Optical Detection and Classification of Military Munitions Underwater

MR23-9001

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Creare LLC

In-Progress Review Meeting

August 13, 2025

Project Team

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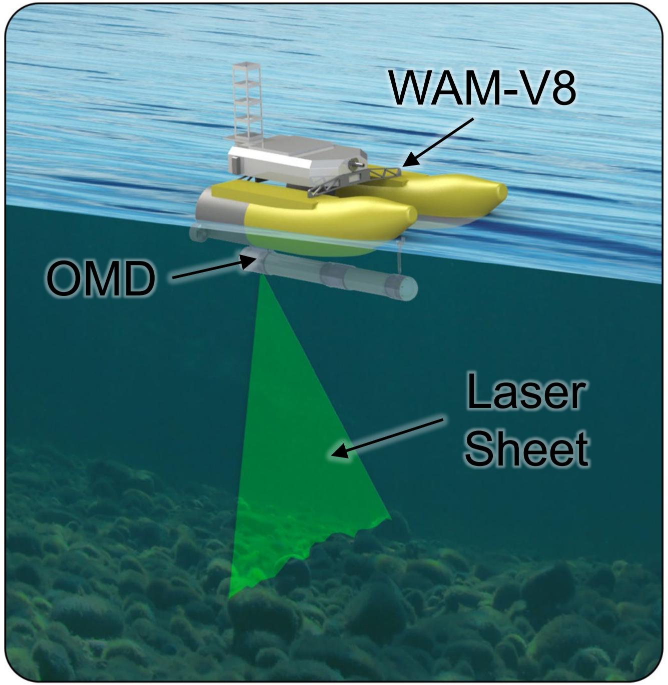
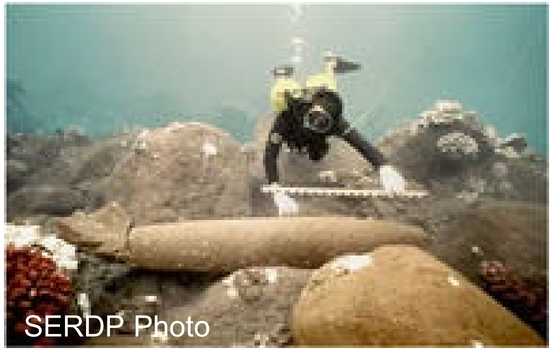
BLUF: Creare Optical Munitions Detector (OMD)

- We are Evaluating an OMD for Optical Detection and Classification of Unexploded Ordinance (UXO) in Shallow Water
  - ➢OMD is deployed underwater
    - Keel of unmanned surface vehicle (USV)
    - Unmanned Underwater Vehicle (UUV)
    - Human-operated vehicles
  - ➢The OMD demonstration test will establish and demonstrate the performance of optical detection
  - ➢We have developed an optimized OMD prototype for the demonstration test
  - ➢We have developed a test plan



Problem Statement

- Many DoD sites have shallow-water UXO contamination
- Recreation often occurs in shallow waters (swimming, fishing)
- Exposed munitions are a particular concern
  - Highest likelihood of interaction with public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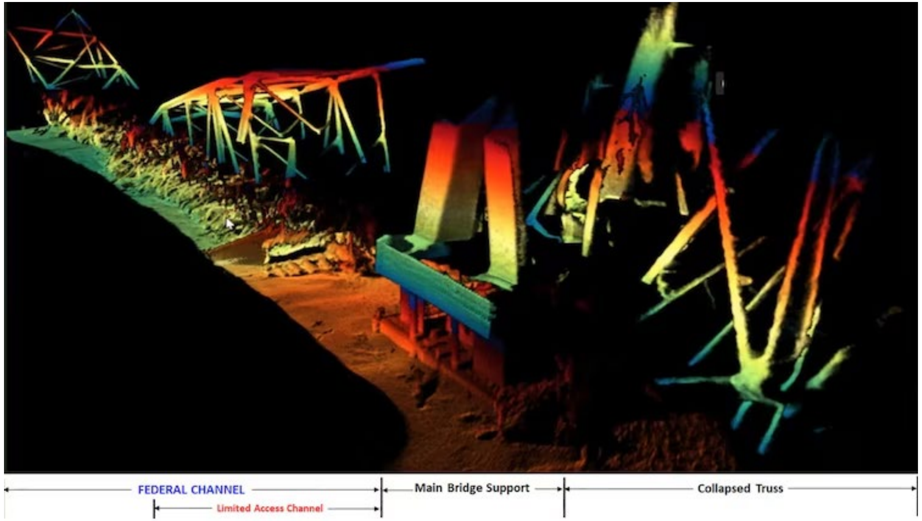
Technical Objective

- Existing Methods for UXO Detection and Classification have Gaps
  - ➢Acoustic and electromagnetic methods
  - ➢Limited resolution and ability to detect targets against background clutter
- Optical Detection
  - ➢High resolution
  - ➢Preserves optical contrast, color, size, and shape
  - ➢Optical images are naturally intuitive
    - – Well suited for automatic target detection (ATD)



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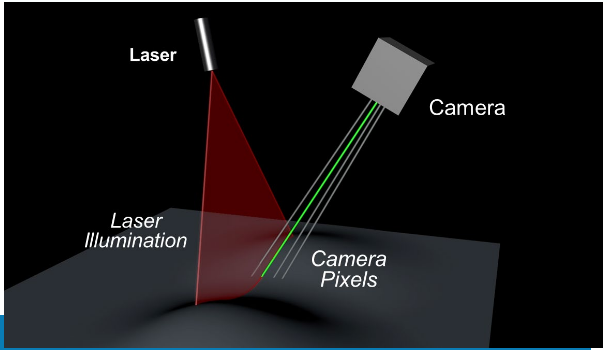
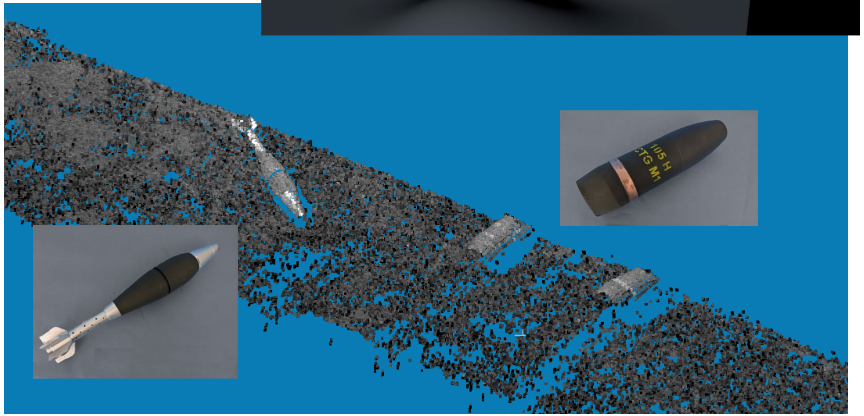
OMD Technical Approach: SLI

- Current OMD Applies Two Optical Methods
  - We may down-select in the future to one method
- Structured Light Imaging (SLI)
  - Also known as laser scanning
  - Laser line “painted” on bottom
  - 3D point cloud triangulated by offset camera
  - Provides high-resolution 3D point cloud
    - Monochromatic (no color)





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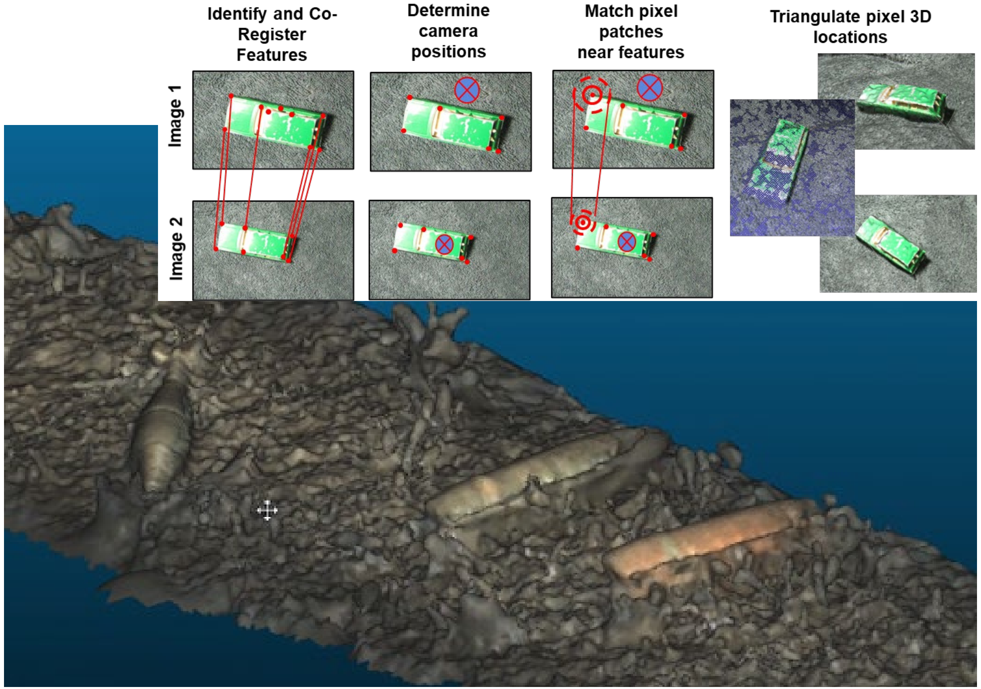
OMD Technical Approach: SfM

- Structure from Motion (SfM)
  - ➢ Second 3D imaging method
  - ➢ Bottom is illuminated using a white light and imaged from multiple views as the vehicle moves
  - ➢ Features in subsequent images are registered to triangulate 3D locations
    - – Requires knowing the relative position of the camera in each image
  - ➢ Produces high-resolution 3D image of the bottom
  - ➢ Preserves color and contrast
- SLI and SfM use Different Cameras and Illumination



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Project Technical Approach

OMD Upgrades

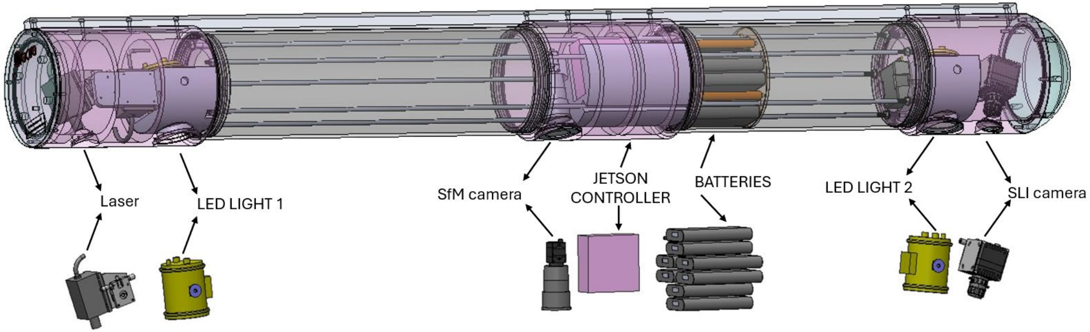
Demo Planning

Execute Tabletop Demonstration

Analysis and ATD

Reporting

- OMD Upgrades
  - Complete redesign and analysis for demonstration test
  - Cameras, illumination, enclosure, power/thermal management, SBC
- Demonstration Planning
- ATD: Automatic Target Detection



Results to Date

- OMD Upgrades
  - Components: Acquired, Unit Testing Begun
  - Electrical System: Design Complete and Components Acquired
  - Mechanical Design: Acquired
- Test Planning
  - Visited Site in January 2025
  - Testing Planned for Coconut Island Hawaii in Early 2026
  - Draft of Test Plan Submitted

Results to Date: Component Selection

Cameras

SLI Camera (FLIR)

- High Speed (162 Hz)
- Monochrome, 5 MPx

SfM Camera (FLIR)

- Low Speed (1 Hz)
- High Resolution (24 MPx)
- Color

Computation

Jetson Orin AGX

- High Speed USB and Ethernet for Image Grabbing
- M.2 Port for High-Speed Image Saving
- Powerful CPU and GPU for on board processing

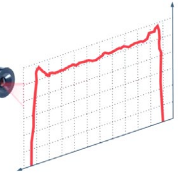
Illumination

Osela Industrial Line Laser

- High Power (3 W)
- Excellent Wavelength for Ocean Transmission (450 nm)

Constellation 120 E (2x)

- Short Flash Duration (< 1 µm)
- High Luminous Flux (> 22,000 lm)



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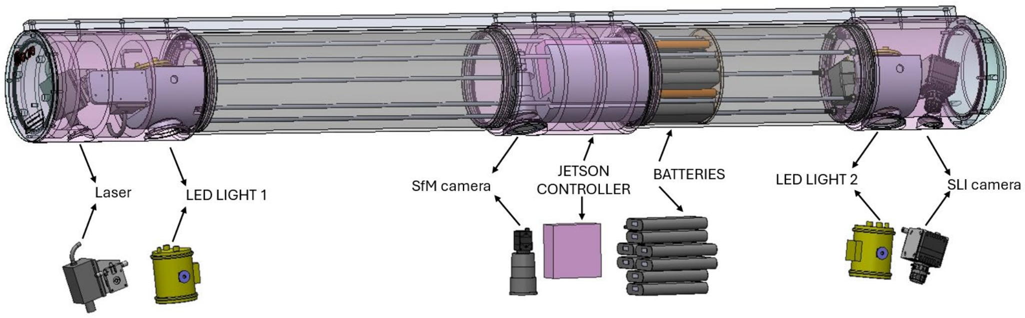
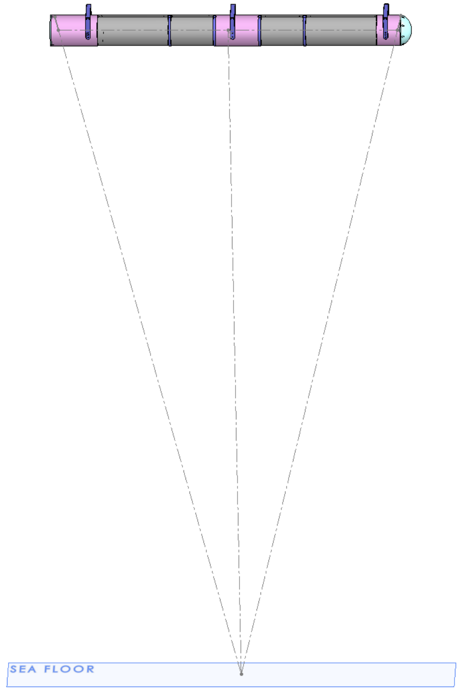
OMD System Configuration

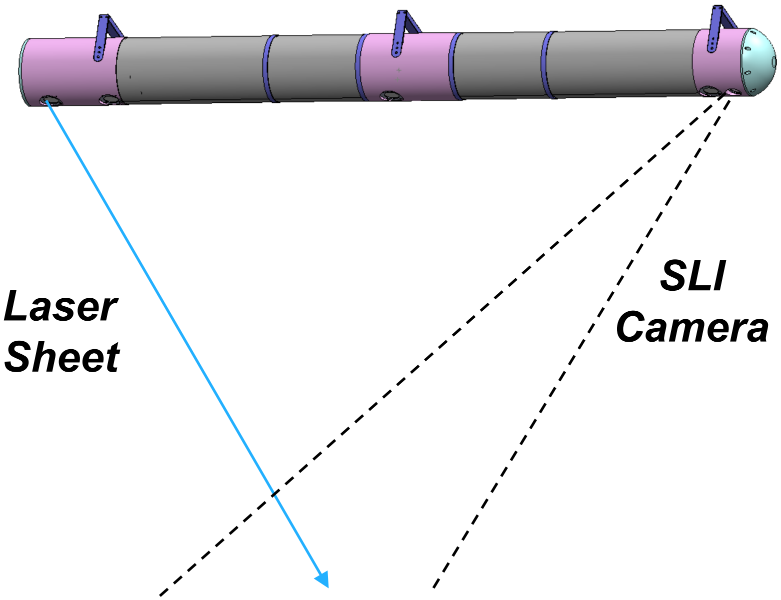
- OMD Packaged in a Cylindrical Enclosure
- Three Modules
  - Aft module contains SLI laser and SfM flash
  - Middle module contains SfM camera and processor
  - Fore module contains SLI camera and SfM flash



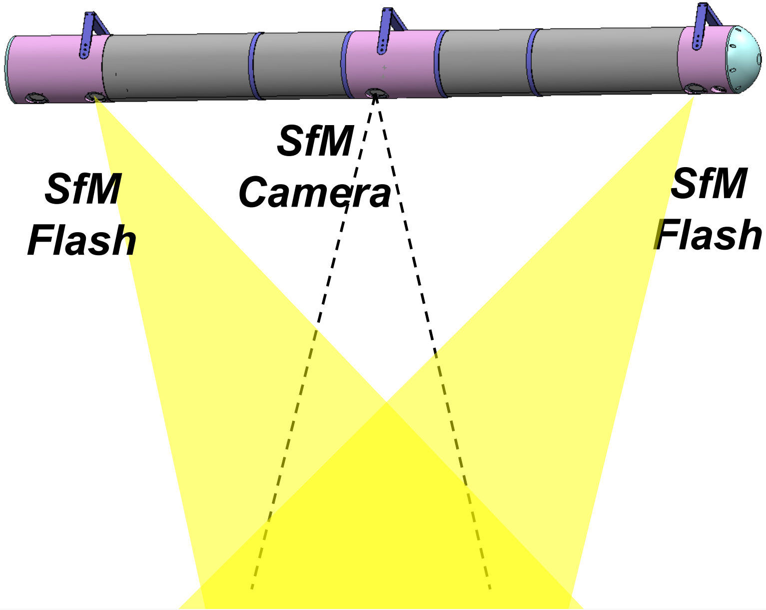


OMD Optical Configuration

- SLI Optical Configuration



- SfM Optical Configuration



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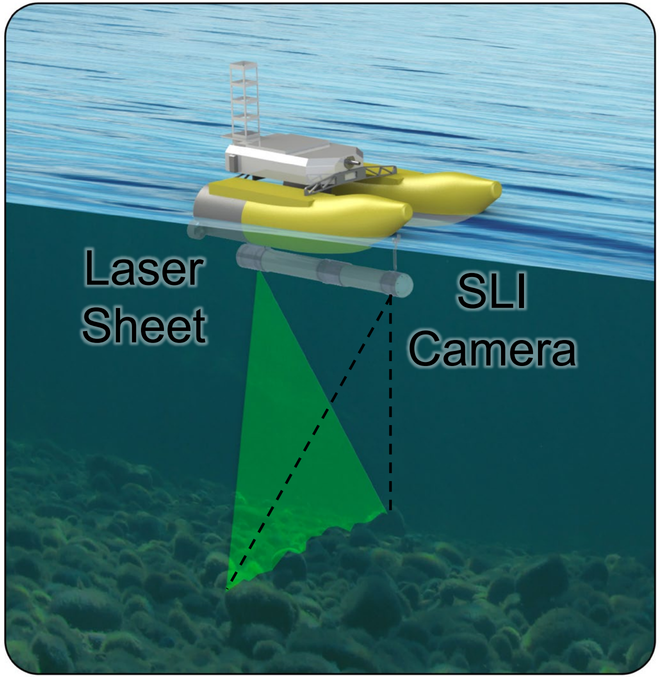
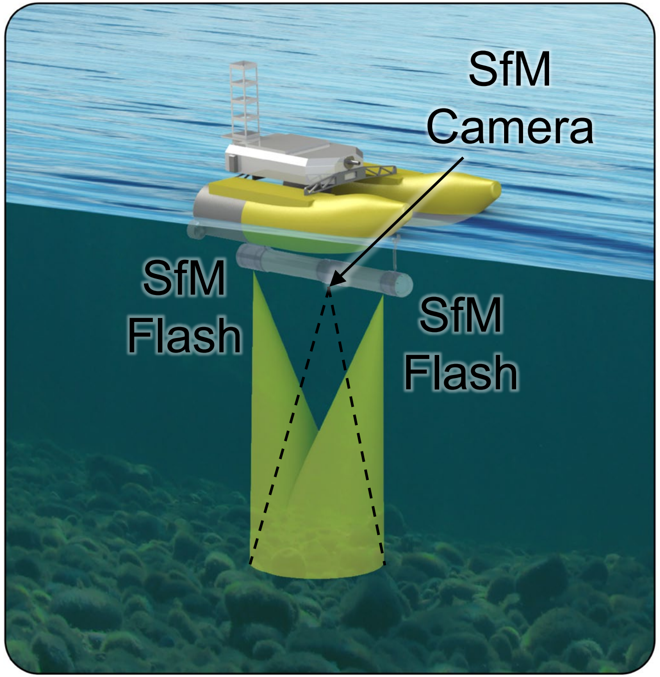
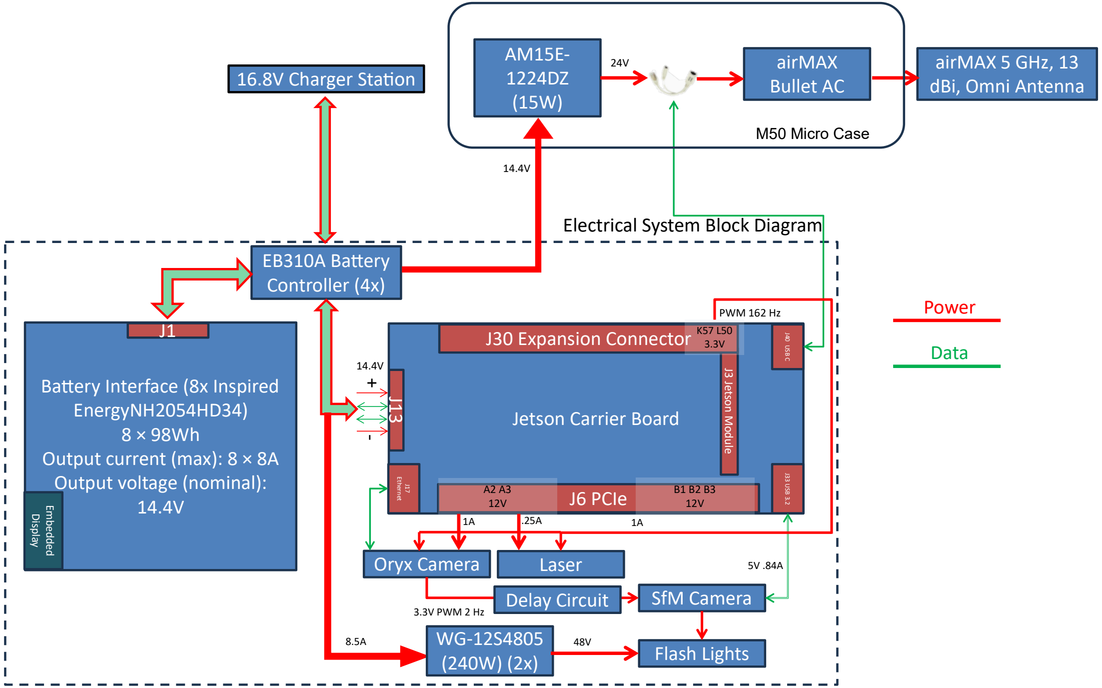
OMD Optical Configuration





Electrical Design

- Integration with ARL RTK GNSS
  - Connect to rover GPS
  - Same system used for ground truth
  - Offset integrated into position
- Control
  - We'll control the system with a wireless router recommended by ARL



Demonstration Test Planning (1)

- Baseline plan is to test at the UXO Test Bed Site Coconut Island Hawaii
  - ➢Calm sea state
  - ➢Clear water
  - ➢Best case for optical
- WAM-V Autonomous Surface Vehicle
  - ➢OMD mounted on submerged 8020 frame
  - ➢Operated by ARL during test

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Demonstration Test Planning (2)

- Requested munition deployment sizes for the engineering test are 20 mm, 40 mm, 60 mm, 81 mm, 105 mm, and 155 mm
- Control zone to include all munition types and clutter objects, locations shared with Creare
- Blind zone to include all munition types and clutter objects, locations help from Creare

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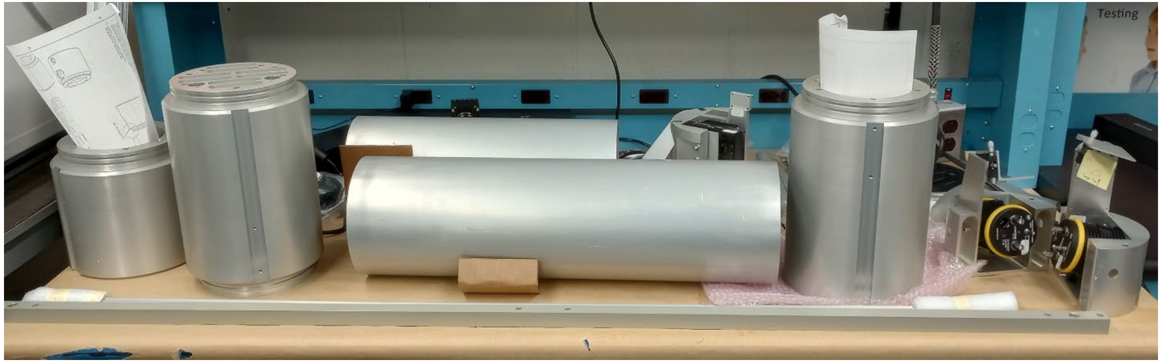
Performance Objectives

Performance Parameter	Test Success Criteria	System Success Criteria
Bathymetric Resolution and Usable Bathymetric Area	• > 62,500 pts/m^2 • Point cloud coverage for > 80% of area surveyed for water depths 2.3–5.8 m	• > 62,500 pts/m^2 • Point cloud coverage for > 95% of area surveyed for water depths 1.9–6.1 m
Detection of Emplaced Objects	• > 75% prob. of detection within 1 m (≥ 40mm) inside a region where point cloud is generated • > 60% prob. of detection within 1 m (≥ 20 mm) inside a region where point cloud is generated	• > 95% prob. of detection within 1 m (≥ 40 mm) inside a region where point cloud is generated • > 90% prob. of detection within 1 m (≥ 20 mm) inside a region where point cloud is generated
Classification of Detected Objects (TOI vs. clutter)	• > 85% correct classification of detected TOI's (≥ 40 mm) • > 75% correct classification of detected TOI's (≥ 20 mm)	• > 95% correct classification of detected TOI's (≥40 mm) • > 90% correct classification of detected TOI's (≥20 mm)
False Alarm Rate Estimate	• < 1 false alarm per 3,000 m^2	• < 1 false alarm per 10,000 m^2
Area Coverage Rate	• > 3000 m^2/hr	• > 4000 m^2/hr
Location Accuracy	• Relative average distance between objects accurate to within 1 m • > 75% of relative distances between objects accurate to within 0.5 m	• Relative average distance between objects accurate to within 0.5 m • > 75% of relative distances between objects accurate to within 0.25 m

Next Steps

- Build and Test Prototype OMD
- Execute Demonstration Test
- Data Analysis
  - ➢Automatic Target Recognition



Why Two Imaging Modalities?

- SfM maintains color information and may be more useful for many missions
  - But is more sensitivity to water clarity due to incoherent illumination
  - Also is more computationally intensive
- SLI works better in turbid water
  - Will function over a wider range of real-world conditions
  - Fast and less computationally intensive
  - Better spatial resolution (~1 mm depending on depth)
- The Demonstration Test Will Allow us to Compare Methods Head-to-Head

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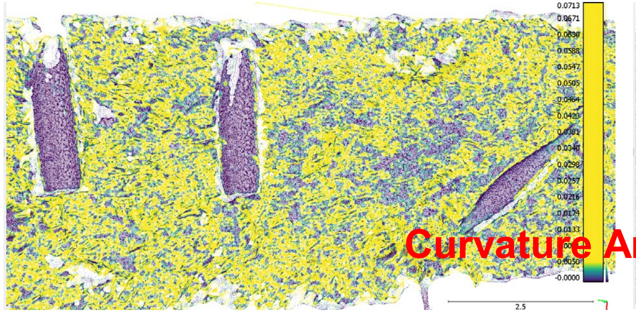
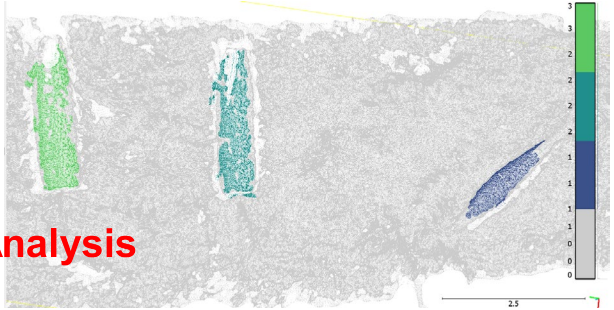
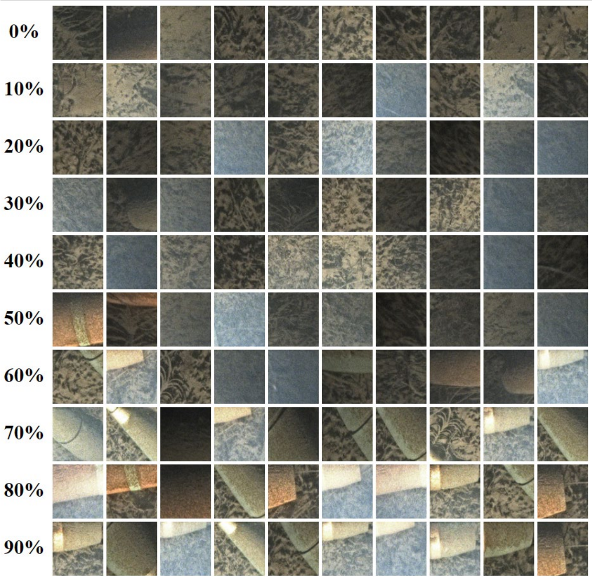
Automatic Target Detection (ATD)

- Image Data are Well Suited for ATD
  - Different ATD methods for SLI and SfM
- SLI Data can be Analyzed for Curvature
- SfM Images Well Suited for DCNN ATD
  - Requires training set for DCNN
  - Need for underwater UXO image data set for training



Curvature Analysis





DCNN Probability "Man Made"

Technology Transfer

- Endpoint of Current Project
  - OMD demonstration in controlled/optimal conditions
- Next Steps
  - Field testing at site with real UXO
  - OMD revisions
    - Down-select optical method
  - DCNN analysis
    - Develop training set

Issues

- Additional funding required to assemble and test prototype
- Delays in scheduling the demonstration test site location and date

BACKUP MATERIAL

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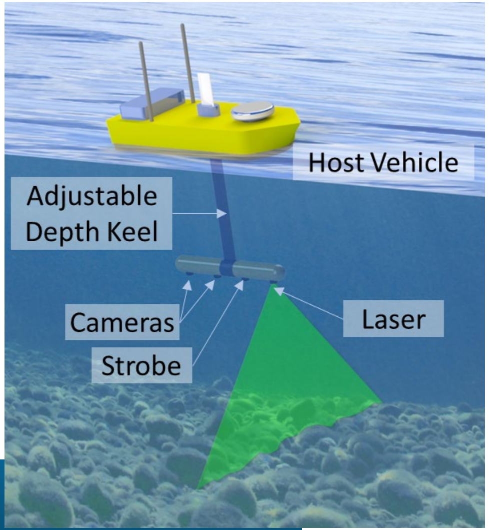
Performers
- Dr. Darin Knaus and Chris McKenna, Creare LLC
- Dr. Jules Jaffe, Scripps Institute of Oceanography

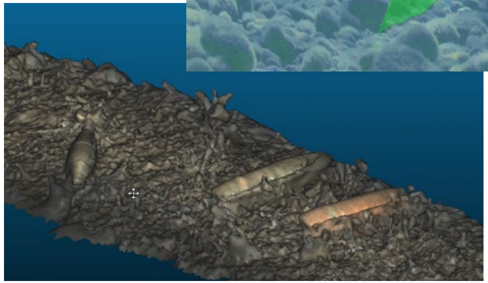
Technology Focus
- *We are developing and demonstrating an optical method for detecting UXO underwater*
- *Optical methods are well suited for automated detection methods but are also subject to water turbidity/clarify and can only see exposed UXO*

Research Objectives
- *The goals of the current program are to revise the OMD design and develop a new prototype suitable for a demonstration test*
- *Then, we will execute a demonstration test at UXO test site*
- *Finally, we will use the data collected to develop and demonstrate automated target detection (ATD) methods*

Project Progress and Results
- *Developed optical model of the OMD*
- *Selected upgraded OMD components*
- *Developed an integrated OMD system design*

Technology Transition
- *Next steps include field testing and OMD enhancements*





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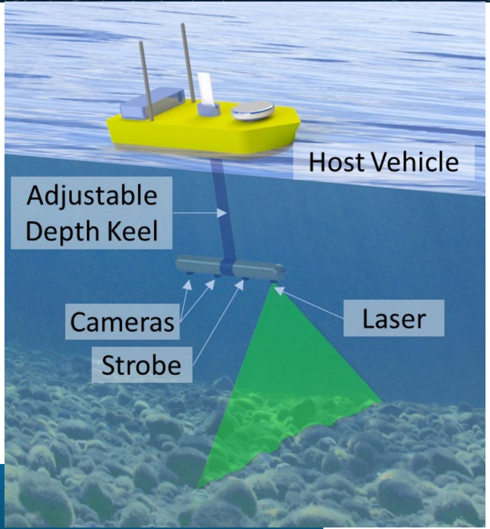
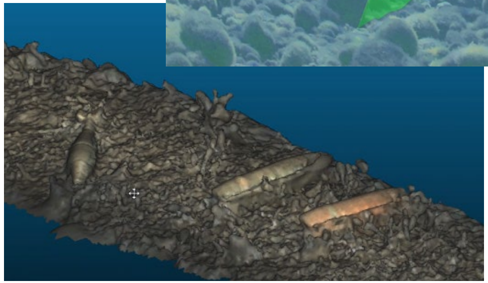
Plain Language Summary

- The Optical Munitions Detection (OMD) technology can be used to systematically locate underwater UXO for mitigation or removal
  - ➢Based on autonomous vehicles and automatic target detection (ATD) for rapid detection and analysis
- Our approach is optically-based and differs from conventional UXO detection methods
  - ➢High resolution 3D data with color and contrast
  - ➢Well-suited for advanced image ATD methods such as Deep Convolution Neutral Network (DCNN) methods
- If successful, the OMD technology will provide a new tool for underwater UXO mitigation

Impact to DoD Mission

- Many Current or Former DoD Sites Contain Underwater UXO are a Hazard to the Public
  - Conventional technologies and methods for UXO detection do not translate well to underwater UXO, or are very labor intensive/time consuming
  - We are developing a new technology for optical underwater UXO detection
  - The technology will enable automated detection using autonomous surface vehicles and AI methods for image analysis
  - The outcome will be a new tool for efficient mitigation of underwater UXO from DoD sites





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Action Items

Demonstration Plan	Submitted	6/15/2025
July 2025 QPR	Submitted	7/15/2025
July 2025 MFR	Pending	8/15/2025
Data Quality Metrics	Pending	9/30/2025
Curvature Uniformity	Pending	9/30/2025
DCNNs	Pending	9/30/2025
Algorithm Train and Test	Pending	9/30/2025
October 2025 QPR	Pending	10/15/2025
Final Report	Pending	2/20/2026
High Level Summary	Pending	3/20/2026
Stakeholder Presentation	Pending	3/20/2026
Worksheet 22	Pending	3/20/2026
Lessons Learned	Pending	3/20/2026
Technology Guide	Pending	3/20/2026
Critical Findings Sheet	Pending	3/20/2026

Publications

- None to date

Acronym List

▪ UXO	Unexploded Ordinance
▪ OMD	Optical Munitions Detector
▪ SLI	Structured Light Imaging
▪ SfM	Structure from Motion
▪ DCNN	Deep Convolution Neural Network
▪ ATD	Automatic Target Detection
▪ ASV	Autonomous Surface Vehicle