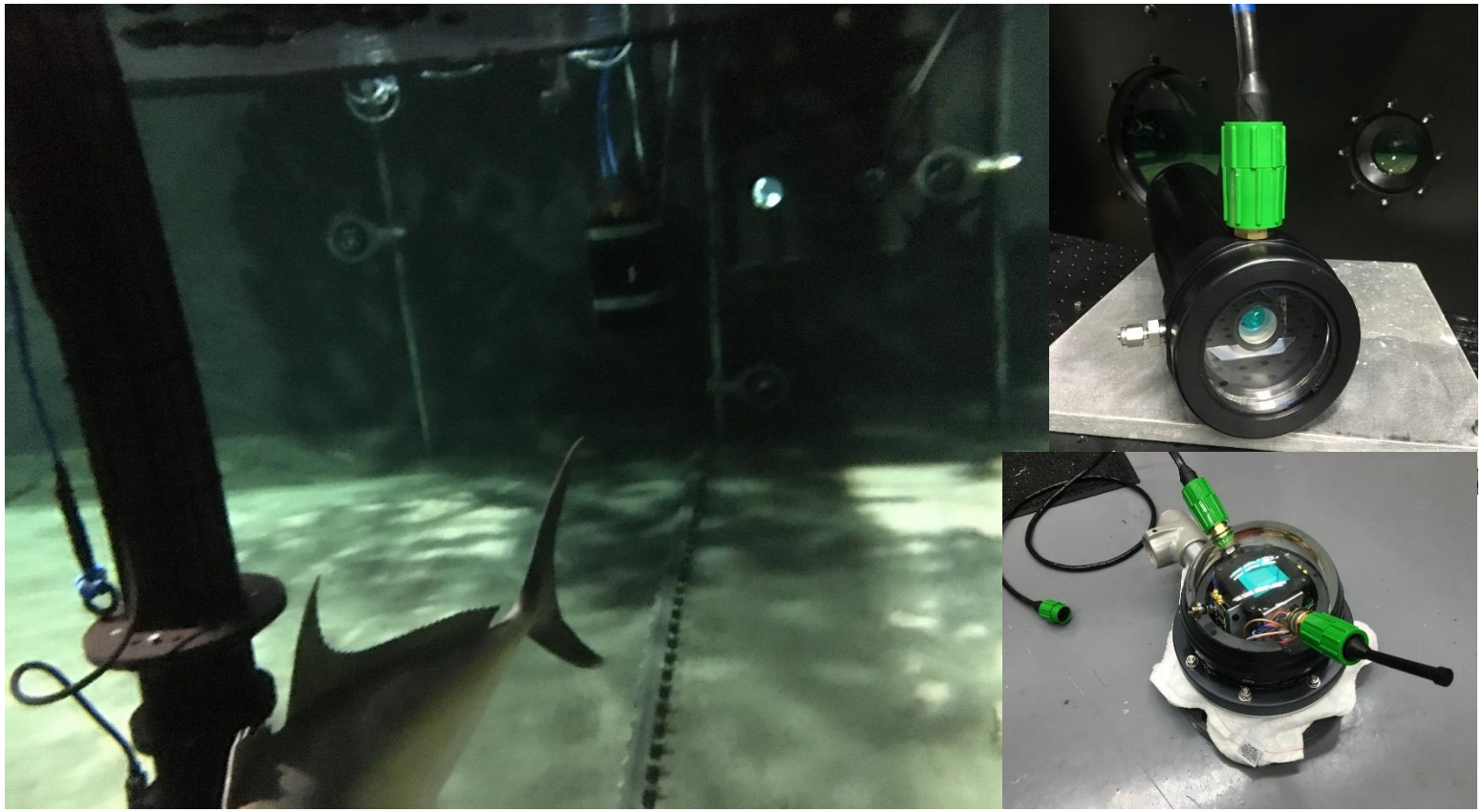

Unobtrusive Multi-static Serial LiDAR Imager (UMSLI) for Wide-area Surveillance and Identification of Marine Life at MHK Installations

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Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Unobtrusive Multi-static Serial LiDAR Imager for Wide-area Surveillance and Identification of Marine Life at MHK Installations:

Using three-dimensional photo-realistic monitoring of a volume of water around energy generation equipment coupled with automated marine life detection/classification, this project has provided a low-cost and effective tool for marine and hydrokinetic (MHK) site monitoring. This pulsed laser system is both eye-safe and invisible to marine life.

The Challenge: This project addresses the need for new instrumentation to capture marine life interaction with MHK devices for environmental baseline and operational project monitoring in extreme, high-energy, and often low-light conditions of MHK sites.

Partners: University of Florida (detection/classification software)
Battelle Memorial Institute (commercialization advisor)

Program Strategic Priorities

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for innovative MHK systems & components
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Project Strategic Alignment

Deployment Barriers

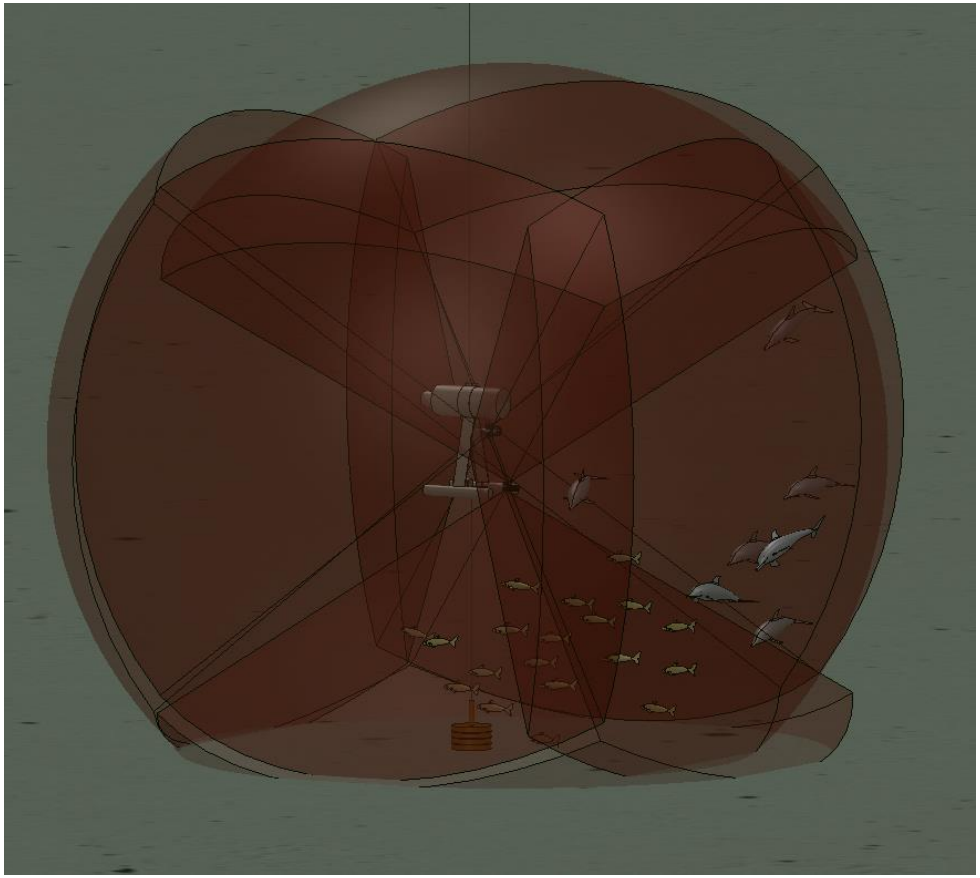
- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

The Impact

- This project will significantly reduce project lifecycle monitoring costs by improving animal interaction data quality over current options and reducing data processing overhead with a novel automated classification tool.
- The potential impact on the industry is that the costs and timelines associated with regulatory approval will be significantly reduced, accelerating commercial energy production.
- The final product of this project is a pre-commercial hardware/software tool which has been demonstrated in lab and field conditions.

Technical Approach

A group of strategically positioned red laser transmitters illuminate a complete volume around an MHK device. Receiver(s) reconstruct the illuminated volume and output imagery of the illuminated areas of interest. Sophisticated software based on machine learning techniques then attempts to classify targets based on visual and behavioral observations.



Test tank UMSLI images taken at 5-6 meters

Technical Approach

- Serial LiDAR imager using low average power red laser diodes, which are both eye safe and invisible to marine life.
- Operates in adaptive mode which projects a sparse grid of pulses with higher peak power for long-range detection (>10 meters) and at closer range (<5m) with high-resolution imagery
- System detection limit and Signal to Noise Ratio are superior to a camera, due to rejection of both backscattering component and ambient solar background
- Multiple wide-angle pulsed laser illuminators and single element detectors can be configured to cover an omnidirectional scene with much wider depth of field to a conventional camera, while also retrieving 3D features of targets
- Classification framework with novel classifier enables accurate identification of a variety of marine animals automatically
- Two-tiered monitoring architecture and watermarking-based data archiving and retrieval approach ensures major data reduction

Accomplishments and Progress

System has been designed (2015), constructed (2016), and lab tested (2016). Also received positive resource manager/regulatory agency support (2015).

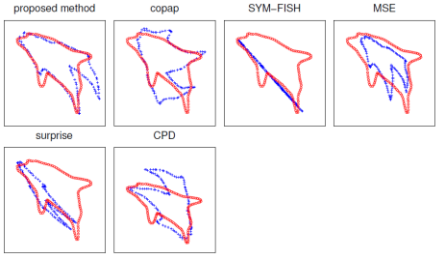
- First-ever demonstration of a marine life eye-safe monitoring tool that unobtrusively illuminates a volume of water to automatically classify animals and observe high-fidelity interaction with MHK equipment
- System has been demonstrated to be effective in low light and turbid conditions (common at MHK sites), while providing 3-dimensional information as well as photorealistic video catalog of animal behavior

Accomplishments and Progress

Successful Go/No-Go (May 2016) met or exceeded established performance metrics.

Hardware performance in clear and turbid water:

Turbidity level	Contrast Ratio	Contrast-Signal-Noise-Ratio (raw image)	Smallest Resolvable Bar
Clear water GOAL	0.7	15	1cm
Clear water RESULTS	**0.8**	**20**	**0.25cm**
> 4 beam attenuation lengths GOAL	0.2	8	2cm
> 4 beam attenuation lengths RESULTS	**0.3**	3.23 (processed: **8.5**)	**1cm**



Test tank data performance of the classifier indicate that various targets (amberjack, turtle, barracuda) **match templates with at least 94% similarity** and meet or exceed state-of-the-art algorithm performance.

Project Plan & Schedule

- Project initiated October 2014. Original planned completion was October 2016, but extended at no cost to March 2017
- All milestones and tasks completed on schedule
- No cost extension due to Go/No-Go modification processing (1 Quarter) time and to accommodate weather windows for final field demonstration tasks during winter months
- Originally scheduled 2015 Go/No-Go adjusted by DOE to 2016 (moved prior to field testing rather than prior to build and lab testing tasks)

Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$50k	$7.6k	$221k	$24k	$200k	$7.8k

- No major variances to project budget
- Approx. 90% of project budget expended to date
- With exception of cost share match provided by Florida Atlantic University, no additional external funds for project

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators:

University of Florida (classification and processing software development sub contractor)

Battelle Memorial Institute (advisory support during development of project to ensure compatibility with commercial tech transfer at project conclusion)

- ## Communications and Technology Transfer

Two conference papers and one journal paper submitted:

Z. Cao, J. C. Principe, B. Ouyang, F. Dalgleish and A. Vuorenkoski. (2015). 'Marine animal classification using combined CNN and hand-designed image features', Proc IEEE/MTS Oceans 2015, Washington DC, USA. October 20-24 2015. IEEE Online http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7404375

Z. Cao, J. C. Principe, B. Ouyang, F. Dalgleish, A. Vuorenkoski. (2016). "Information Point Set Registration for Shape Recognition", 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'16).

Z. Cao, J. C. Principe, B. Ouyang, F. Dalgleish, A. Vuorenkoski, B. Ramos, G. Alsenas, "Marine animal classification using UMSLI in HBOI optical test facility", Springer Multimedia Tools and Applications special issue on Machine Learning for RS Image Processing (In review).

Next Steps and Future Research

FY17/Current research: Final tasks to be completed include field demonstration and reporting. Milestones include Operational hardware performance results and analysis (3.3.1) and Software and database testing review (4.8.1).

Proposed future research: Future research includes further optimization of (1) detection efficiency, (2) field of view and range of detection, (3) level and diversity of taxonomic classification, (4) deployment duration, as well as (5) reduce production cost, and (6) optimize effectiveness in high energy tidal and wave energy site conditions.