Undersea Communications

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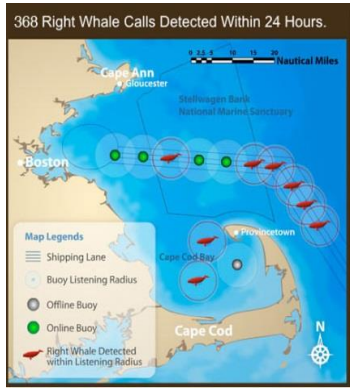
Roles for Unmanned Undersea Systems

PNT = Precision Navigation & Timing
SLAM = Simultaneous Localization & Mapping
DCLT = Detection, Classification, Localization, Tracking

Discovery



- Climate science
- Marine mammal monitoring
- Persistent surveillance

Dirty

- Deep-water oil rig inspection
- Gas vents
- Shipwreck investigation

Dangerous

- Monitoring battlezone
- Minefield
- Forward deployment
- Extreme depth

Technology Area	Challenge
Energy	Long Endurance, Variable Power
Communications	High BW, Covertness, Networked Ops
Autonomy	Complex behavior, Obstacle Avoidance, No Man-in-Loop
Navigation	PNT, Variable Speed, SLAM
Platforms	Navigation, Deployment & Recovery, Low Cost
Sensors	Wide Area, Long Range, Low SWaP
Processing	Low SWaP, High FLOPS, Improved Algorithms
Information Assurance	Security, Cost, Robustness, Dynamic Logistics

Vehicle autonomy is a critical element for current and future undersea systems

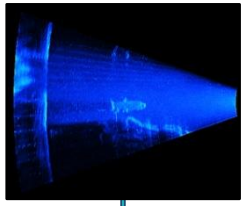
Outline

- Undersea-Undersea
- Air-Undersea

Undersea Sensor Data Rates

Sonar Volume Scan

- 0.5 m range resolution
- 16-bit ADC

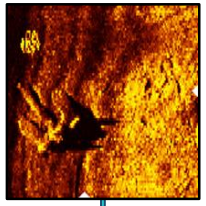


Imagenex Profiling Sonar

- 3° azimuth resolution, 20 frames per second

Sonar Seafloor Image

- 1800 kHz sonar, direct sampling
- 16-bit ADC



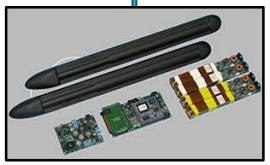
Deepsea Power & Light HD Video

- 1080p/30 uncompressed
- 720p/60 MPEG2

10 kbs | 100 kbs | 1 Mbs | 10 Mbs | 100 Mbs | 1 Gbs

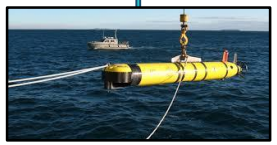
Balt Robotics Video over Acoustic Modem

- 640 × 480 pixels, 15 frames per second
- 0.02 bits per pixel



Marine Sonic Imaging Sonar

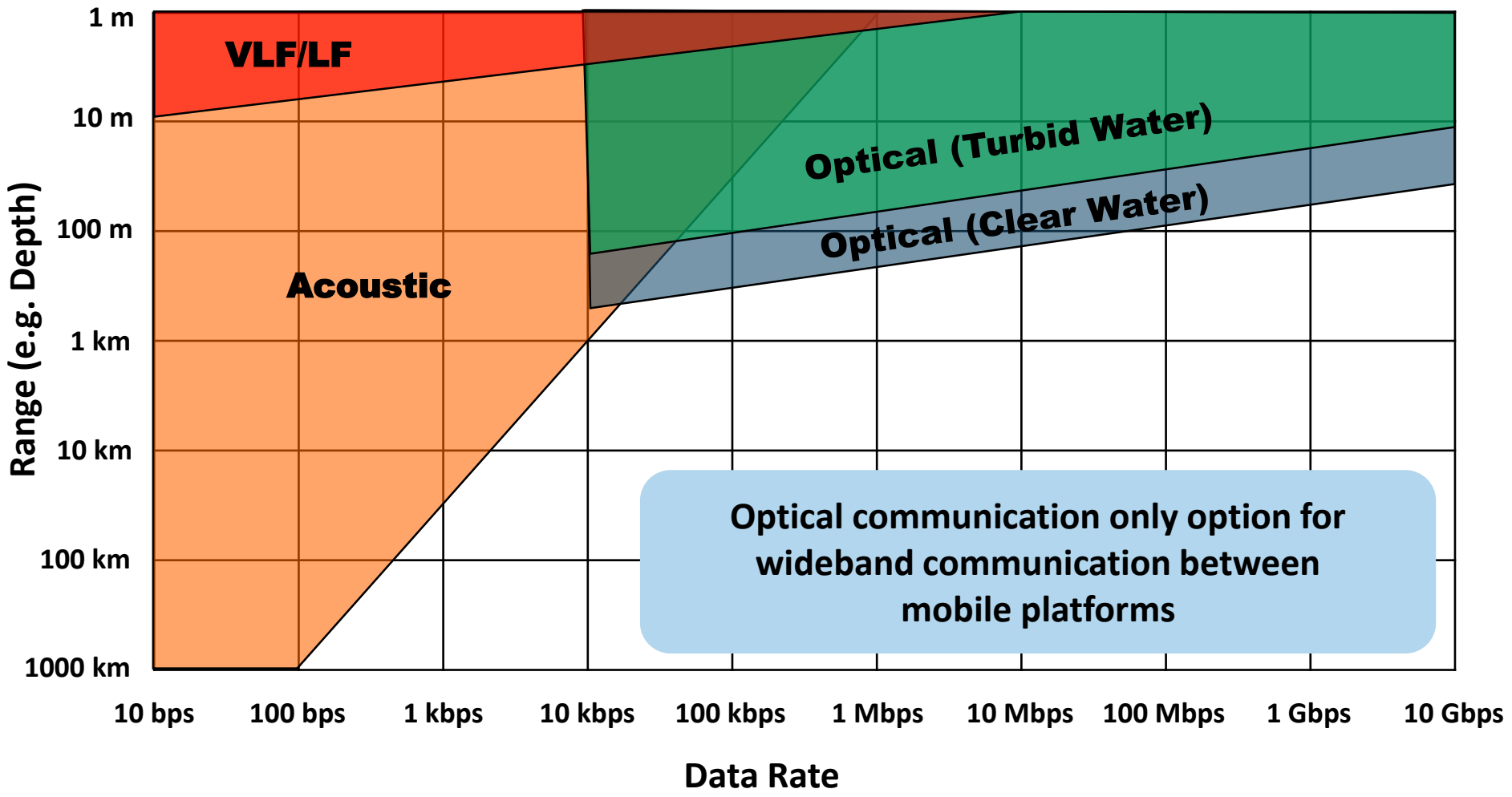
- 0.5 cm × 3.5 cm resolution



Countermine Mission

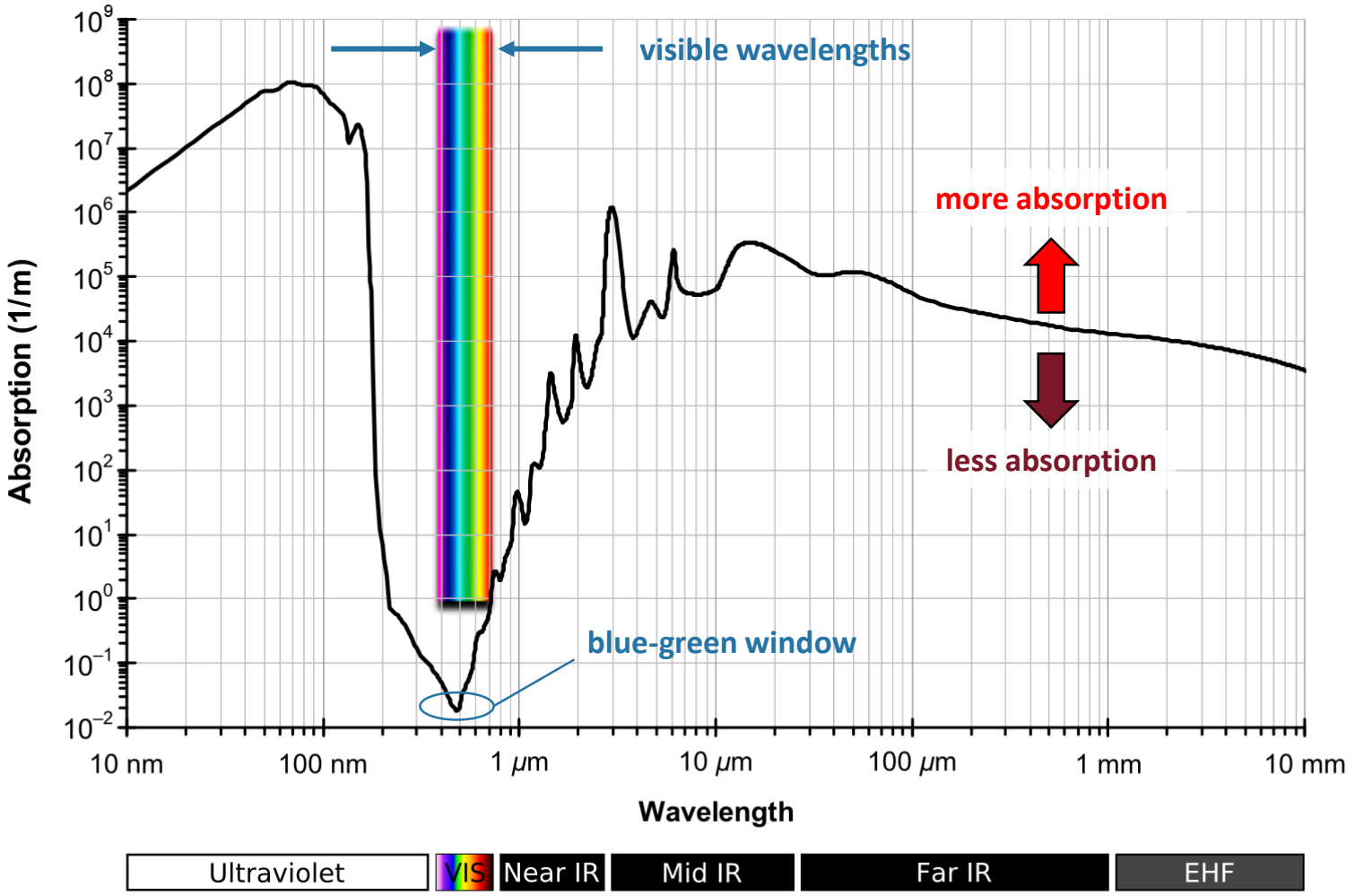
- 880 Gbyte on-board storage allocated for 12-hour mission

Undersea Communications Tradespace



Optical Transmission through Water

- Ultraviolet and Infrared are strongly absorbed
- **<u>Long-distance links</u>:** Use the blue-green window



Narrow-Beam Undersea Optical Links

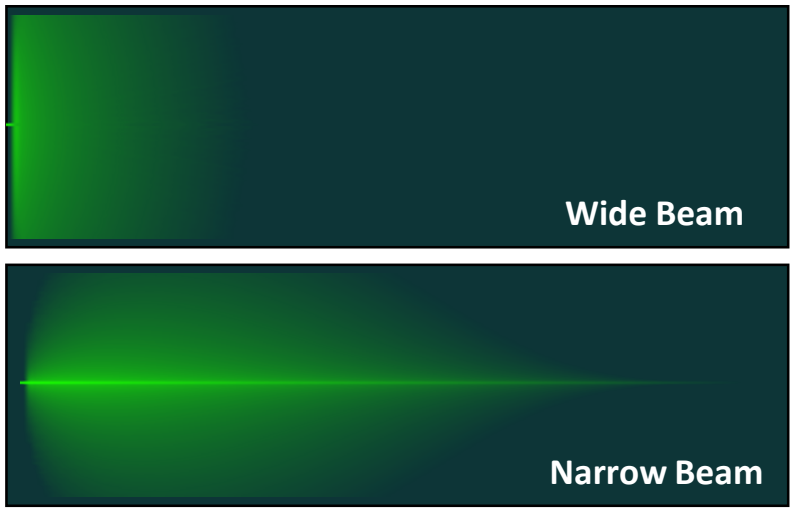
Transmitter Energy Efficiency

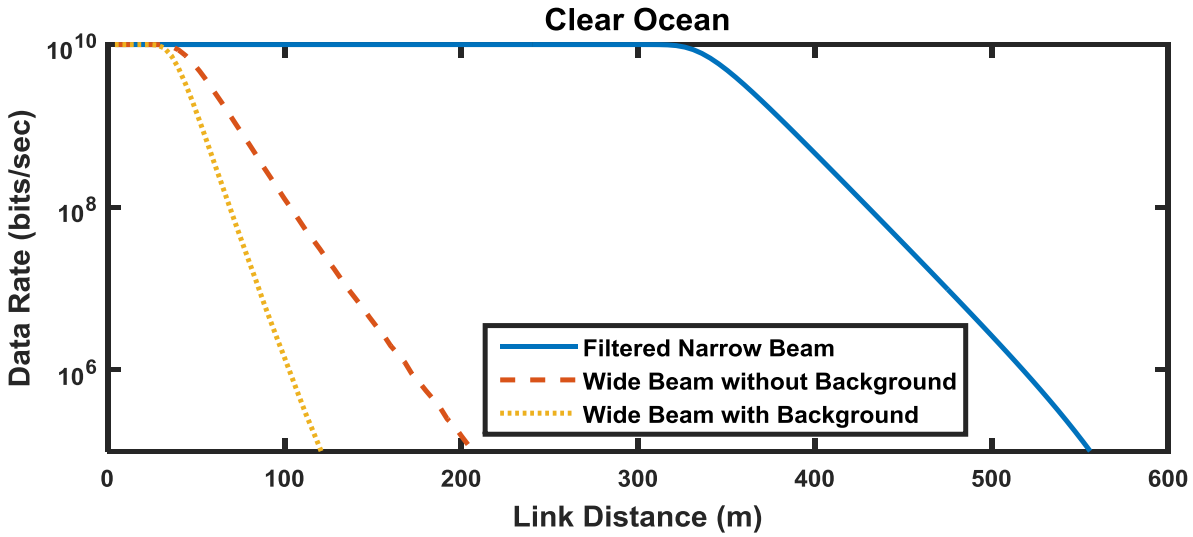
- Collimated beam has 50–70 dB gain vs. wide beam
- Allows use of low-powered (<100 mW) lasers for Gbit/sec links
- Requires accurate pointing and tracking

Receiver Background Rejection

- Angular and spectral filtering provides >100 dB background rejection
- Allows operation near the surface in daylight
- Requires accurate pointing and tracking

Undersea lasercom with narrow transmit beams can significantly increase the achievable ranges and data rates

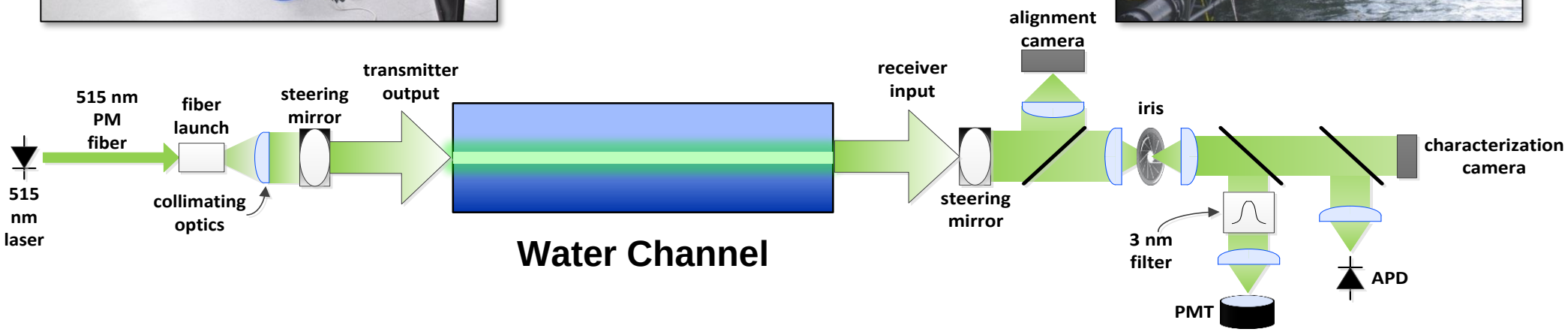




Communication Transmitter/Receiver Development

Lab Development

Field Test

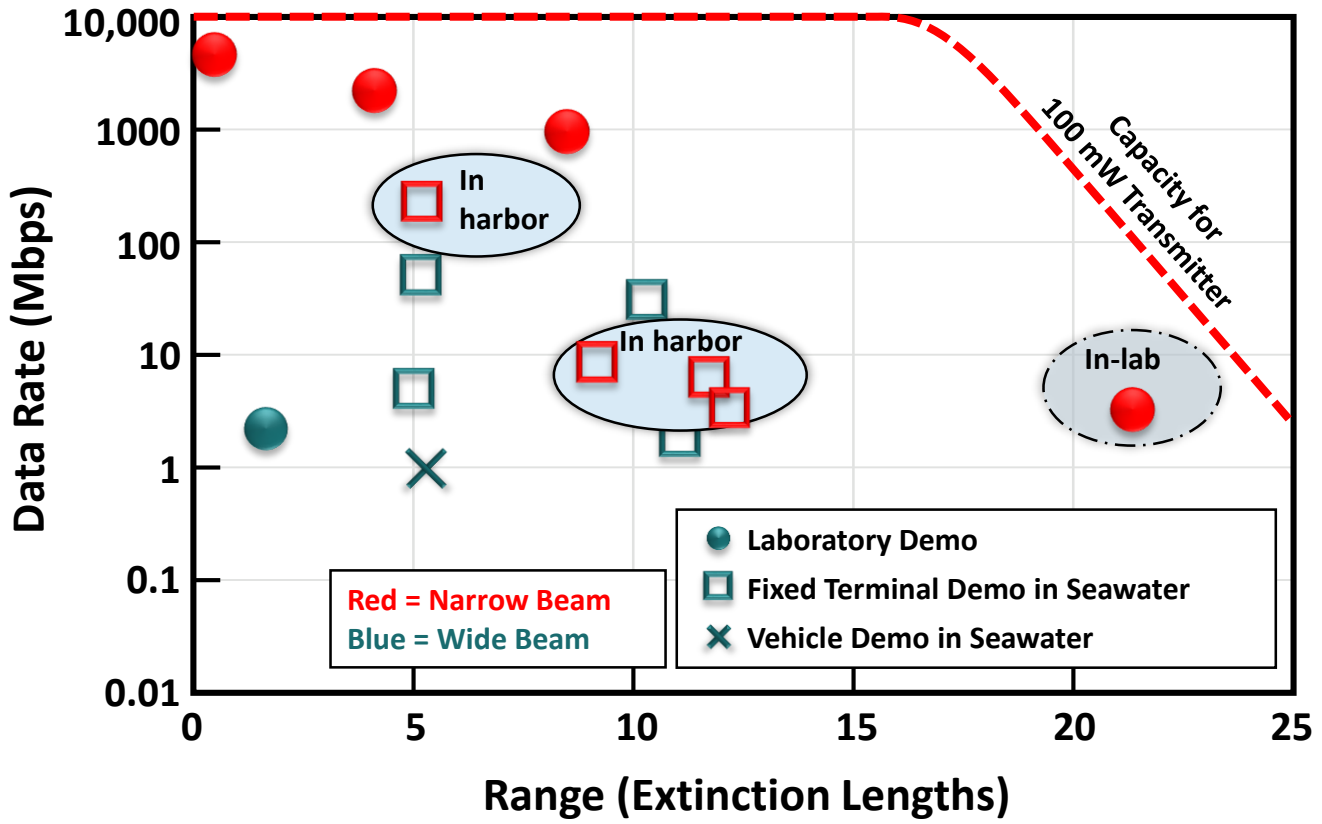


Developed and demonstrated laser communication between fixed terminals in Narragansett Bay, RI

Narrow-Beam Communication Performance

Accomplishments

- Laboratory test bed demonstrated modem can operate with 97 dB end-to-end channel loss
  - 20 mW launch power, 21 extinction lengths
  - <1 detected photon/bit sensitivity at 5 Mbps
- Capacity-approaching day/night operation in natural waters
  - 0.25 mW launch power, 11.5 extinction lengths
  - 1.2 detected photon/bit sensitivity at 8.7 Mbps
- High-rate communications in natural water
  - 125 Mbps communication



Natural water performance matched laboratory performance

ROV Development

BlueROV2 + Terminal

- Purchase cheap COTS remotely operated vehicle (ROV) to carry terminal
- 100 m tethered operation
- Control based around PixHawk quadcopter autopilot

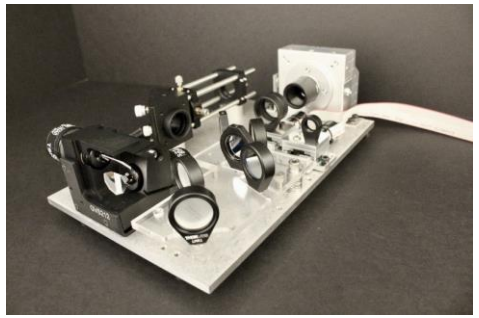
Modular ROV Frame

- Simple to adjust thruster location to minimize surge/sway while moving
- Simple to ballast/trim
- Extensible to hold extra payloads

ROV Testing

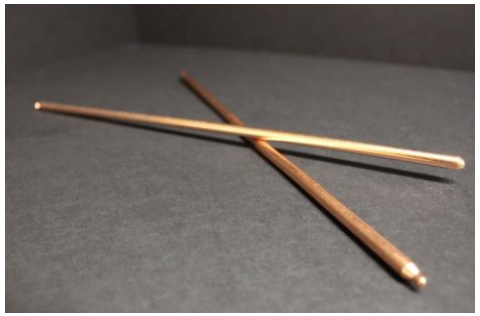
ROV design is adaptable for hosting additional payloads

Terminal Development



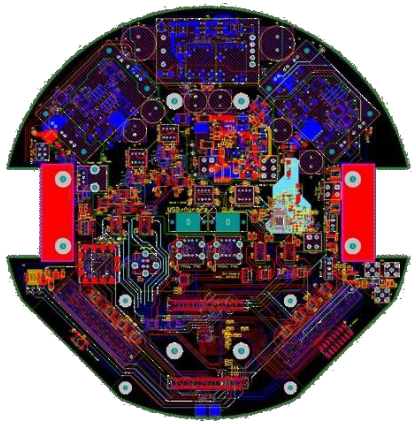
Optical Path

- Built and aligned on bench
- Verified performance of lasers, filters, and mirrors
- Integrated into terminal for system testing



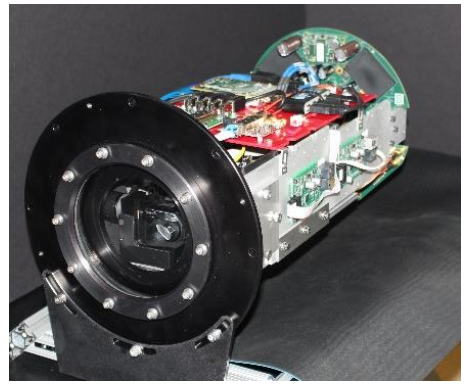
Thermal Control

- Use heatpipes and TECs to cool camera, PMT, and FPGAs
- Developed control systems in MicroZed FPGA



Motherboard

- Custom board to fit behind optics
- Connects control system to all other components



Payload Packaging

- Fit payload 9” diameter PREVCO tube
- Rigidly attached to front panel, blind mated to back panel
- Tether disconnected at back panel

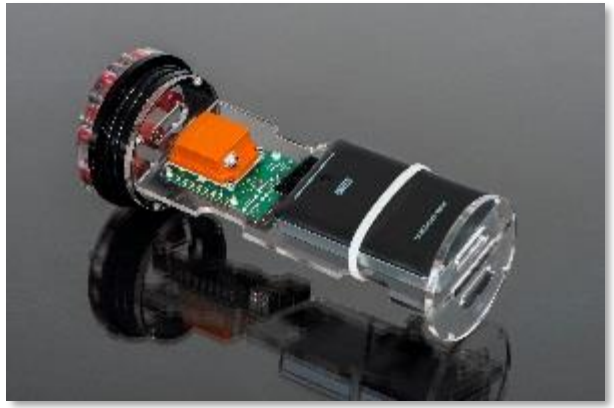
Lasercom terminal SWaP is compatible with medium-sized (e.g., Remus 600 or Bluefin 21) UUVs

Algorithm Development

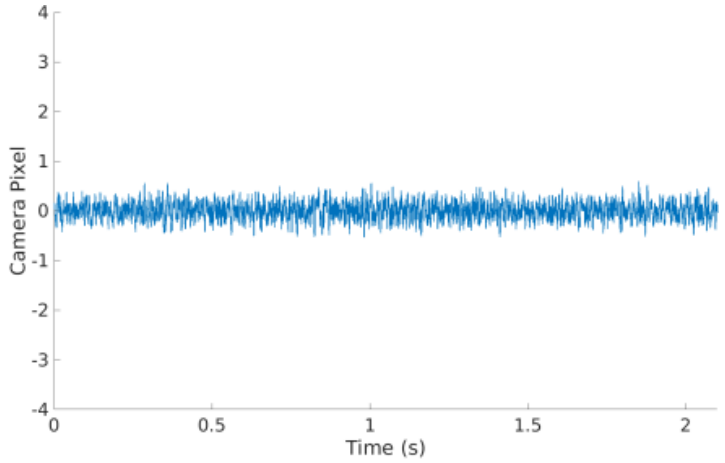
Pointing, Acquisition, and Tracking (PAT)

- Measure vehicle vibration and motion profiles
- Developed and simulated control loops using measured vibration and motion profiles
- Integrating and testing on real-time electronics platform

Gyro + Accelerometer Module



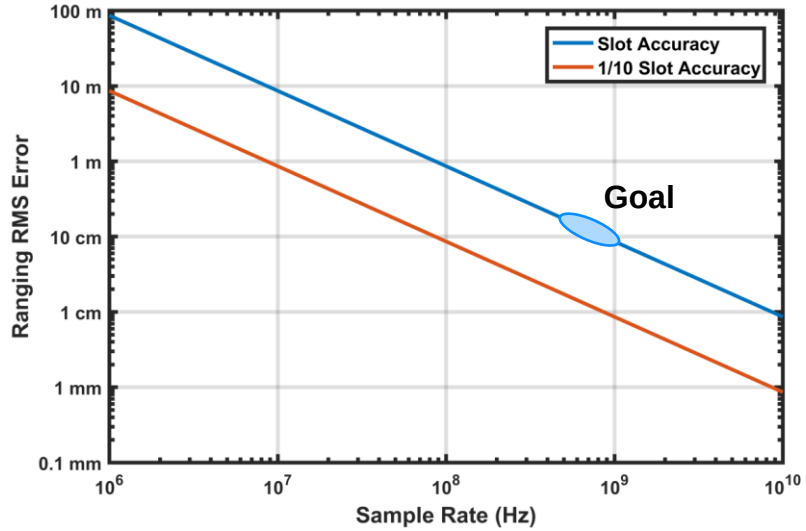
Residual Error In Simulations <25 mrad



Position and Ranging

- Narrow optical beam can be used for simultaneous communication and ranging
- Ranging accuracy between 1 to 10 cm can be achieved with current modem design

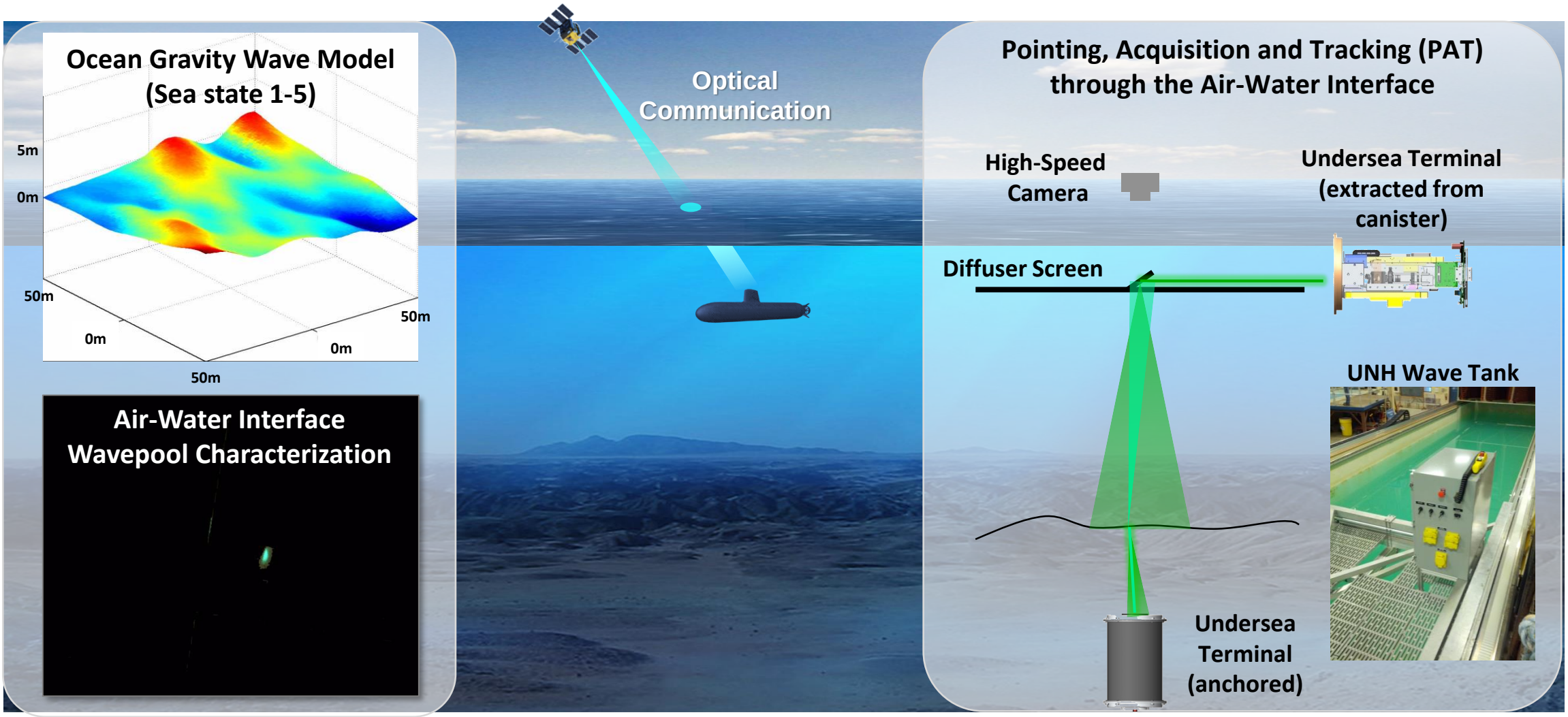
Optical Ranging Performance



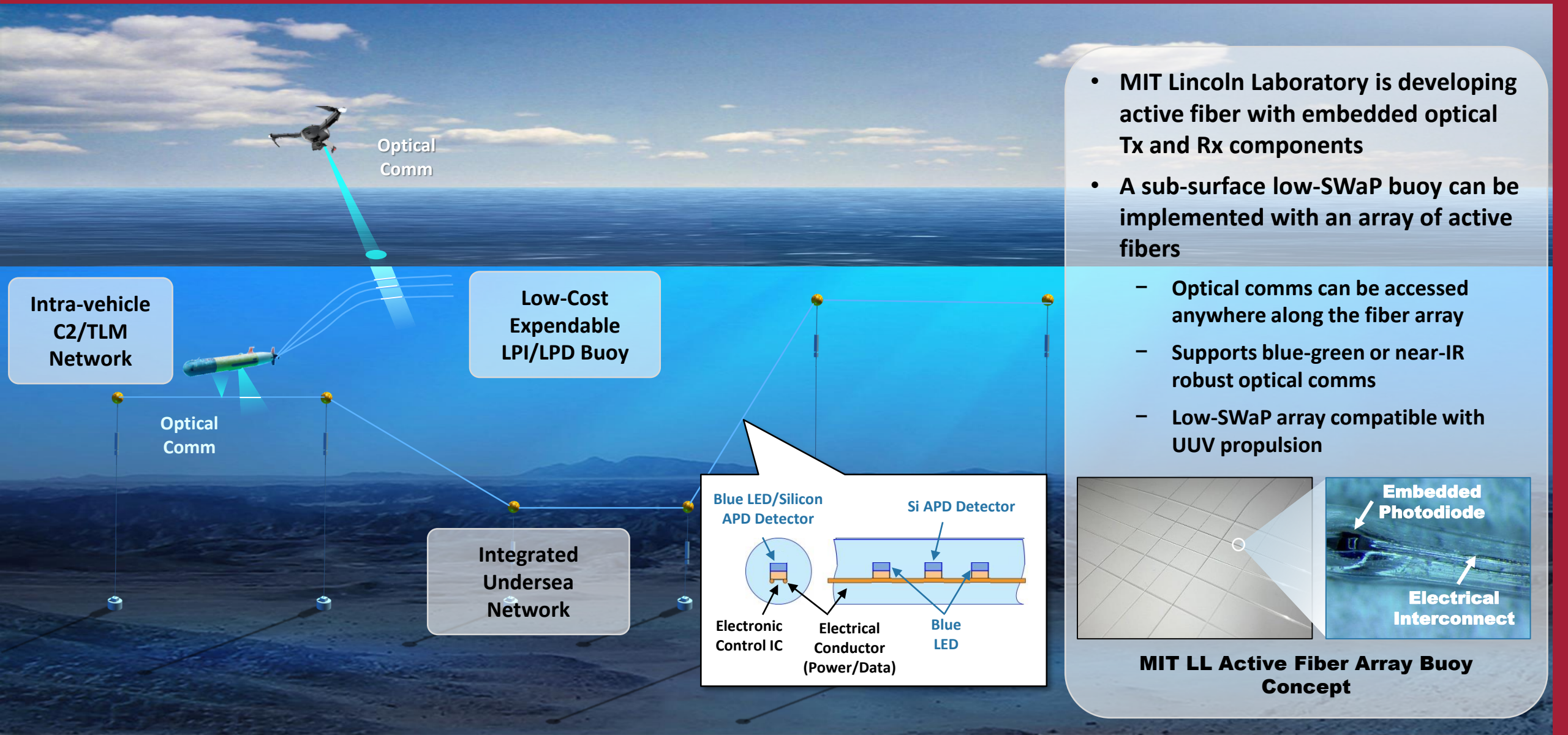
Outline

- Undersea-Undersea
- Air-Undersea

Direct Air-Water Interface Optical Communications



Low-Profile Active-Fiber Buoy Array



- MIT Lincoln Laboratory is developing active fiber with embedded optical Tx and Rx components
- A sub-surface low-SWaP buoy can be implemented with an array of active fibers
  - Optical comms can be accessed anywhere along the fiber array
  - Supports blue-green or near-IR robust optical comms
  - Low-SWaP array compatible with UUV propulsion

MIT LL Active Fiber Array Buoy Concept

Summary

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- Laser communications could impact broad range of undersea applications
  - Undersea networks, mobile AUV links, submarine tactical and strategic communications
- Narrow-beam lasercom approach enables high-rate and robust undersea communication links
  - Significant performance gains are possible compared to previous undersea lasercom demonstrations
  - Terminal prototypes needed to demonstrate this capability exists today
- Narrow-beam lasercom advantages being demonstrated in laboratory and ocean harbor test bed environments
- **We are interested in collaboration opportunities to transition advanced undersea optical communications technology to undersea programs or autonomous vehicles**