Munitions Response Library for Site Management

MR21-5207

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In Progress Review Meeting

21 MAY 25

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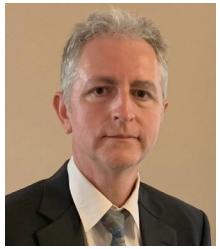

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ESTCP

Bottom Line Up Front

- Developed a repository to **house and utilize technology transitions** for testing and validating the models at ESTCP Demonstration Sites
- Utilized an accepted Navy standard for code versioning and validation and state-of-the-art technology to test and push **new and update existing models and databases**
- **Maine Demo**
- With the shifting of the program focus, we pivoted and developed a website where environmental information at ESTCP Demonstration sites will be **accessible in one location to allow for site assessment and user feedback**

Project Description

OBJECTIVE OF THE DEMONSTRATION

Enhance site manager awareness and predictive capability of the potential for munitions to migrate, bury, or become exposed by:

- Developing and deploying Mobility Monitoring Units (MMU) at Mile Beach, Reid State Park, ME
- Determining the skill and limitation of the models in the Munitions Response Library to predict the MMU mobilization and/or burial

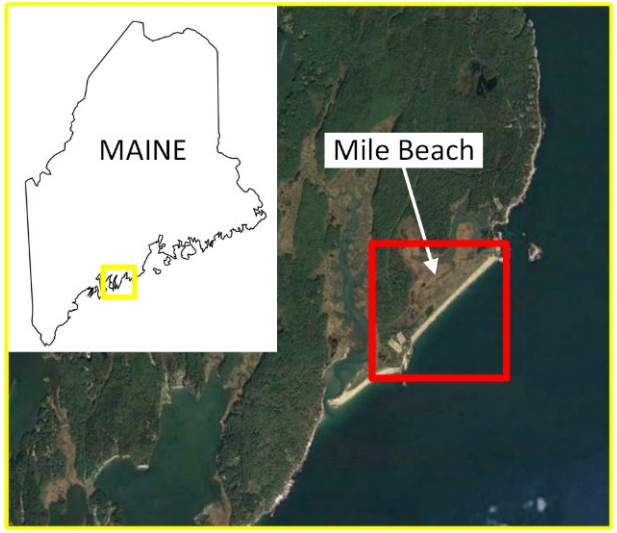
PROJECT DELIVERABLES:

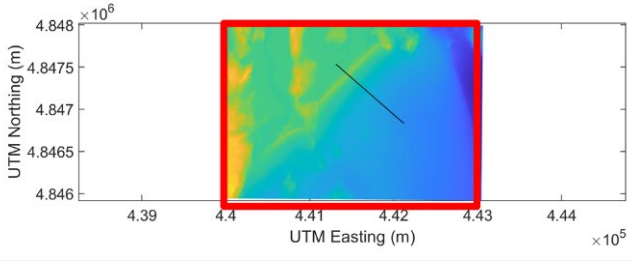
1) Develop surrogate MMU munitions characteristic of the field site;
2) Identify initial field conditions and deployed a suite of MMUs;
3) Routinely quantify the MMU position and burial depths
4) Provide a categorical and quantitative assessment of performance objectives of UnMES/MRL for predicting migration and burial under a range of forcing conditions;
5) Solicit feedback from site and program managers on UnMES data products for site decision making.

Site Description: Mile Beach, Maine

- Reid State Park, ME ideal location with timely need for demonstration to characterize mobility and burial
  - Aerial rocket training site during WWII that has since become a popular state park
  - Time-Critical Removal Action in Dec 1997 removed 82 munitions items from a 4-acre area
  - Current site for ESTCP DCL technology demonstration (Schultz, White River Technologies)
- Mobility Monitoring Units (MMU) developed 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 demonstrating and modeling munitions mobility and burial at MRS
  - MMU allow for extended deployment with low footprint or impact to site while increasing the likelihood of capturing MB&E during energetic events

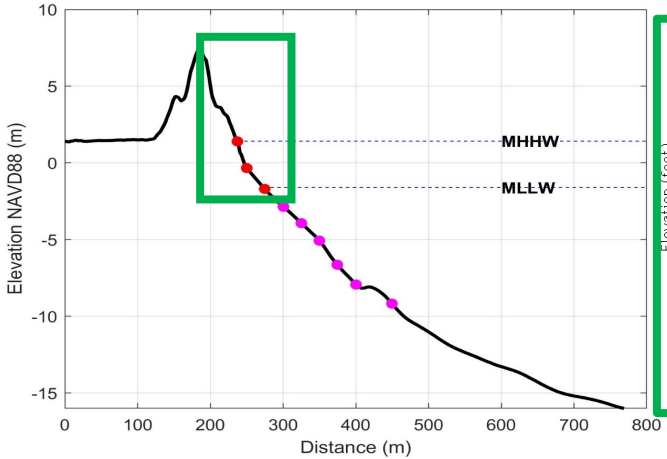
Site Description: Mile Beach, Maine

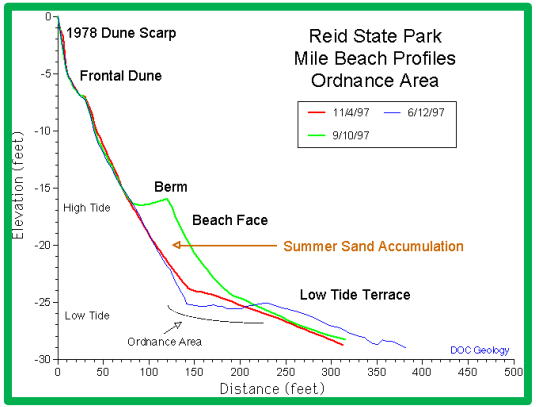




- Planned Cross shore transect (~ 300m x 50m footprint)
  - MMU at regular distance or depth intervals from MHHW or MLLW out to 10m depth

nediation location





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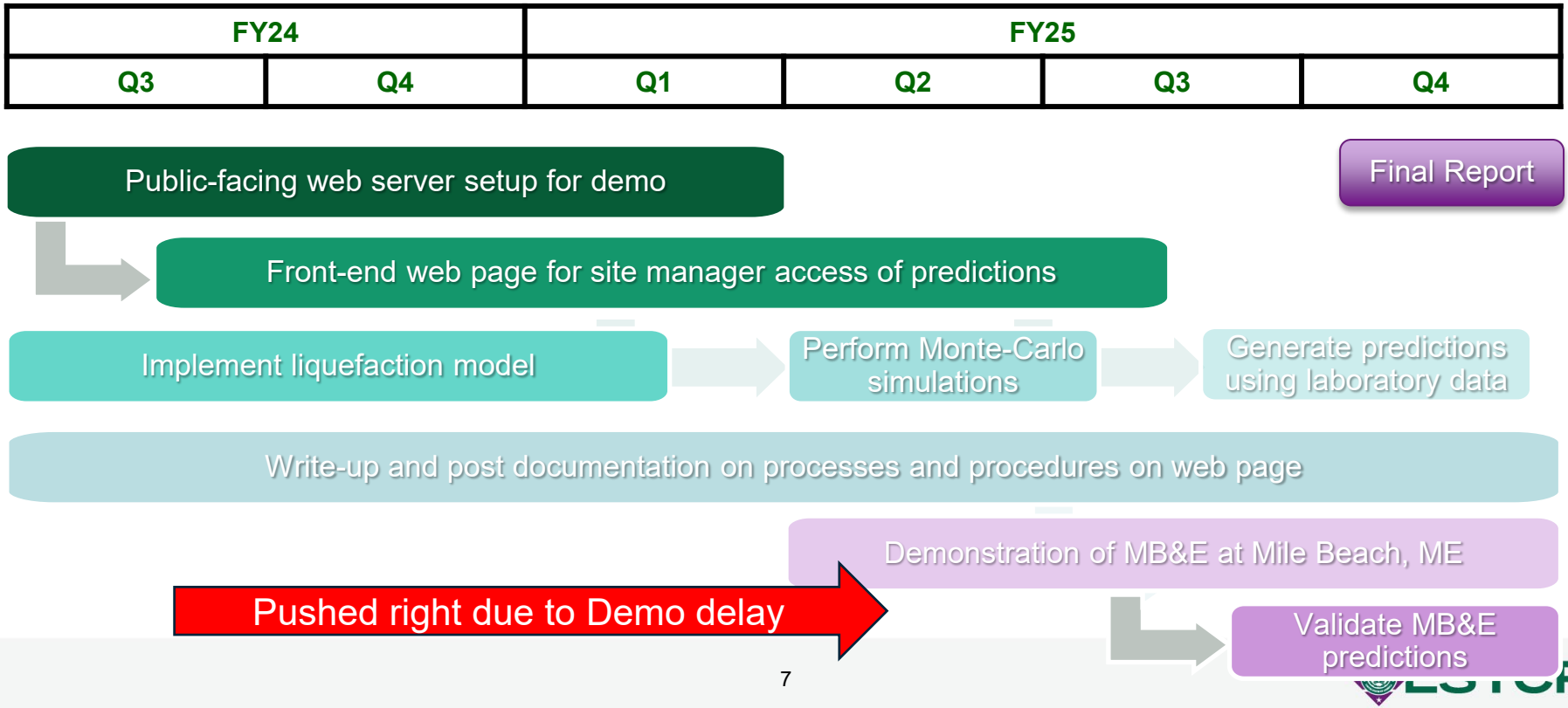
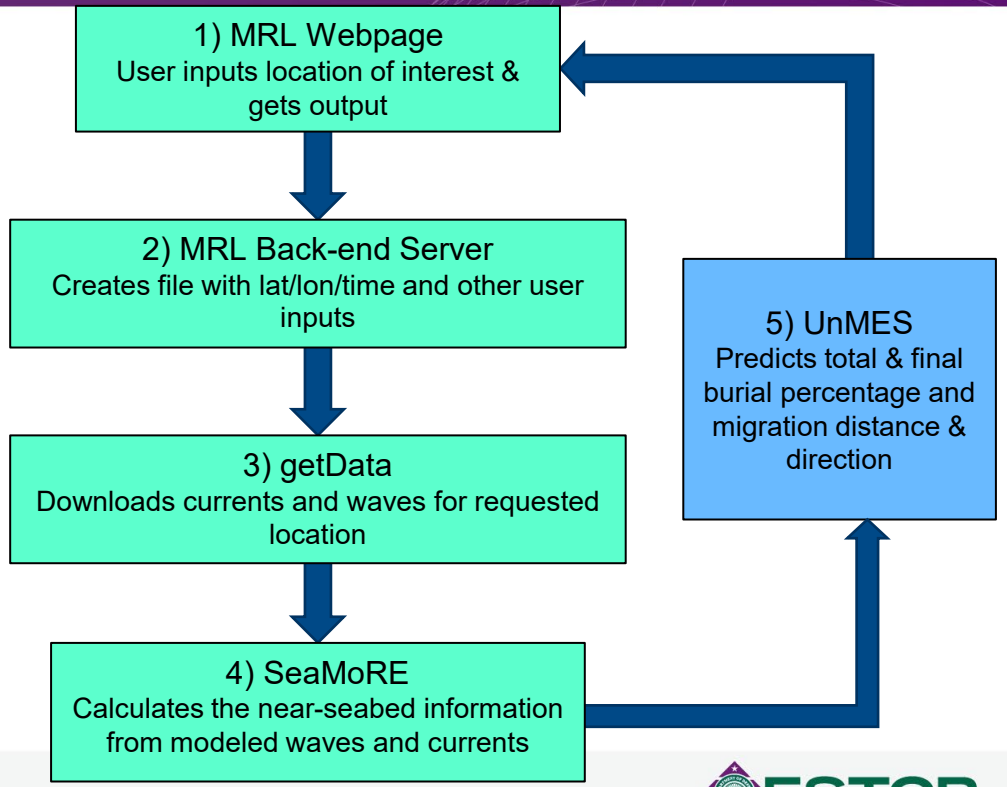
Technical Approach (Extension year)



MRL: UI Back-end Flow Chart

1. The user inputs the location, time, and munition of interest and presses “submit”.
2. Generation of input files to obtain and/or calculate the environmental variables triggered on the back-end server
3. Publicly accessible hydrodynamic data is downloaded
4. The near-bed environmental information is calculated and formatted into an UnMES input file.
5. UnMES ingests the input file and predicts the fate of the munitions at the location and time of interest



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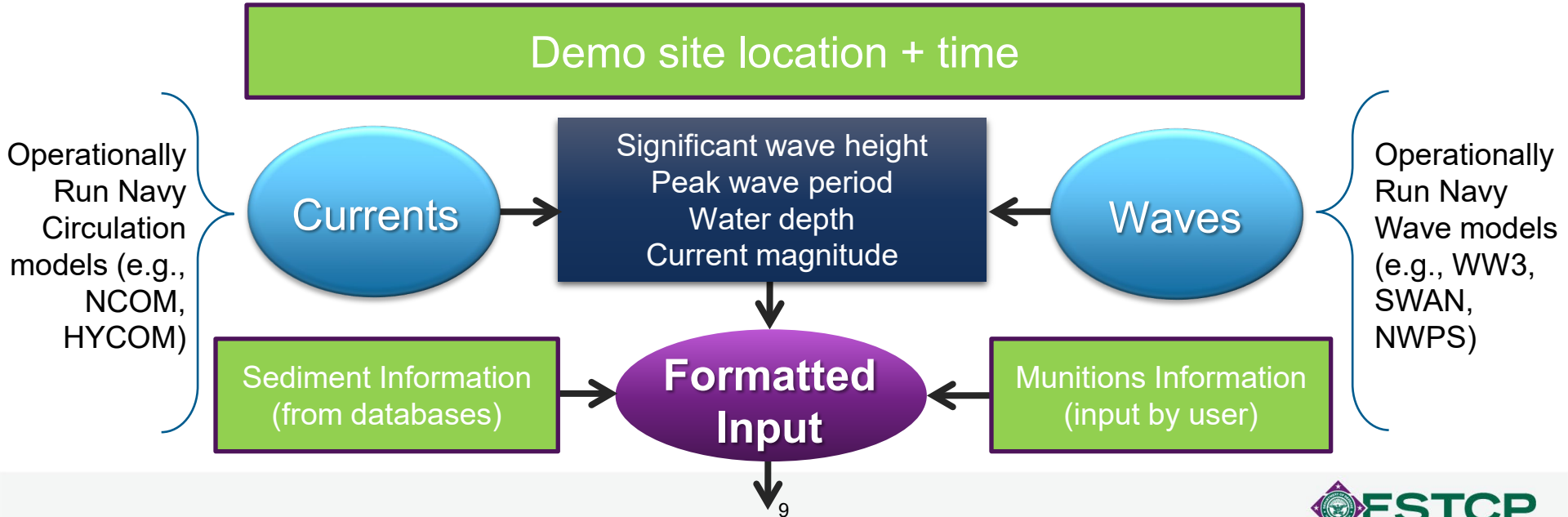
MRL: Obtain Environmentals – Steps 1-4

User inputs information in the green boxes into the Web portal. The system gathers and formats all the necessary information and runs UnMES to predict the probability of munitions burial and migration.



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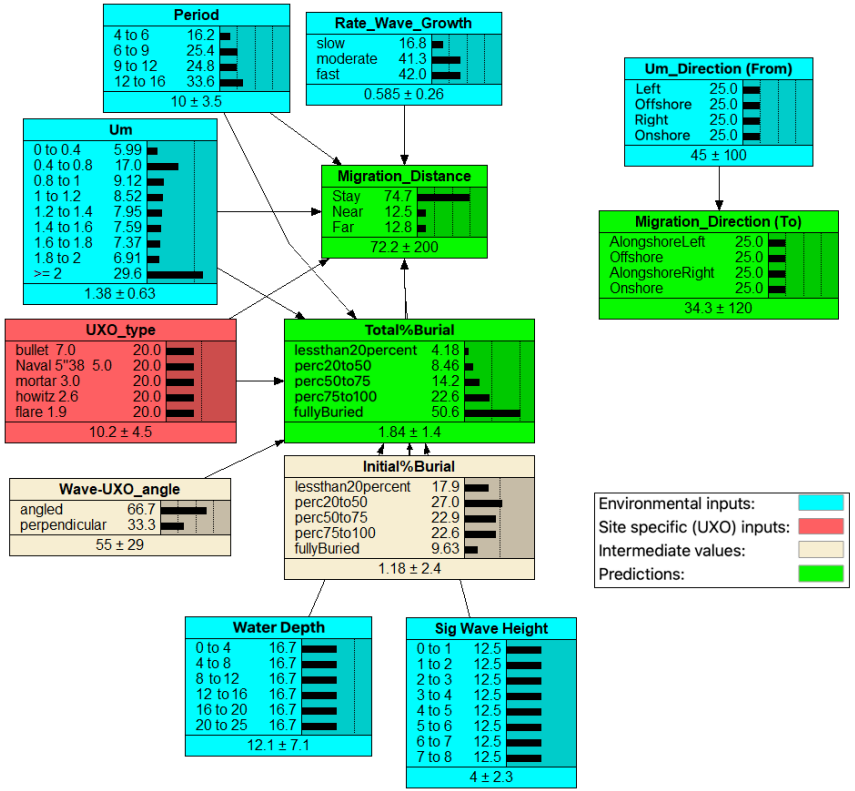
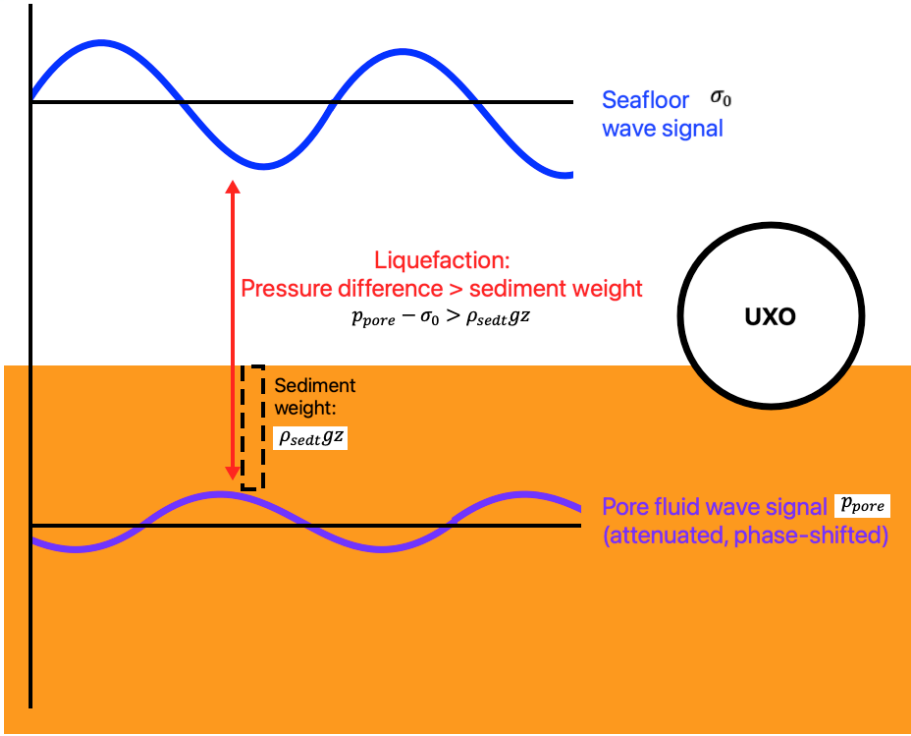
UnMES: Network

- Nodes updated to include:
  - Water depth
    - Range from 0 to 50m
  - Significant Wave Height, H_s
    - Range from 0.01m – 8.0m
- New nodes are required for calculation of burial via liquefaction
- Additional updates
  - calculate wave growth rate and Erosion/Accretion from model output



UnMES: Updated liquefaction algorithm

- Storm duration divided into 30-minute segments
- Previous algorithm:
  - Calculated L and B for each segment
  - Burial integrated over duration
- New: For each segment:
  - Generate time series of surface elevation from a JONSWAP spectrum generated from Hs, Tp using random phase method
  - Input time series into poroelastic model to generate time series of liquefaction *degree*
    - Degree scales from 0 (no liquefaction) to 1 (full liquefaction)



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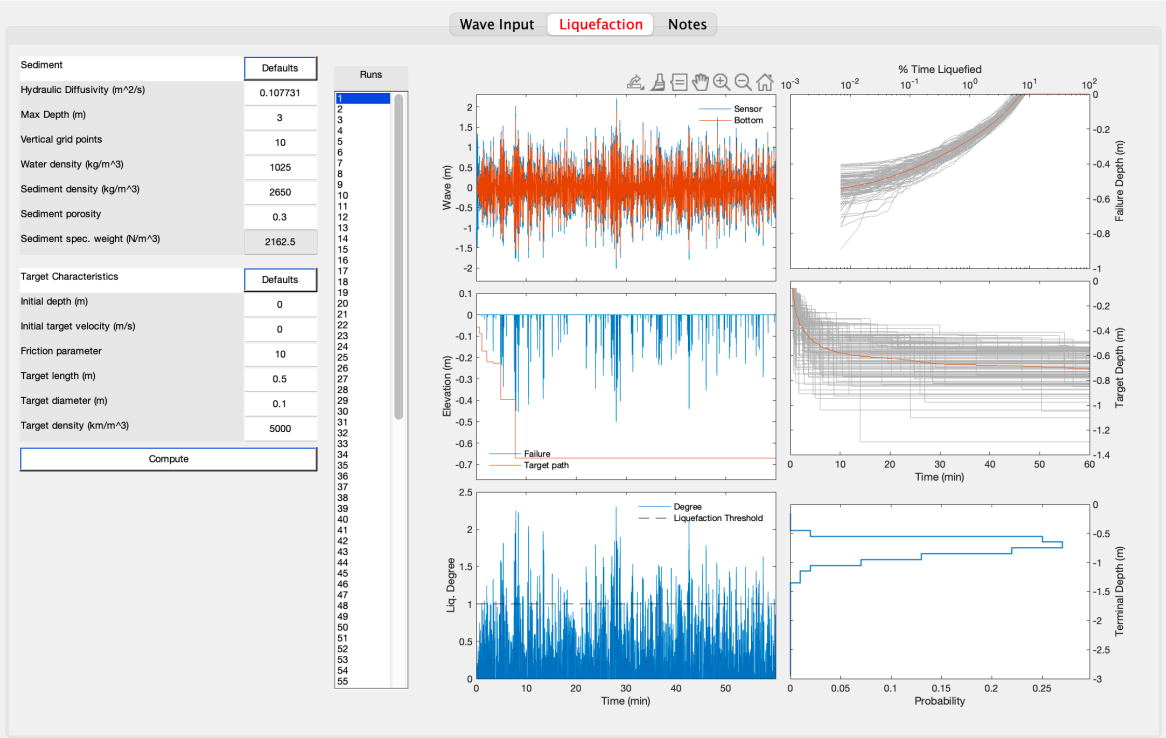
UnMES: Updated burial algorithm

- Burial algorithm updated to solve for vertical momentum equation accounting for buoyancy, gravity, and frictional drag
  - Frictional force, hydrodynamic buoyancy are proportional to liquefaction degree
- Equation is solved for each 30 min subinterval of the storm sequence

UnMES: Liquefaction & burial

- Results provide statistically expected value of munition burial with depth

GUI developed by Harald Klammler, which implements liquefaction burial code now incorporated into UnMES



UnMES: Training data

- Updated liquefaction and burial algorithm include physics at cost of runtime
  - Ineffective use of Matlab functions; rewritten to optimize and remove bottlenecks
  - Optimized code is still expensive → Requires HPC

# of MC samples	Unoptimized	Optimized
1	87 s	13 s
250	6.6 hr	54 min

Speed tests done on single core, Macbook M2 Pro.

Performance Objectives

MMUs

- Objective 1: Diver ability to relocate a MMU using acoustic tags
- Objective 2: Precision of the counter weighted float platform for MMU positioning
- Objective 3: Precision of the USV approach for MMU positioning
- Objective 4: Accuracy of MMU positioning approaches

UnMES

- Objective 1: UnMES capability to correctly predict the mobilization response for at least 90% of the diver observations
- Objective 2: UnMES capability to correctly predict the burial response for at least 90% of the diver observations

Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria
MMU Quantitative Performance Objectives			
Diver ability to relocate MMU using acoustic tags	Comparison with number of deployed MMU that are not lost	Count	>80% found over the course of the experiment
Diver MMU localization precision	Standard Deviation	Repeated surveying of the same MMU	Horizontal position standard deviation < 1.5 m (deep water), < 1 m (shallow water)
USV MMU localization precision	Standard Deviation	Repeated surveying of the same MMU	Horizontal position standard deviation < 2 m
UnMES Quantitative Performance Objectives			
UnMES capability to predict burial	Comparison with MMU position data	MMU position data obtained by researchers or divers	Correct prediction response >90% of diver observations
UnMES capability to predict the mobilization distance	Comparison with MMU burial data	MMU burial data obtained by researchers or divers	Correct prediction response >90% of diver or USV observations

Performance Objectives

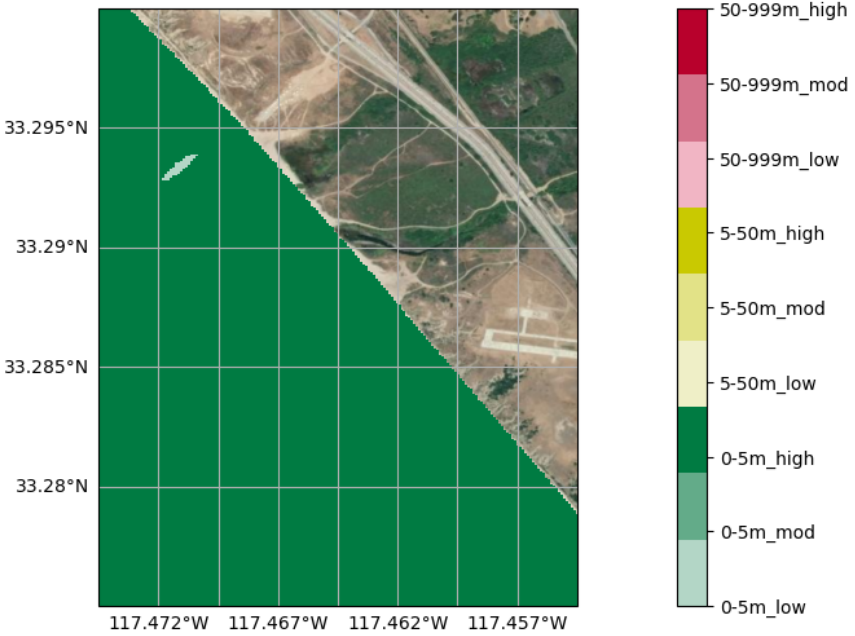
UnMES model – Response Categories

- Burial Prediction Categories
  1) **Munition exposed** – likely detectable by typical mid-high frequency acoustic methods and/or by divers using eyesight, metal detectors or acoustic pingers
  2) **Munition fully buried with burial depth O(munition diameter)** – potentially detectable by typical mid-high frequency acoustic methods and/or by divers using metal detectors or acoustic pingers
  3) **Munition fully buried at depths greater than munition diameter** – not likely detectible by typical mid-high frequency acoustic methods or any diver-based approaches
- Mobility Prediction Categories
  1) **Munition migrated less than 5m** – Munition is within the vicinity of initial deployment and likely still recoverable by divers without increased timeline and at the least positional uncertainty
  2) **Munition migrated between 5m and 50m** – Munition is still within region/beach area and likely recoverable within the site/range by typical detection methods, but with a longer timeline
  3) **Munition migrated more than 50m** – Munition is located outside of the immediate region/site and is not likely recoverable without searching an extended area

Performance Objectives

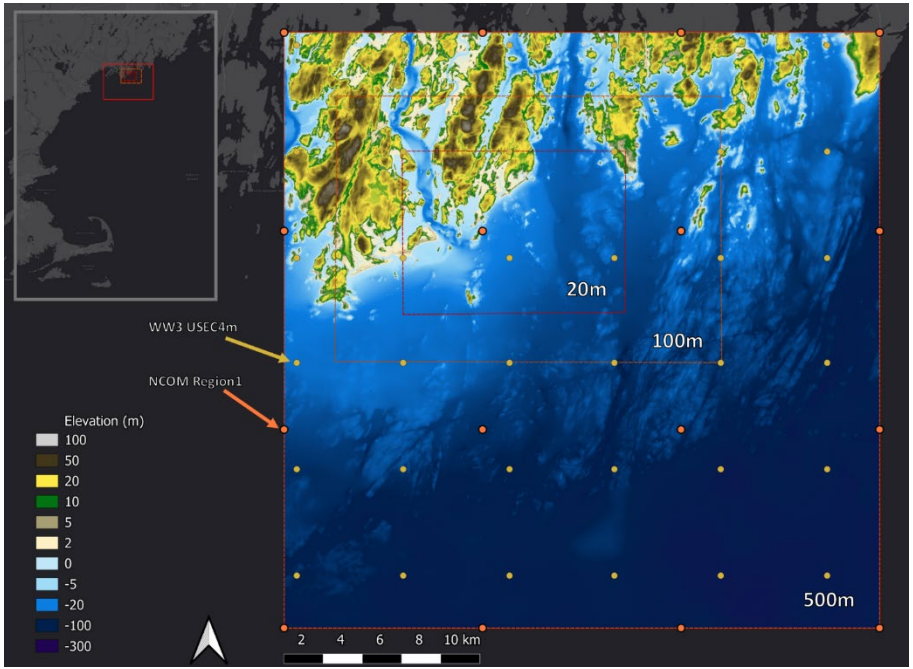
UnMES model - Confidence

- High Confidence
  - Highest response probability > 60% AND
  - Remaining 2 response probabilities both < 30%
- Moderate Confidence
  - Highest response probability > 60% AND
  - Remaining 2 response probabilities both > 30%
- Low Confidence
  - Highest response probability < 60%



Hydrodynamic Model Setup

- complex coastline
- local model domain driven by output from regional scale operational forecasts and/or hindcasts of water level, currents, waves, wind and atmospheric pressure
- NOAA water level observations from nearby stations to calibrate water level
- Spotter buoy to calibrate wave height
- Validation will be used to assess the model skill at reproducing accurate data at Mile Beach



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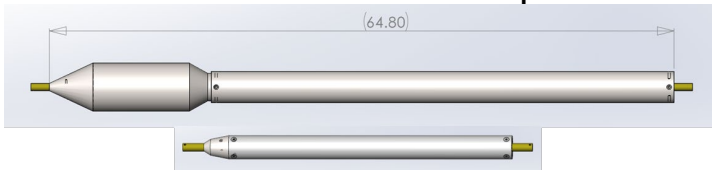
Results to Date

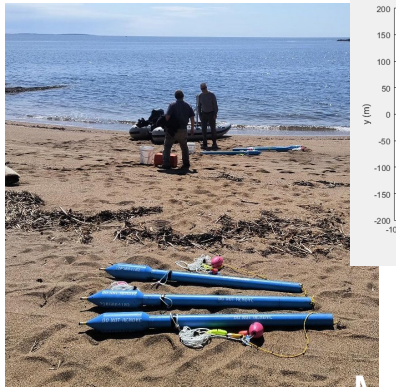
- MMU Fabrication
  - Historical use of 2.25”, 3.5” and 5” training rockets
    - Focused on 2.25” and 5” rockets based on descriptions of most items recovered

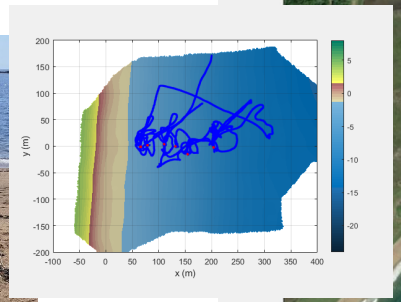


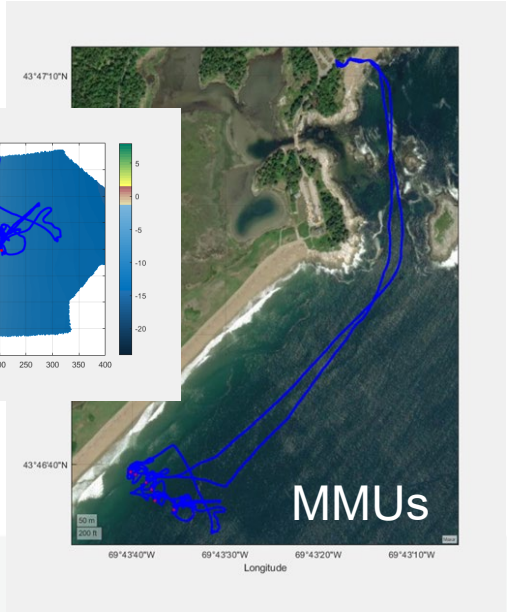
  - Constructed 16 seeds thus far (8 each type) to known parameters (length, caliber, weight)
  - Integrated two acoustic tags for tracking via ASV or diver pinger locator
    1. Integrated into nose cone
    2. Suspended above munition with float and graduated line to monitor burial depth

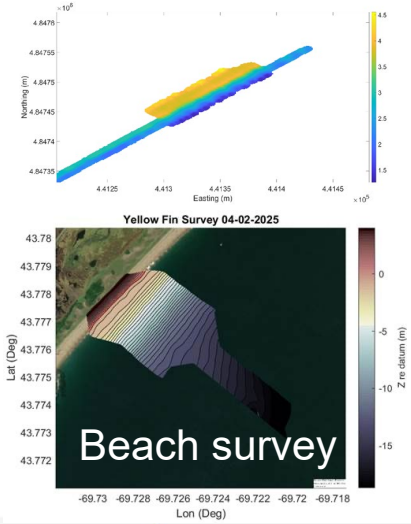
Results to Date

- Reid State Park Deployment
  - Spotter wave buoy (15.6 m depth @ N 43.77473, W 69.72339)
  - MMUs (6)
  - Beach Survey









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Results to Date

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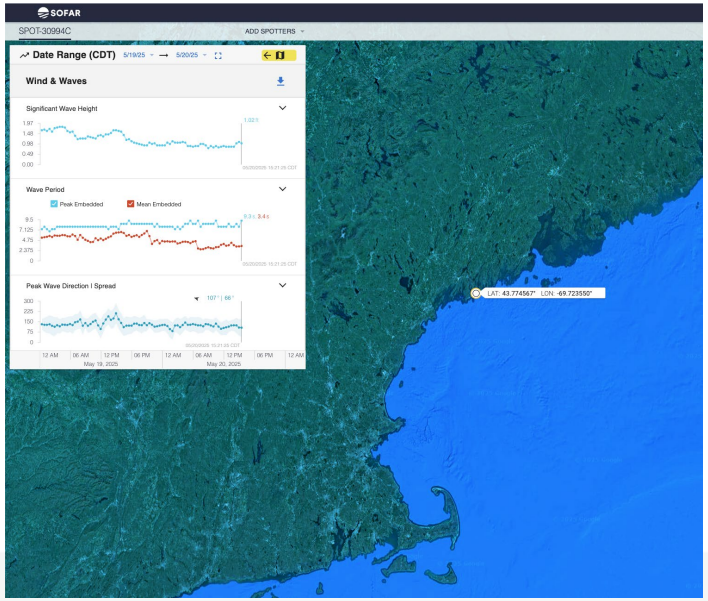
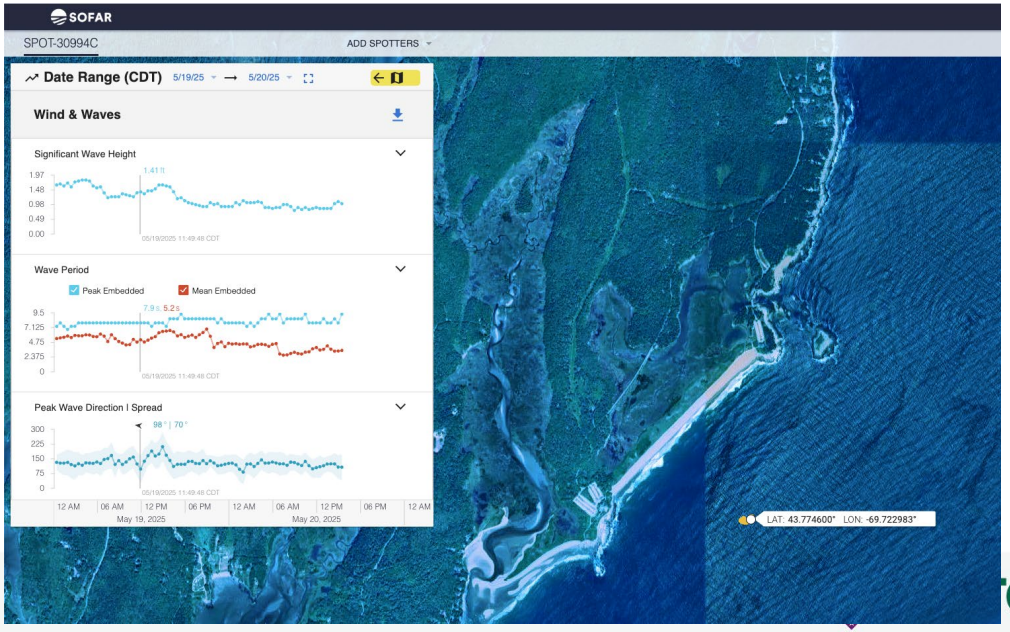
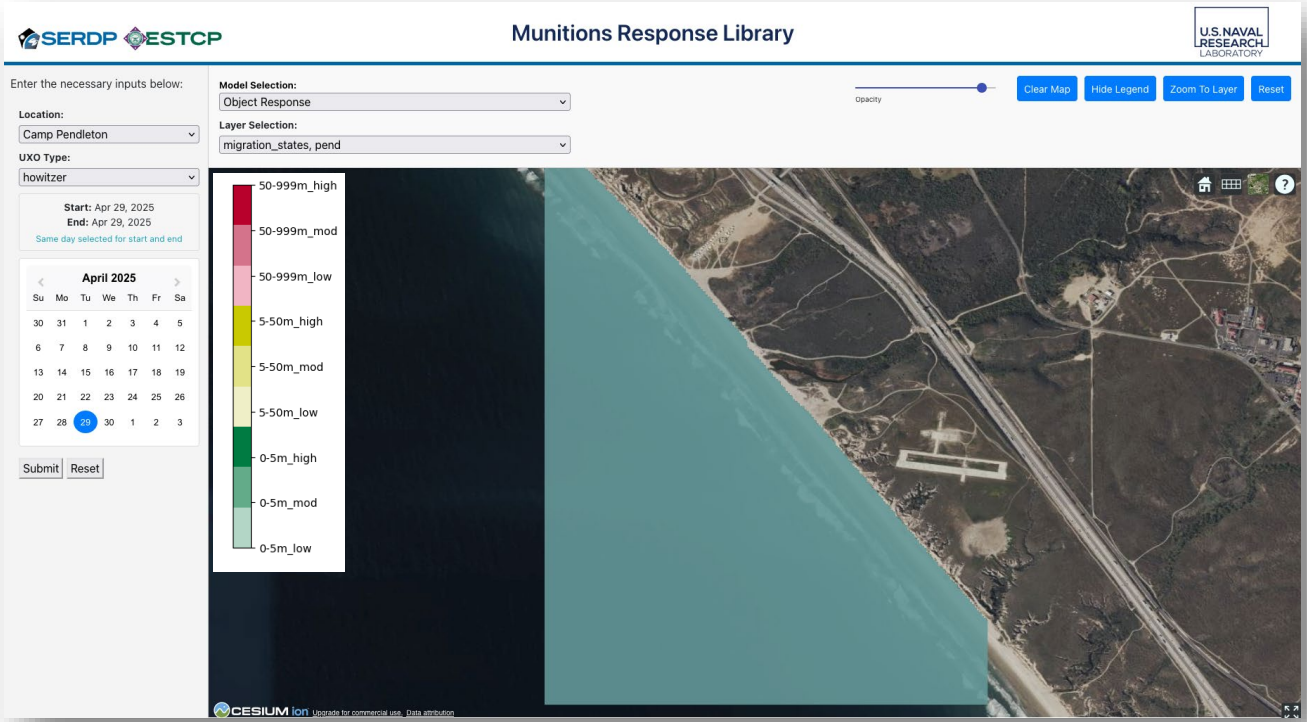




Results to Date

- MRL Web UI
  - Waves/currents
  - Sediment Mobility
  - Object response
- Object response
- Shows model forecast output
- Runs UnMES for a specific date, sediment type, and time



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Results to Date

- UnMES Validation in Senegallia, Italy – ESTCP Seed Project

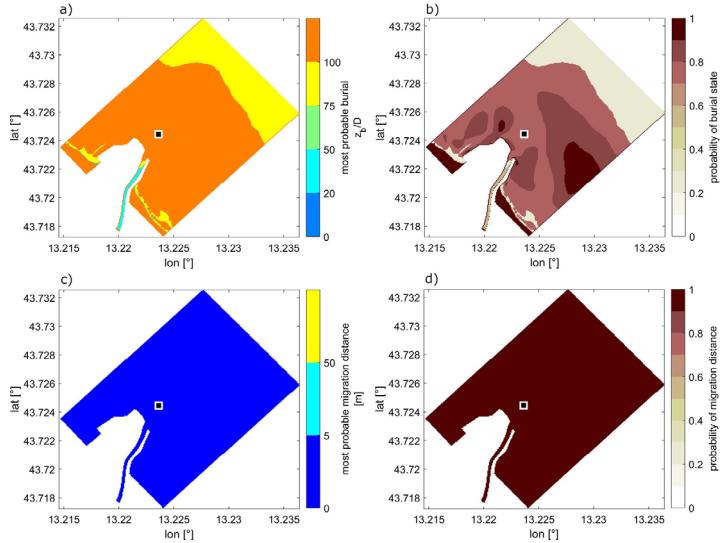


Fig. 15. UnMES predictions for the Naval5_38 UXO at the peak of the forcing (January 7th, 10:00). The black square indicates the location where the objects were deployed during the test at sea (S). UnMES predicted a 75% probability of full burial of the object (panels a, b) and a 100% probability for less than 5 m of migration (panels c, d), in matching what was observed in the field.

Estuarine, Coastal and Shelf Science 320 (2025) 109297

Baldoni, A., Lorenzoni, C., Penko, A. M., Postacchini, M., Melito, L., Scaradozzi, D., & Brocchini, M. (2025). Munitions mobility and burial in a microtidal estuary. Estuarine, Coastal and Shelf Science, 320(109297), 109297. https://doi.org/10.1016/j.ecss.2025.109297

Issues

- Demonstration delayed several months due to permitting and modification to meet state of Maine requirements
- Lost a main developer due to hiring freeze – reductions in workforce

Next Steps

- Complete Maine Demo model
- Maine demo/UnMES Validation
- Project Final Report – 30 SEP 25

Technology Transfer

- MMU protocols transferred to USACE for future deployments
- Web-based tool to view environmental information on demonstration sites
- Web UI to run interactive model
- Setup at each Demonstration Site

Technology Transfer

- Production of a Final MRL Demonstration System
  - Implement UnMES updates
  - Test system's retrieval of wave and current forcing
  - Build database repository in back-end and front-end data access
  - Write-up and post documentation on processes and procedures
  - Provide documentation for site manager MRL demo at specific sites

BACKUP MATERIAL

MR21-5207: Munitions Response Library for Site Management

Performers: *Allison Penko et al.*
U.S. Naval Research Laboratory

Technology Focus

- *Development of a model and database repository for access to environmental information needed to manage MRS and FUDS*

Demonstration Site

- *Internet portal with repository and and usage guidance*

Demonstration Objectives

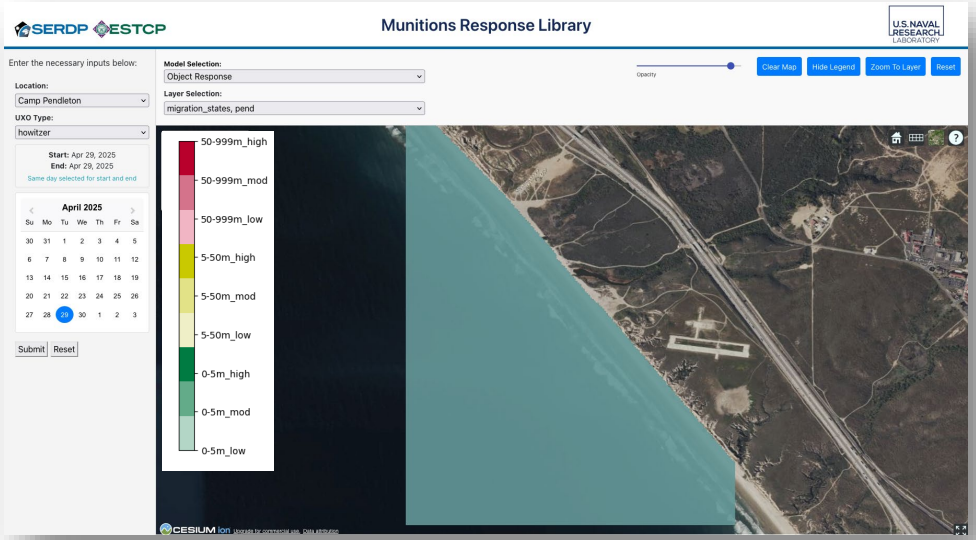
- *Solicit feedback from end users on repository usability*

Project Progress and Results

- *Back-end repository and tests completed, database started, front-end GUI prototype*

Implementation Status

- *Initial end-user coordination planned before end of FY, follow-on project focuses on direct feedback from users at demo sites.*



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Plain Language Summary

- We are developing a web-based tool that allows for scientists to upload their numerical capabilities to be versioned in a code repository and data to be visualized and analyzed.
- The code will be examined, tested, optimized, and put through implementation tests to ensure proper usage.
- The data will be QA/QC'd, standardized, and stored appropriately for ease of use.
- We will include documentation and training demos to allow for optimal use.

Action Items

Project final report including guidelines and configuration management of the MRL
Pending

Deliverable: Final Report

Action Type: Subtask

- Due Date: 3/30/2025 Proposed Date: 9/29/2025 Overdue 51 days

With the many changes in both workforce and data dissemination framework this quarter, as well as the push of the Maine deployment, we are requesting a proposed date to allow for testing of the MRL in Maine

Impact to DoD Mission

- The establishment of a community standard repository for site management and remediation related models and data will ultimately reduce costs. We anticipate that different sites will require different types and amounts of maintenance and remediation; however, we expect our internet portal to have resources that will benefit every site manager dealing with underwater contamination of UXO. Without our proposed standardization of models and data, each site manager would be left to execute and defend management and remediation decisions individually without the best practices and acceptance criterion that our effort will provide.

Publications

Baldoni, A., Lorenzoni, C., Penko, A. M., Postacchini, M., Melito, L., Scaradozzi, D., & Brocchini, M. (2025). Munitions mobility and burial in a microtidal estuary. Estuarine, Coastal and Shelf Science, 320(109297), 109297. https://doi.org/10.1016/j.ecss.2025.109297

Billings, W. Z. & Simeonov, J. (In prep). Poroelastic modeling of momentary liquefaction: Review and improvements. NRL Technical Report.

Billings, W. Z., Dohner, S. & Simeonov, J. (2024). Estimating the contribution of seafloor sediment flux to local in-situ suspended sediment concentrations over time. AGU Fall Meeting, Washington DC [poster].

Billings, W. Z. & Simeonov, J. (2024). Applying Bayesian inversion methods to determine the in-situ coefficient of consolidation via a poroelastic model. AGU Fall meeting, Washington DC [poster].

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- Klammler, H., Penko, A. M., Staples, T., Sheremet, A. & Calantoni, J. (2021). Observations and modeling of wave-induced burial and sediment entrainment: Likely importance of degree of liquefaction. JGR Oceans, 126, e2021JC017378. DOI: 10.1029/2021JC017378.

Additional Slide(s) for High-Quality Photos

Acronym List

Acronym	Meaning
2D	Two-Dimensional
AoI	Area of Interest
API	Application Programming Interface
BAA	Broad Agency Announcement
CAC	Common Access Card
COAMPS	Coupled Ocean Atmosphere Mesoscale Prediction System
COTS	Commercial Off The Shelf
DoD	Department of Defense
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
FY	Fiscal Year
GPS	Global Positioning System
MBE	Mobility, burial and exposure
MC	Monte Carlo
ME	Maine
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MMU	Mobility Monitoring Unit
MR	Munitions Response
MRL	Munitions Response Library
MRS	Munitions Response Sites
MRUE	Munitions Response in Underwater Environments
NCOM	Navy Coastal Ocean Model
NRL	Naval Research Laboratory
PM	Program Manager
PNNL	Pacific Northwest National Laboratory
ROC	Receiver Operator Characteristic
RMSE	Root Mean Square Error
S	Specific Gravity
SERDP	Strategic Environmental Research and Development Program
SON	Statement of Need
UnMES	Underwater Munitions Expert System
USBL	Ultra Short Baseline Survey
USV	Unmanned Surface Vessel
UXO	Unexploded Ordnance
WW3	Wave Watch 3 Model