ULTRA

Underwater Laser Telecommunications and Remote Access

DE-FE003187

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U.S. Department of Energy

National Energy Technology Laboratory

Carbon Management and Natural Gas & Oil Research Project Review Meeting

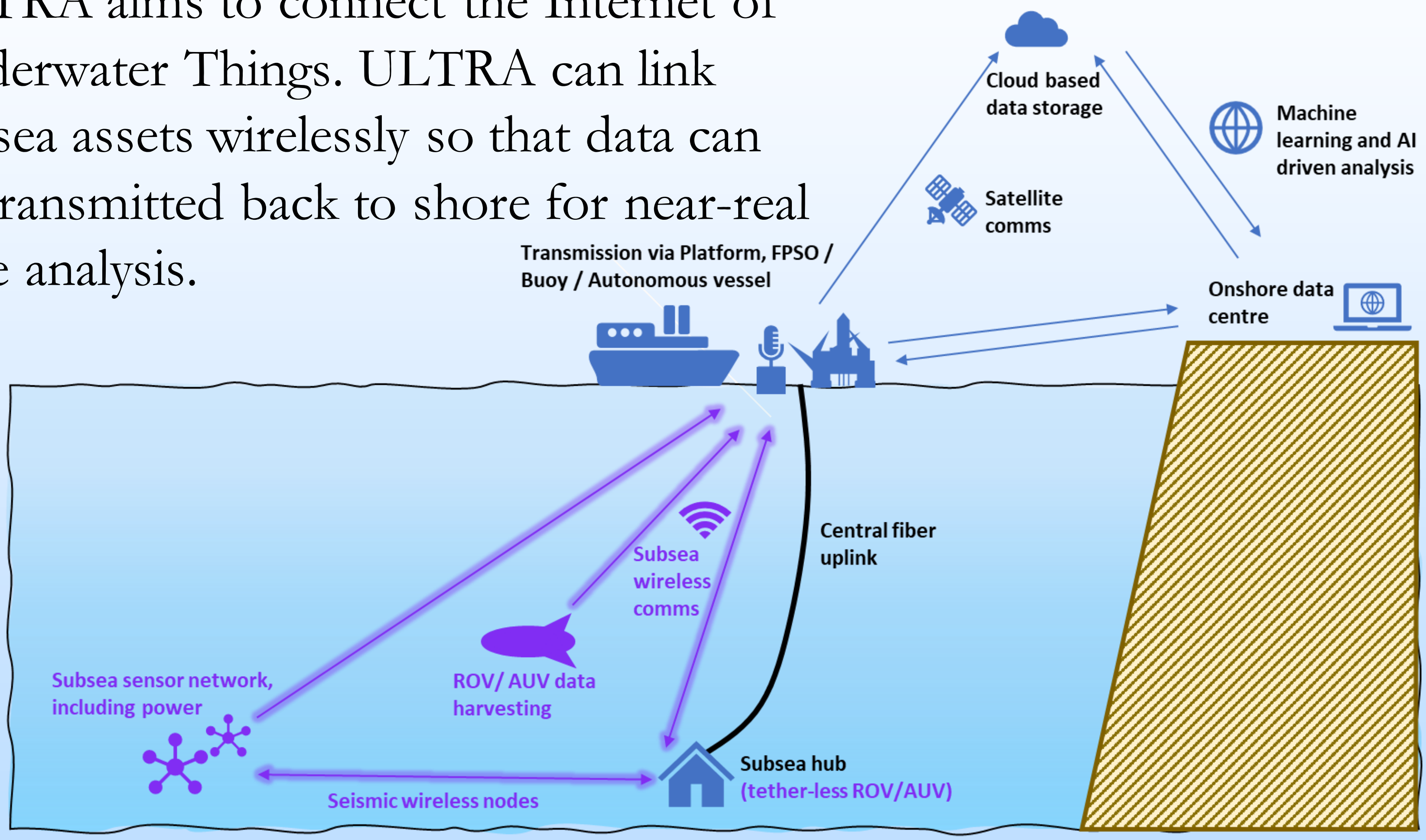
Virtual Meetings August 2 through August 31, 2021

Outline

- Approach and Background
- Current Technical Status
- Accomplishments
- Lessons Learned
- Project Summary and Next Steps

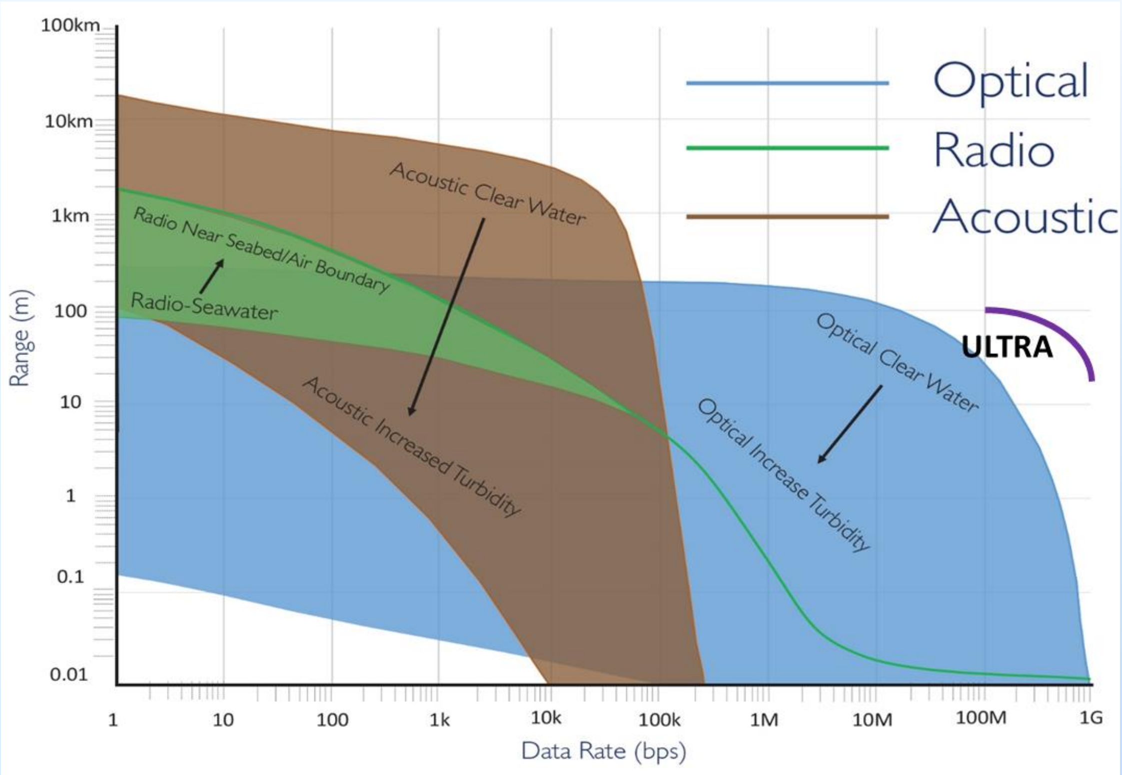
Approach

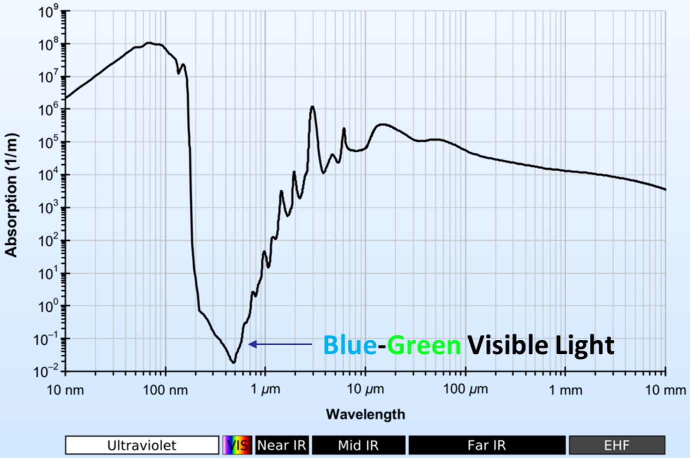
ULTRA aims to connect the Internet of Underwater Things. ULTRA can link subsea assets wirelessly so that data can be transmitted back to shore for near-real time analysis.

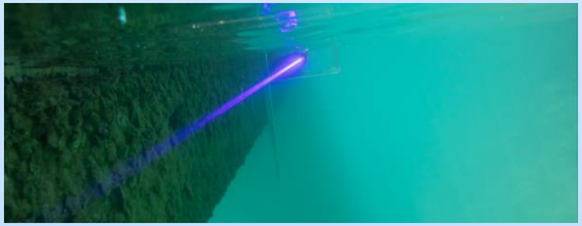


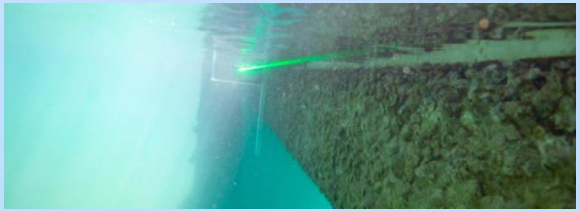
Background

- Data transmission through ocean water using a tight-beam, bi-directional, full duplex laser network interface.

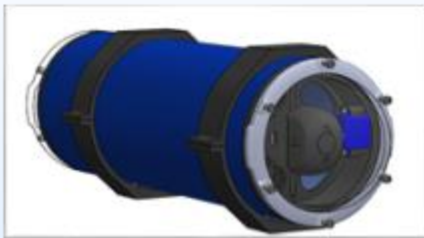






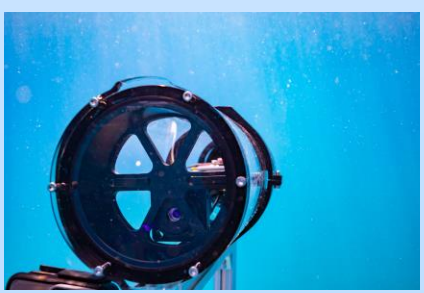


Technical Status Overview



ULTRA Module

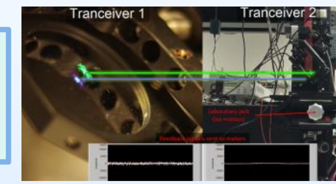
Marinization



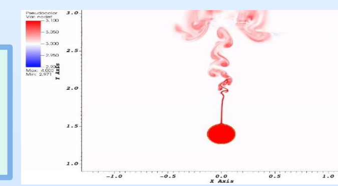
Optical Pointing

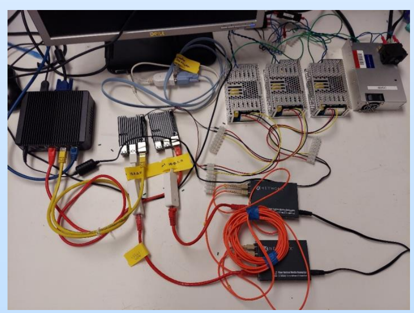
Target Acquisition

Beam Steering



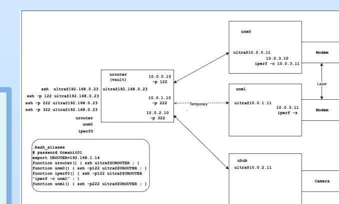
Environmental Modeling



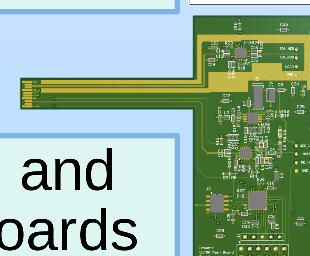


Electronics

Network Architecture

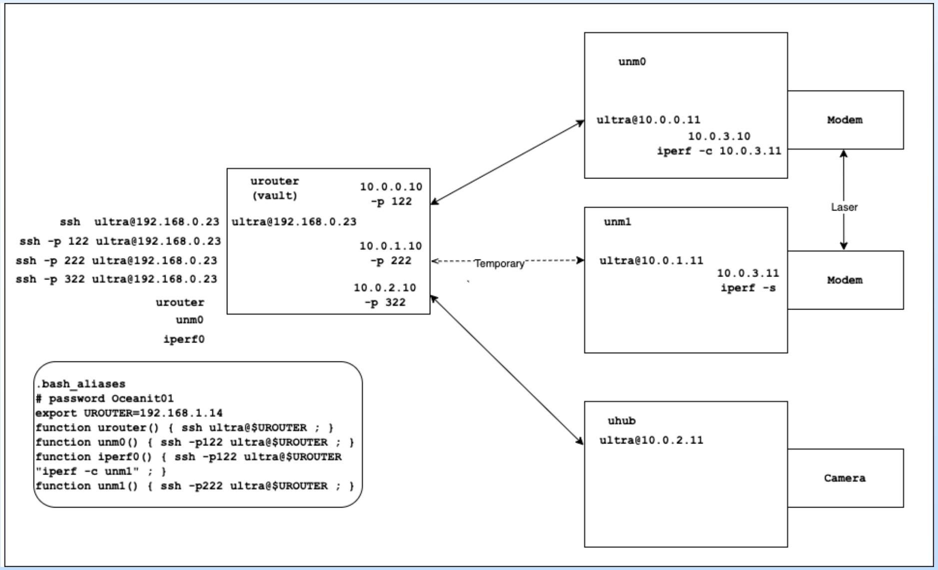


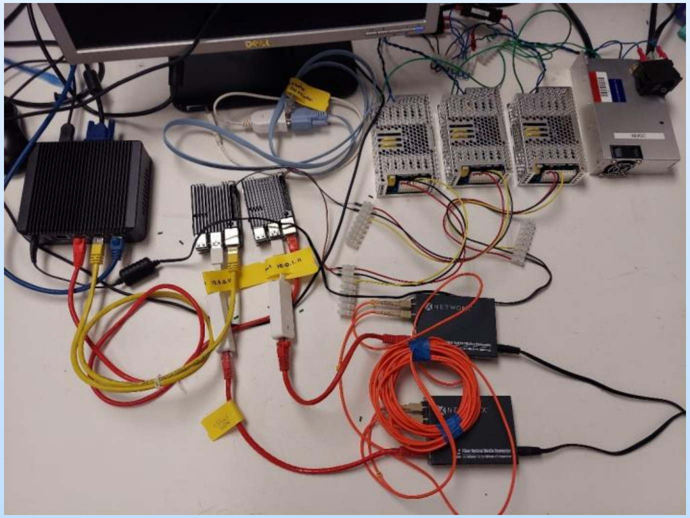
Modem and Driver Boards



Status: Network Architecture

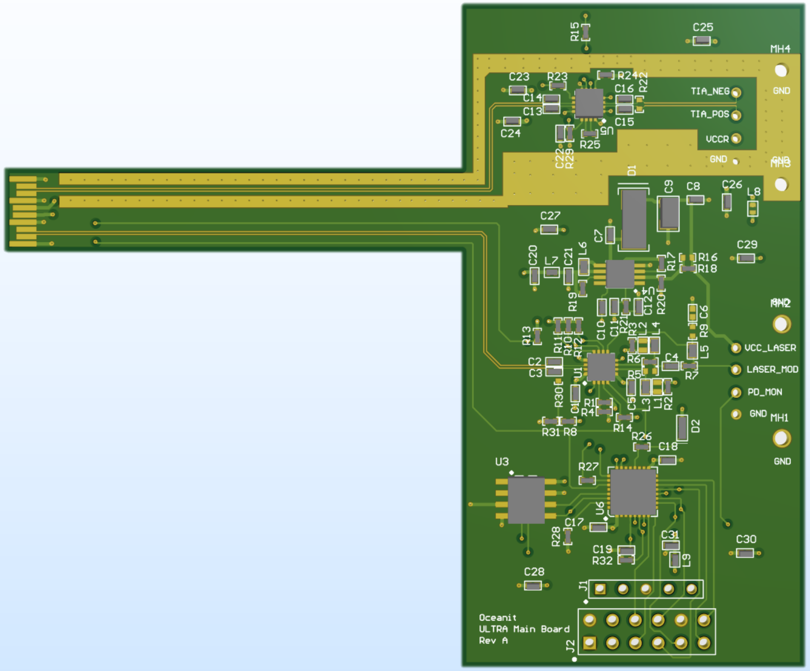
- IP tables built around data forwarding and meta data distribution
- Scalable for larger installations
- Built around bi-directional testing

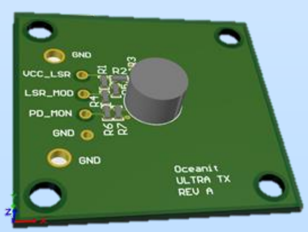


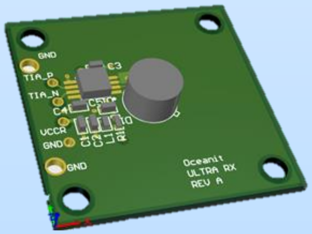


Status: Modem and Driver Boards

- Custom Modem boards designed and built to accommodate up to 1Gb/s
- Custom TX LASER driver boards designed and built
- Custom RX PD driver boards designed and built
- Power delivery system for all components designed and built

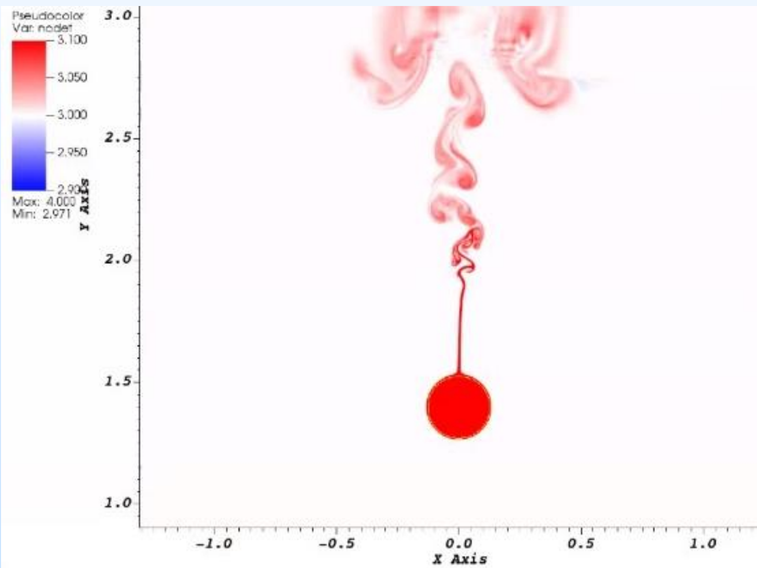




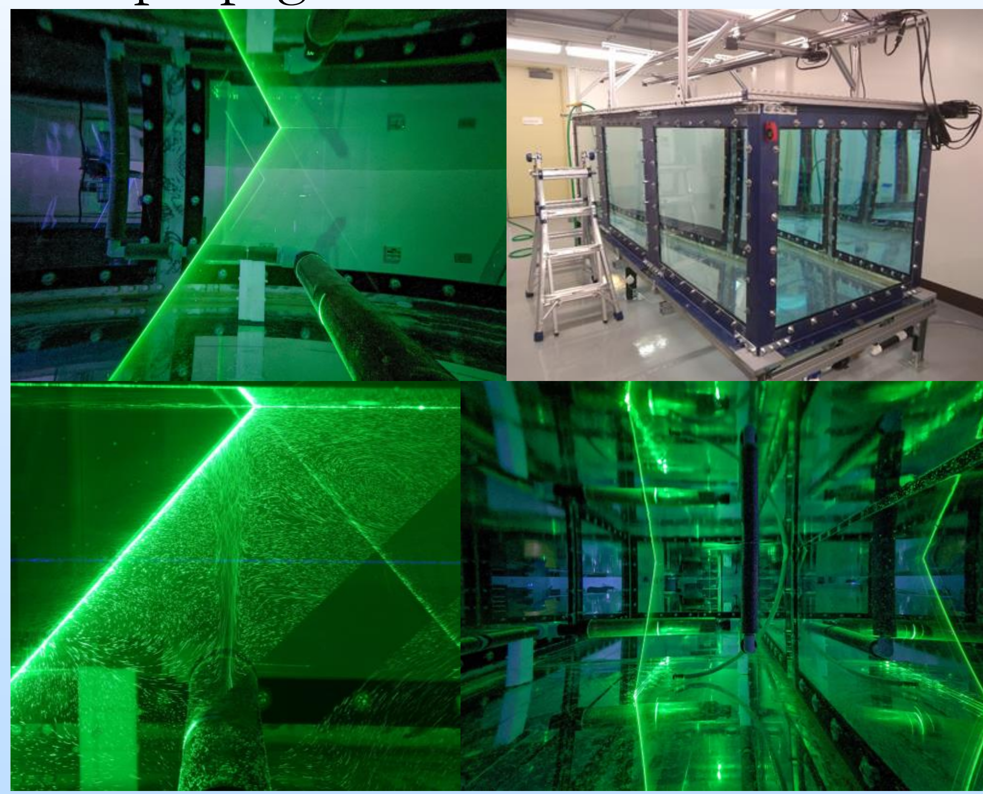


Status: Environmental Modeling

The project uses LLNL's ALE3D-4I multiphysics modeling software to perform fluid dynamics simulations of subsea environmental factors – primarily temperature – affecting laser propagation.



Thermally buoyant flow from a subsea wellhead jumper modeled with ALE3D-4I.



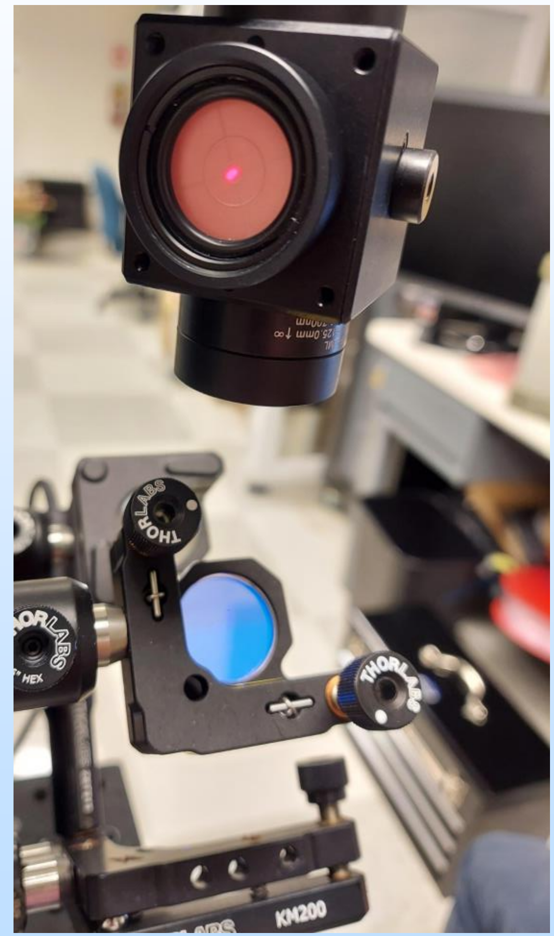
Experimental setup at University of Hawaii

Status: Field Tests

- 400m Offshore
- 11m depth
- Initial Marinization
- Characterized test site conditions
- Demonstrated subsystem capabilities

Accomplishment: Optical Pointing

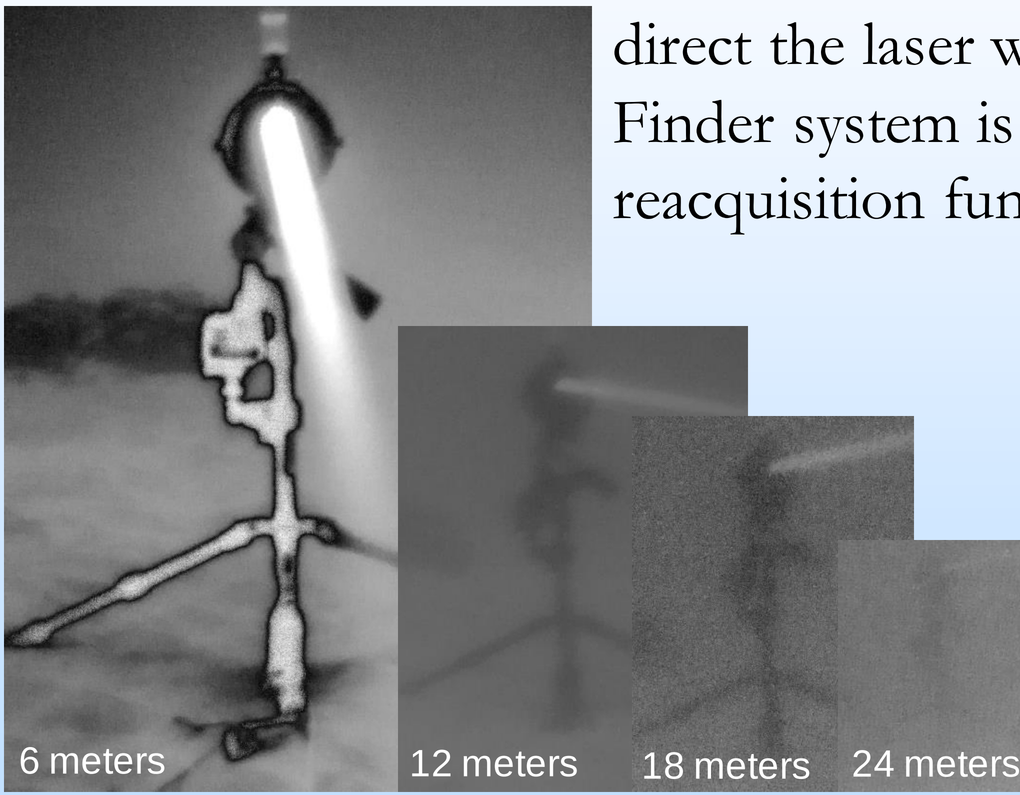
Oceanit developed a coaxial dual-color transmission optical system that precisely controls the transmission of laser energy. Bandwidth and range can be maximized while power consumption is minimized.



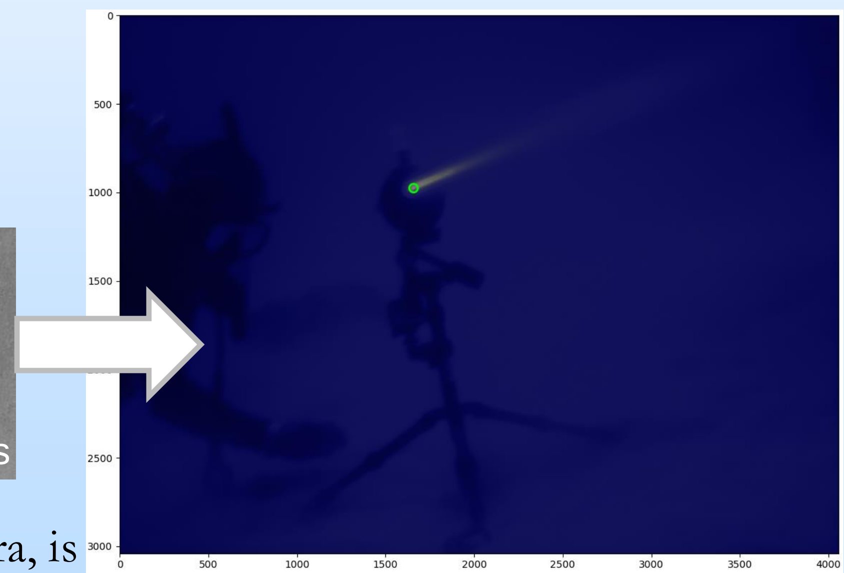
Laboratory testing and design (above), ocean water testing (left)

Accomplishment: Target Acquisition

Data from ocean water test at 11 meters deep in midday sun:



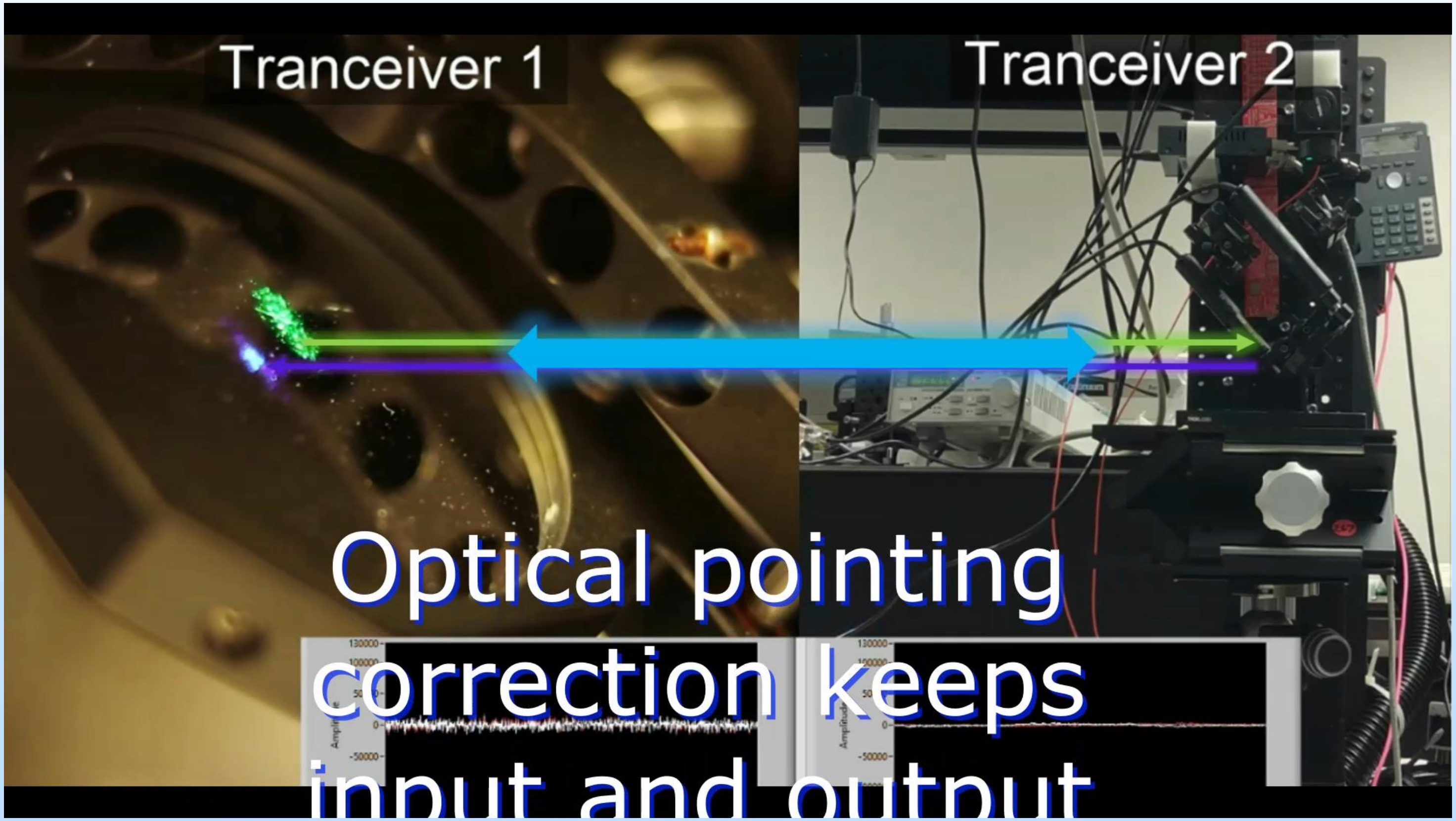
The ULTRA system uses an optical sensor to detect the location of neighboring nodes and to direct the laser where to point. This optical Node Finder system is used for the start-up and reacquisition functionality.



The 2D image coordinate point is acquired by the camera, is converted into the laser coordinate system and sent to the laser controller.

Accomplishment: Beam Steering

Beam steering is achieved by cross-linked Meta-stable feedback loops that produce high accuracy tracking solutions for the transmitters and receivers.

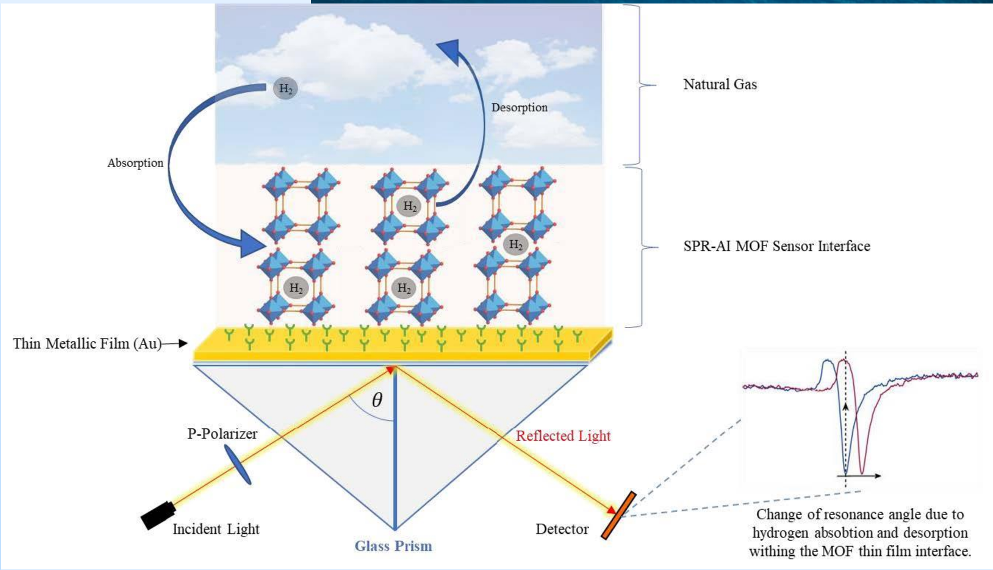


Lessons Learned

- Beam steering system can be advanced to yield faster processing and tracking.
- Chip shortage has affected basic electronic component supply chains.
- Unanticipated difficulty with 3rd-party motor control board developer.
- Future iterations may require specialized components to further reduce SWaP.

Synergy Opportunities

- Safety & Efficiency
  - Temperature
  - Pressure
  - Vibration
  - Flexure
  - Flow
  - Corrosion
  - Erosion
- Decarbonization & Sequestration
  - Hydrates
  - Infrastructure Stress/Pressures
  - Leak detection
- Hydrogen Transport
  - Distributed pipeline health monitoring
  - Leak detection



Project Summary

- Key Findings
  - System placement near thermal sources must be carefully considered to avoid disruption.
  - Typical test location conditions produce 5-15 meters of visibility, limiting transmission to 10-30 meters
- Next steps:
  - Modulation Integration
  - Tracking Integration
  - Initial Marinization
  - Technical Demonstration

Appendix

– Benefit to the Program
– Project Overview
– Organization Chart
– Gantt Chart
– Bibliography

Benefit to the Program

- Reduced operating costs
  - Fewer personnel and hardware resources required to monitor the reservoir
- Increased extraction efficiency
  - Up-to-the-minute subsurface information will allow for ad hoc adjustment to survey programs and inform well stimulation operations
- Increased safety
  - Fewer personnel on-station reduces the inherent risks of accident and injury
  - Updated reservoir and well state data reduces the probability of undesirable well events
- Improved ROI
  - Enables timely input to reservoir management decisions
  - Shortens the intervention cycle time

Project Overview

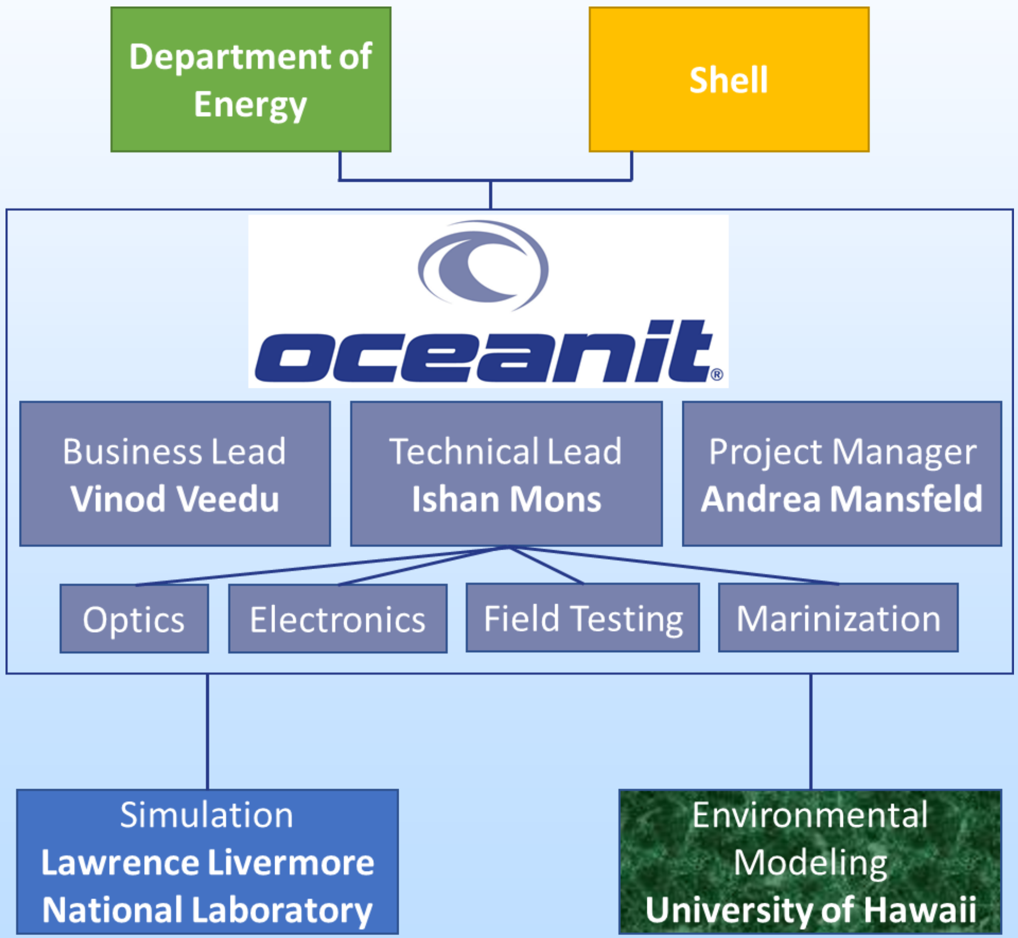
Goals and Objectives

The objective of this project is to address bandwidth and parallelism deficiencies in currently available undersea wireless optical communications technologies. These goals will be achieved using tight beam focused free space optical networks of 450/515nm light amplification by stimulated emission of radiation (LASER) nodes distributed along the sea floor, allowing for a highly scalable network backbone connecting a wide array of residency sensors as well as command and control devices. Enabling residency for constant real time monitoring and control will drastically increase operational efficiency and safety. This effort will shall include electronic/optical encoding optimizations, optical alignment technology improvements, marinization, and a demonstration of network scalability. Additionally, the feedback control loop will be integrated with a pointing gimbal to allow for larger angle corrections (>10°) modulation bandwidth in excess of 1GHz. demonstrate maximum bandwidths at or above 100Mb/s while reducing power consumption below 5 Watts per transmitter and be able to transmit over 100 meters of ocean water.

Project Goals

- The end goal of the ULTRA project under this FOA is to develop a wireless subsea broadband network aimed at seismic OBN networks used to characterize EOR fields by changing the data collection methodology for OBNs to near real time.
- The major project goals for Phase I are to 1) develop an optical pointing system that pairs with developed software to control the LASER emitter, 2) design a custom small form factor pluggable LASER driver board and test with the network interface controller and 3) demonstrate underwater transmitting of data in the ocean.

Organization Chart



Gantt Chart

				Budget Period 1								Budget Period 2			
				Year 1				Year 2				Year 3			
Task #	Milestone	Start Date	End Date	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.0	Project Management and Planning	1/1/2020	1/1/2023												
2.0	Technology Maturation Plan	1/1/2020	1/1/2023												
3.0	Data Management Plan	1/1/2020	1/1/2023												
4.0	Optical Pointing System Development	1/1/2020	7/1/2021												
4.1	Target Acquisition	1/1/2020	4/1/2021												
4.2	Beam Steering	7/1/2020	7/1/2021												
4.3	Enviromental Modeling	7/1/2020	1/1/2022												
A	**Optical System Design Complete**		7/1/2021												
5.0	Electronic Optimization and Testing	7/1/2020	1/1/2022												
5.1	Transmission Interface	7/1/2020	10/1/2021												
5.2	Sensor Interface	10/1/2020	1/1/2022												
B	**Electronic System Design Complete**		1/1/2022												
6.0	Marinization and Hardening	10/1/2020	1/1/2022												
C	**Completed Marinized System**		1/1/2022												
7.0	Industry Engagement	1/1/2020	1/1/2023												
7.1	Site Selection	7/1/2021	1/1/2023												
E	**Deployment Commitment and Go/No-Go**		1/1/2022												
8.0	Controlled Condition Underwater Testing	1/1/2022	4/1/2022												
D	**Underwater System Demonstration**		4/1/2022												
9.0	Shallow Water Testing	1/1/2022	7/1/2022												
9.1	Range Test	1/1/2022	7/1/2022												
9.2	Multi-node Parallel Test	4/1/2022	10/1/2022												
F	**Subsea Demonstration**		10/1/2022												
10.0	Deep Water Systems Integration	7/1/2020	1/1/2023												
G	**System Integration**		1/1/2023												
11.0	Field Deployment	10/1/2022	1/1/2023												
H	**System Delivery**		1/1/2023												

Bibliography

– N/A