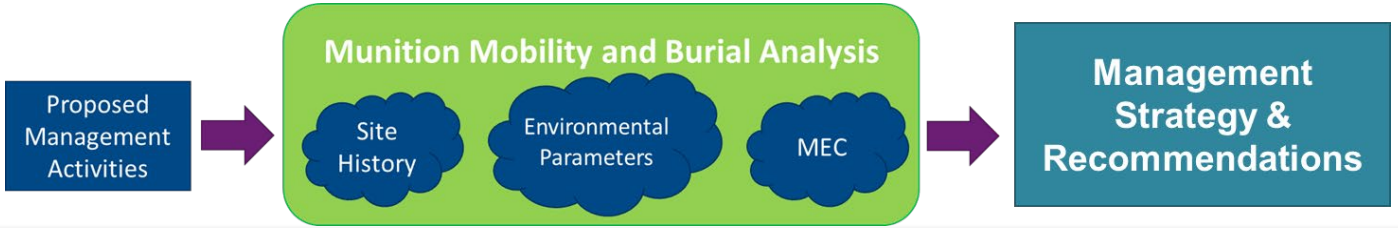
Transitioning from Field to Forecasting

- MMU observations → model development
- Provide tools for MRS management
  - Ex: Underwater Munitions Expert System Model (UnMES) – Rennie et al., 2019
  - Monitor for Mobility and burial at MRS
- Determine fate of munitions at MRS
  - Better inform DCL



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
  - Monitor for mobility and burial at MRS
  - Observations to develop mobility and burial models
- Long-term site management that includes predicting munitions phenomenology represents a future mission critical technology

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Acknowledgements

- SERDP & ESTCP
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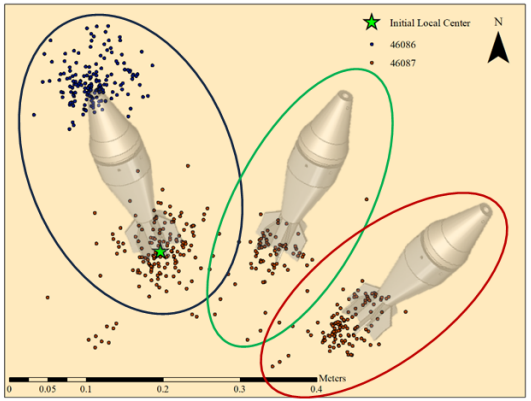
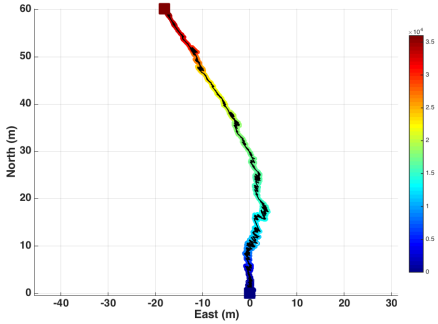
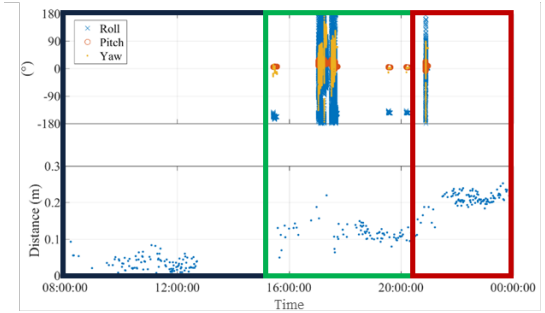
  - Marcelo Garcia
  - Blake Landry
  - Allison Penko
  - Sarah Rennie
  - Nina Stark
  - Art Trembanis







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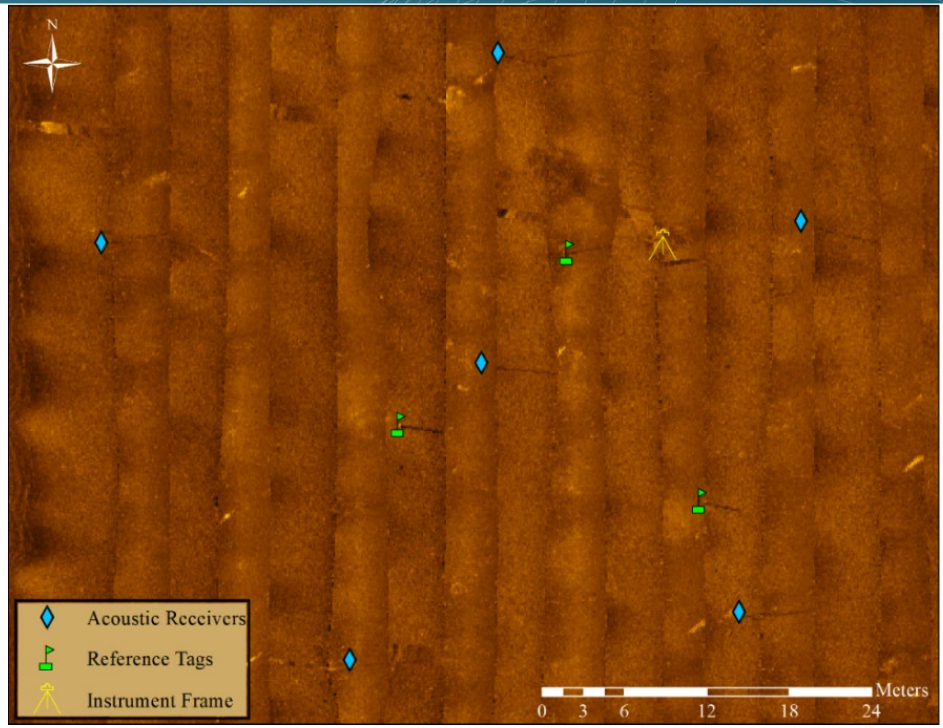
Source Projects

- MR-2227
  - https://serdp-estcp.mil/projects/details/b9dabb8a-cfbc-45a7-af4c-7c70e8492e70/mr-2227-project-overview
- MR-2320
  - https://serdp-estcp.mil/projects/details/84a23a05-67f5-4bfc-b59c-7c206e1d26e1/mr-2320-project-overview
- MR-2410
  - https://serdp-estcp.mil/projects/details/433e1f59-6310-41bc-bf4b-9fe81e88224d/mr-2410-project-overview
- MR-2730
  - https://serdp-estcp.mil/projects/details/316316aa-fd82-4507-b96d-bb8a74a230e1/mr-2730-project-overview
- MR19-1317
  - https://serdp-estcp.mil/projects/details/f9550a1a-e05a-4f21-8deb-38c9c4add9da
- MR21-1227
  - https://serdp-estcp.mil/projects/details/9fa4ba4b-6c11-47e4-8f9f-cb4e6f0d3a30/mr21-1227-project-overview

VPS Grid

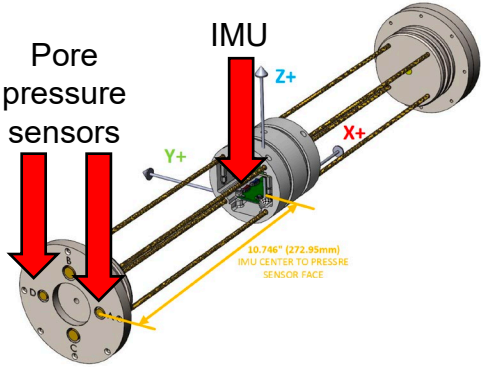
- VPS Grid and Surrogate Tracking
  - ♦ 6 receiver system in pentagonal grid allows for maximum overlap in shallow water
    - ➢ 10-13 instrumented surrogates deployed and monitored by VPS tracking
      - 60mm
      - 81mm
      - 4.2inch
      - 155mm

    - ➢ Multiple acoustic detections per minute per tag



Field Site

– Surrogates were deployed in two groups:
  - Group 1: SN2, SN3, and SN4 (smaller units)
  - Group 2: SN8, SN9, and SN10 (larger units)
  - Label numbers indicate density, from lightest to densest



	81mm diameter, 510mm long			155mm diameter, 750mm long		
	SN2	**SN3**	**SN4**	**SN8**	**SN9**	**SN10**
Density (kg/m^3)	3149	4069	4847	3350	3999	4945
In-air weight (kg)	8.27	10.69	11.56	47.41	56.59	69.99

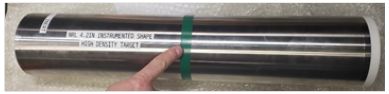
Inferred depths: Orientation

	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

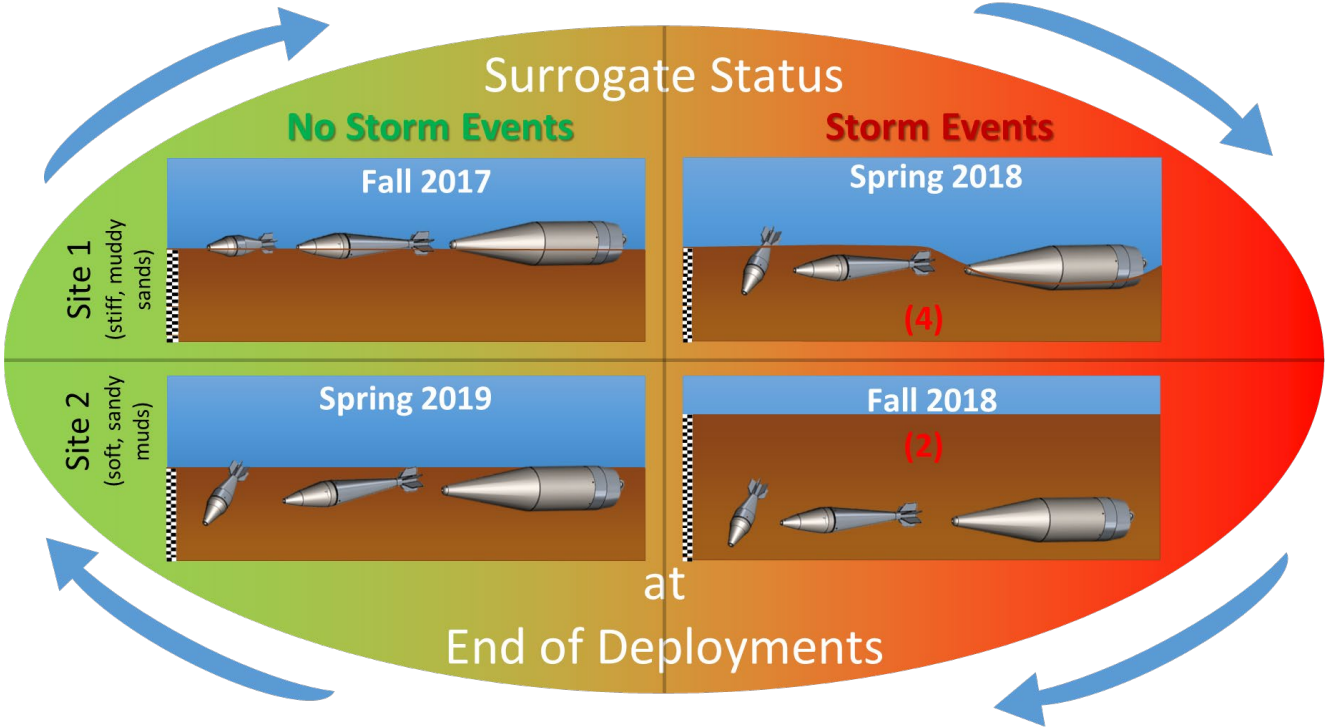
~20° from the mean wave direction is the cut-off between partial and immediate full burial

Wave Direction



Wave Direction

Deployment Summary



(*Number of Extra-Tropical Cyclone Storm Events)

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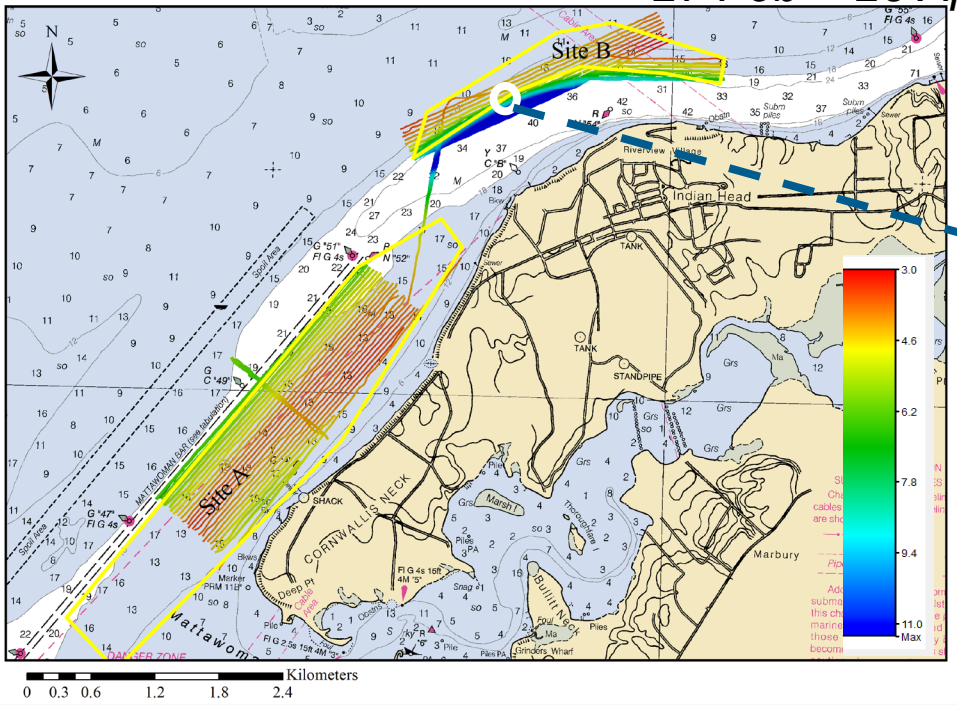
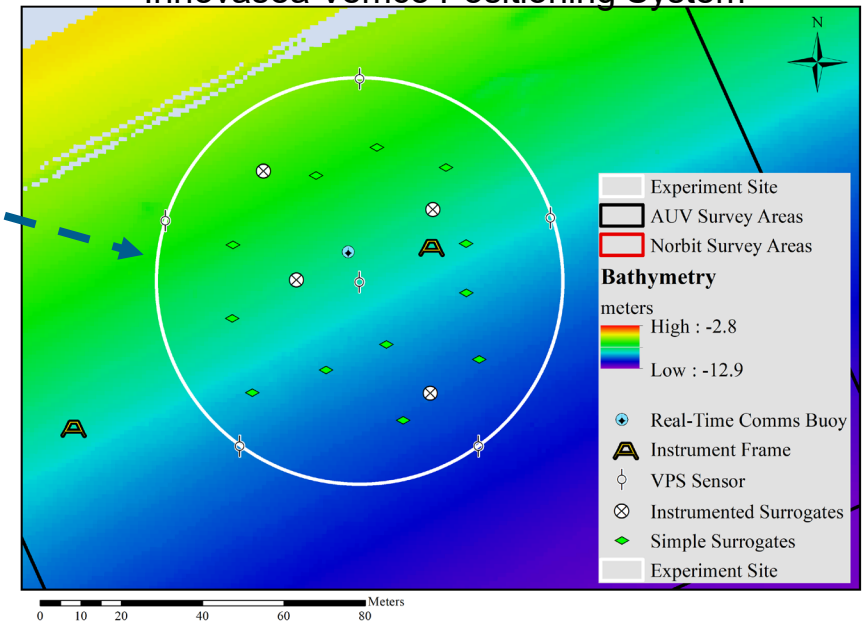
Spring 2023 Field Experiment

27 Feb – 28 April, 2023



Innovasea Vemco Positioning System



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