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Optical Detection and Classification of Military Munitions Underwater

MR23-9001

Drs. Darin Knaus and Chris McKenna

Creare LLC

In-Progress Review Meeting

January 14, 2025

Project Team

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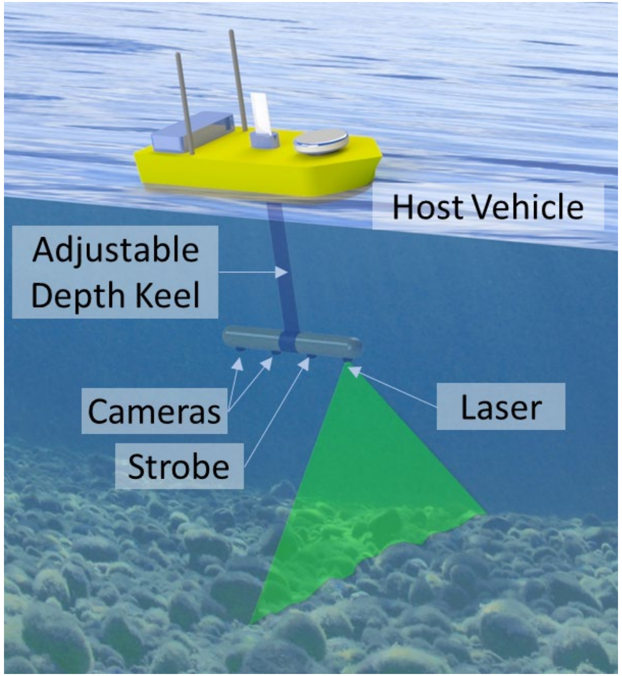
BLUF: Creare Optical Munitions Detector (OMD)

- We are Evaluating an OMD for Optical Detection and Classification of Unexploded Ordinance (UXO) in Shallow Water
  - ➢OMD deployment is agnostic
    - – 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



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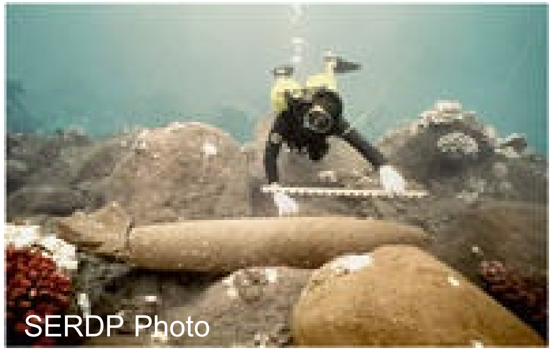
Problem Statement

- 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


SERDP Photo


osd.mil Photo

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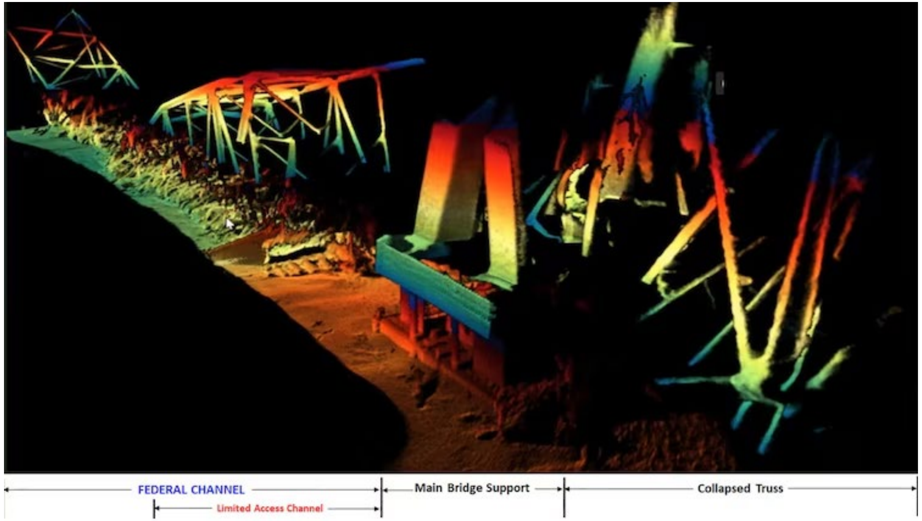
Technical Objective

- 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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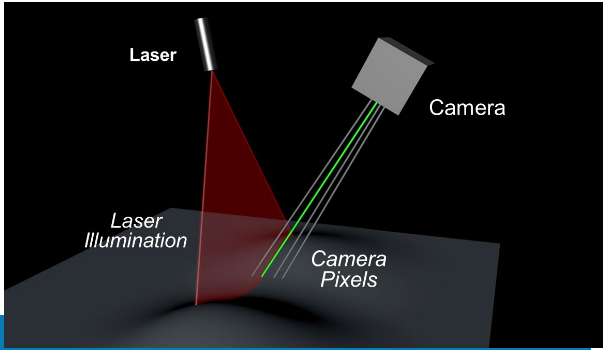
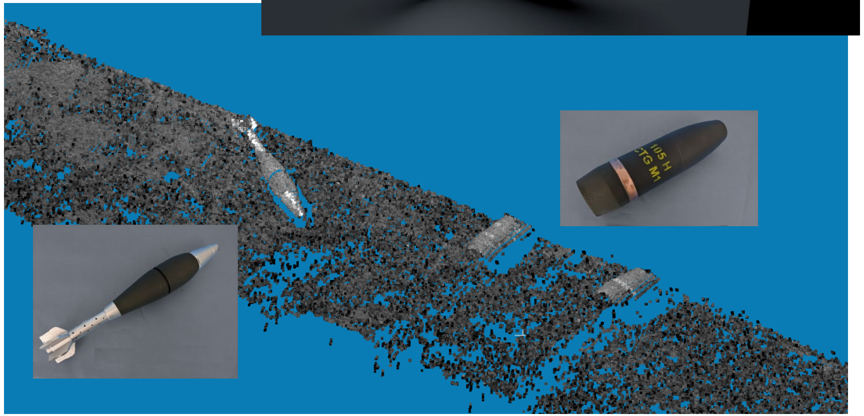
OMD Technical Approach: SLI

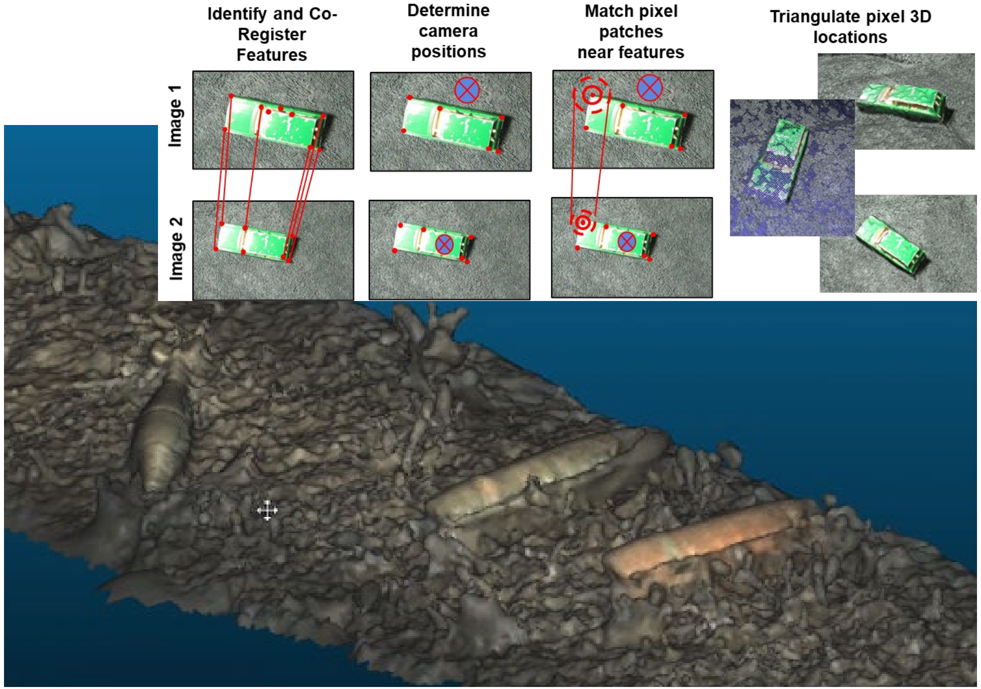
- Current OMD Applies Two Optical Methods
  - We may down-select in the future to one method
- Structured Light Imaging (SLI)
  - Also known as laser scanning
  - Laser line “painted” on bottom
  - 3D point cloud triangulated by offset camera
  - Provides high-resolution 3D point cloud
    - Monochromatic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





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

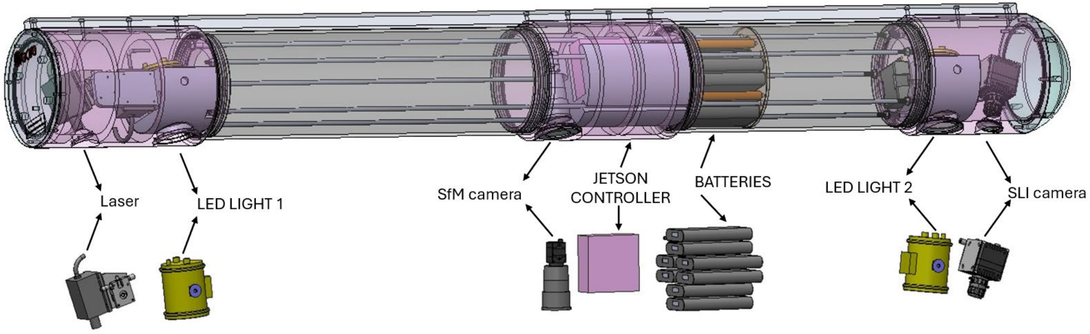
Demo Planning

Execute Tabletop Demonstration

Analysis and ATD

Reporting

- OMD Upgrades
  - Cameras, illumination, enclosure, SBC
- Demonstration Planning
  - Coconut Island Hawaii
- ATD: Automatic Target Detection



Results to Date

- OMD Upgrades
  - Components: Acquired, Unit Testing Begun
  - Electrical System: Design Complete, Parts Purchased
  - Mechanical Design: Design Complete
- Test Planning
  - Visiting Site in January
  - Testing Planned for Coconut Grove in Feb/Mar
  - Draft of Test Plan in Review

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

Constellation 120 E(2x)

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

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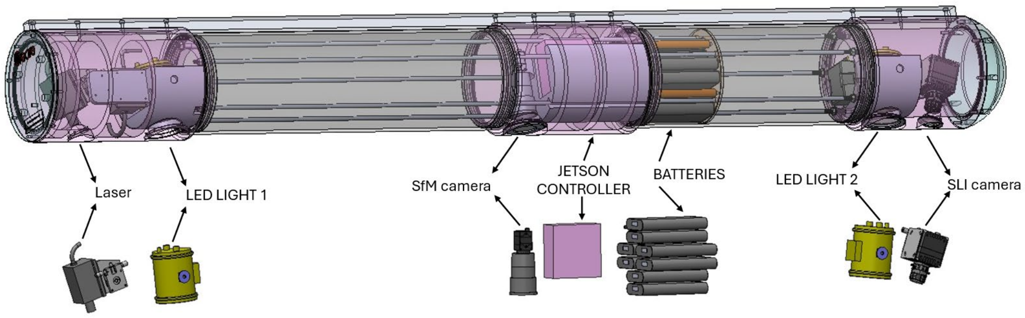
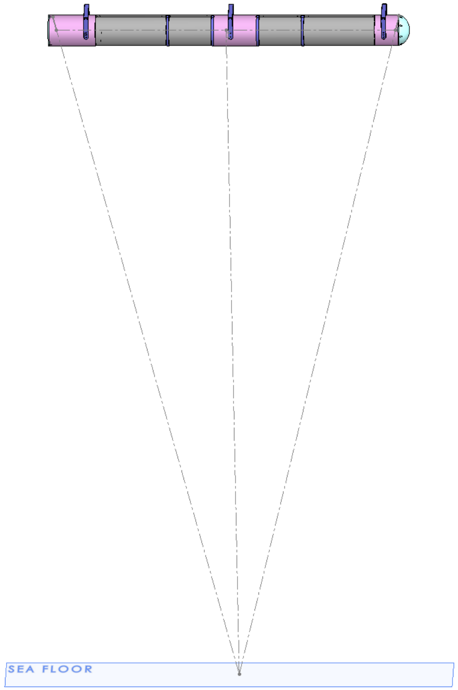
OMD System Configuration

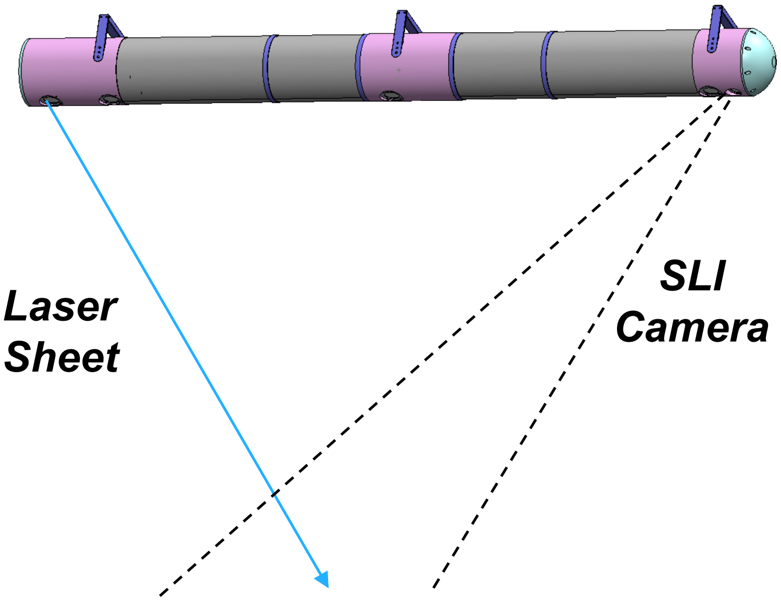
- OMD Packaged in a Cylindrical Enclosure
- Three Modules
  - Aft module contains SLI laser and SfM flash
  - Middle module contains SfM camera and processor
  - Fore module contains SLI camera and SfM flash



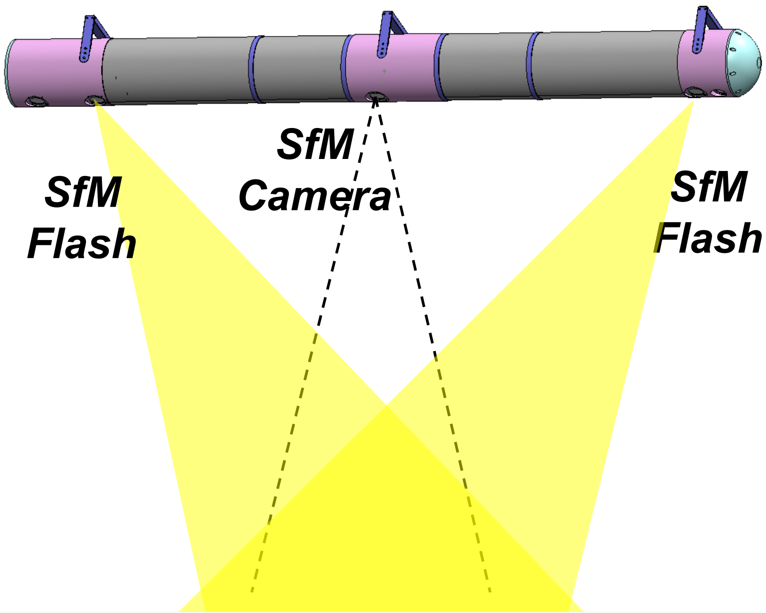


OMD Optical Configuration

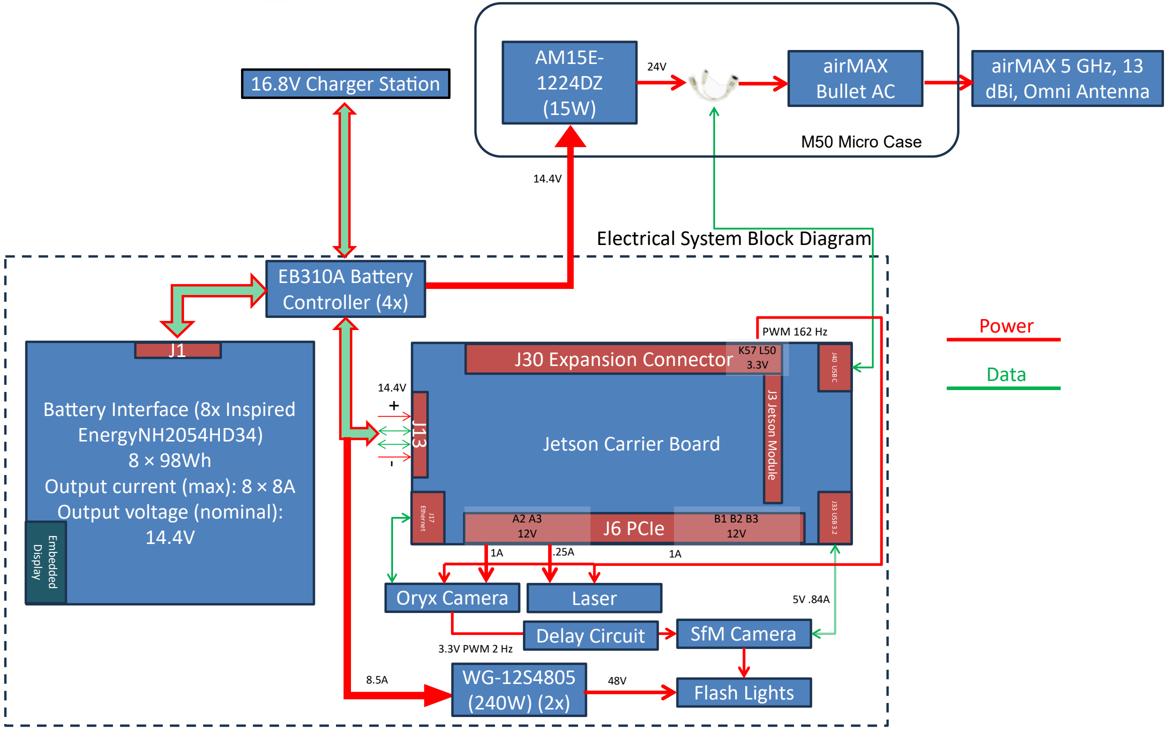
- SLI Optical Configuration



- SfM Optical Configuration



Electrical Design



Demonstration Test Planning

- 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 8020

Demonstration Test Planning

- Requested munition deployment sizes for the engineering test are 20 mm, 40 mm, 60mm, 81mm, 105mm, and 155mm
- 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

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

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Next Steps

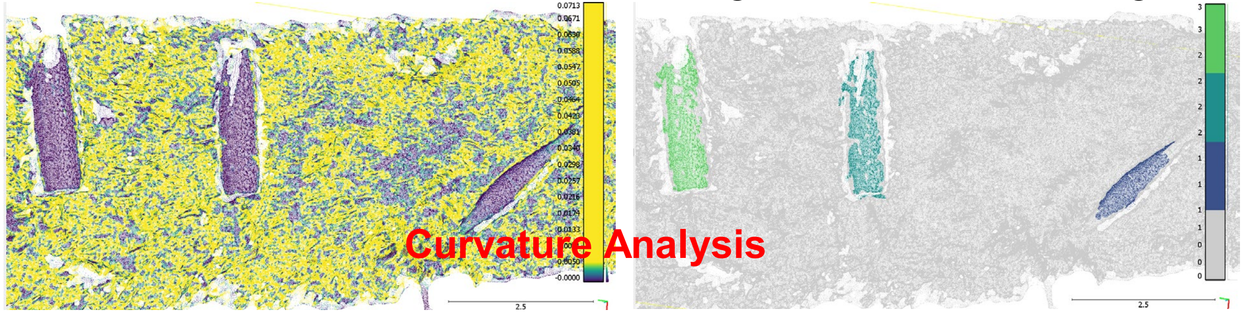
- Hawaii Site Visit
- Build and Test Prototype OMD
- Execute Demonstration Test
- Data Analysis
  - Automatic Target Recognition

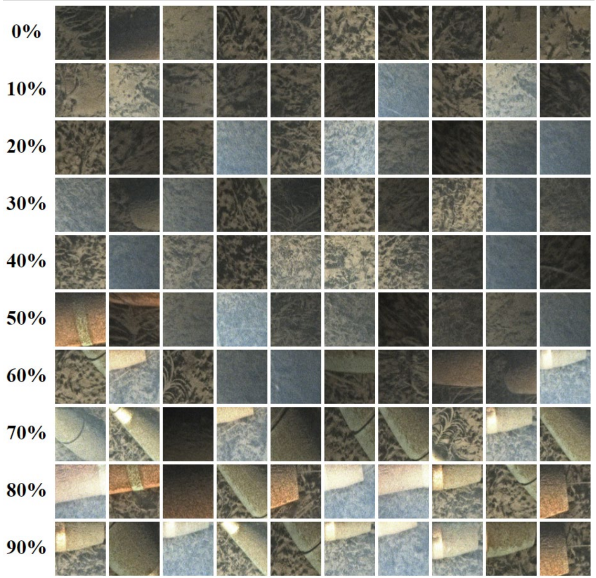
Why Two Imaging Modalities?

- 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

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





DCNN Probability "Man Made"

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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

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Issues

- Test date needs to be decided
- Additional funding required for substantial data analysis

BACKUP MATERIAL

MR23-9001: Optical Detection and Classification of Military Munitions Underwater

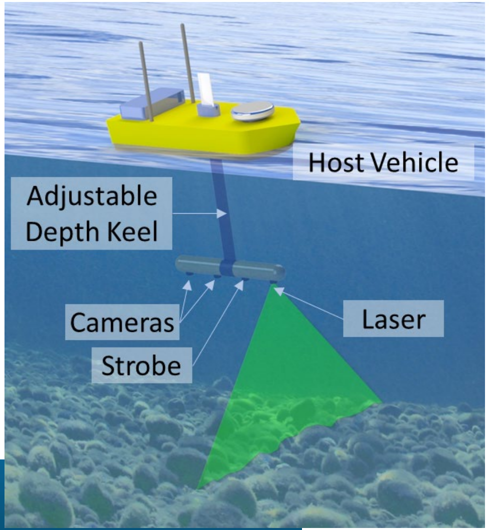
Performers
- Dr. Darin Knaus and Chris McKenna, Creare LLC
- Dr. Jules Jaffe, Scripps Institute of Oceanography

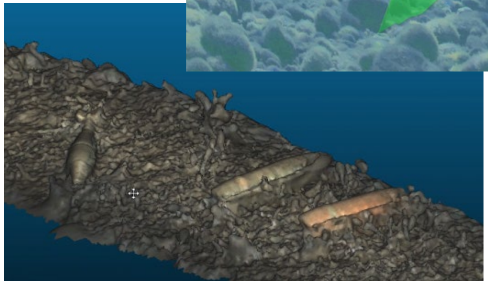
Technology Focus
- *We are developing and demonstrating an optical method for detecting UXO underwater*
- *Optical methods are well suited for automated detection methods but are also subject to water turbidity/clarify and can only see exposed UXO*

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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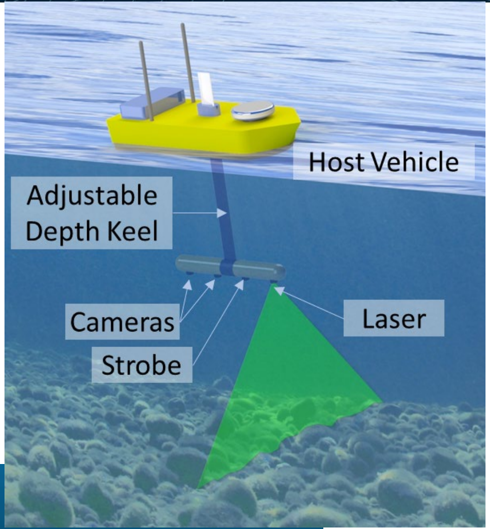
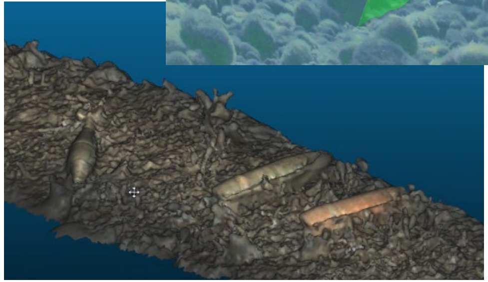
Plain Language Summary

- 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 that's is 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

Create Project Plan	Closed	2/28/2024
FY23 Expenditure Plan	Closed	3/5/2024
Professional Headshot	Closed	3/29/2024
March MFR	Closed	4/15/2024
April 2024 QPR	Closed	4/15/2024
April MFR	Closed	5/15/2024
Laser Illumination	Closed	5/31/2024
SfM Illumination	Closed	5/31/2024
SfM Cameras	Closed	5/31/2024
May MFR	Closed	6/15/2024
July 2024 QPR	Pending	7/15/2024
Data Collection System	Pending	7/31/2024

Shakedown testing	Pending	7/31/2024
Site Visit	Pending	7/31/2024
Test Planning	Pending	7/31/2024
Contrast Target	Pending	7/31/2024
Vehicle Integration Plan	Pending	7/31/2024
Demonstration Plan	Pending	7/31/2024
Demonstration Testing	Pending	9/30/2024
Banner Image	Pending	10/31/2024
Data Quality Metrics	Pending	1/31/2025
Curvature Uniformity	Pending	1/31/2025
DCNN	Pending	1/31/2025
Algorithm Train and Testing	Pending	1/31/2025
Final Report	Pending	2/28/2025

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