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ADAC Year 8 Annual Meeting

April 2022

ADAC Project Briefing

(**LRAUV**) for Under-Ice Mapping of Oil Spills and
Environmental Hazards

A presentation by

PI Amy Kukulya (WHOI)

PI Brett Hobson (MBARI)

and Noa Yoder (WHOI, presenter)



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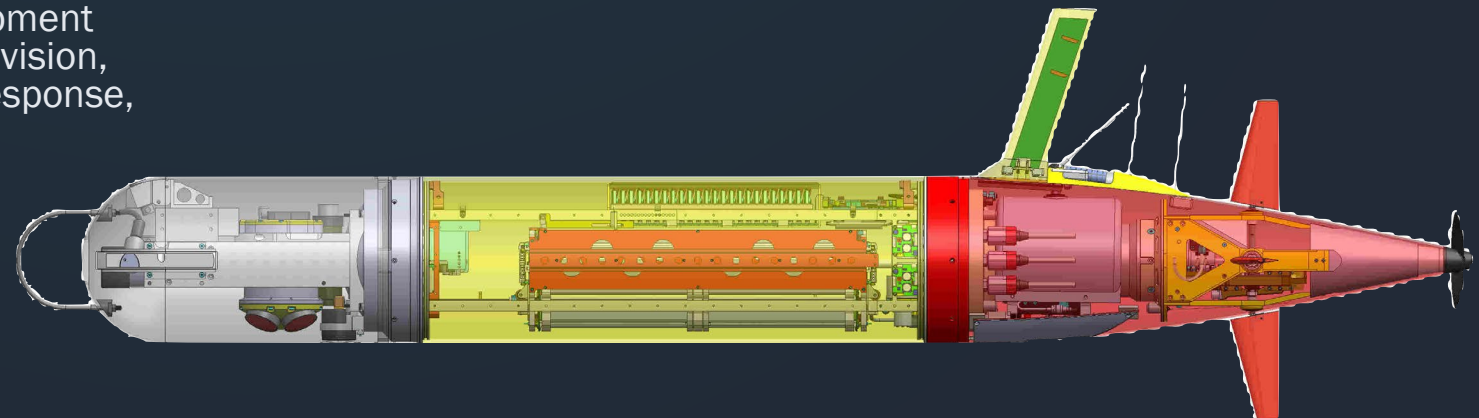


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ADAC Project (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards

- Project Principal Investigator(s): PI/PM Amy Kukulya (WHOI), Co-PI Brett Hobson (MBARI)
- Woods Hole Oceanographic Institution, Monterey Bay Aquarium Research Institute
- Supporting Team: Daniel Gomez-Ibanez, Noa Yoder, Amanda Besaw, Brian Kieft, Ben Raanan, Ryan Govostes, Steven Seeberger, Kaitlyn Tradd, Adarsh Salagame, Aidan Kenny, Cameron Fairclough
- Project Champion: Kirsten Trego, HQ USCG MER
- Project Advocates: Dr. Robyn Conmy, EPA USEPA/NRMRL/RTEB, USCG Research and Development Center, Dr. Jay Choy BSEE/Oil Spill Preparedness Division, Dr. Lisa Dipinto, NOAA, Office of Restoration and Response, Mr. Brian Dolph, USCG R&D Center



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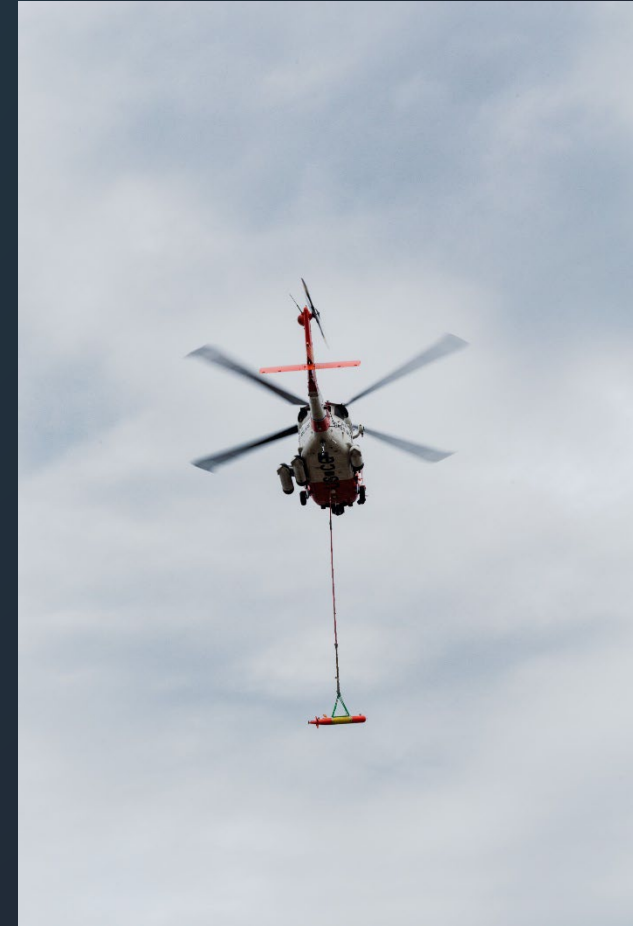
LRAUV: Description and Baseline

- **Baseline:** Currently, there is no USCG baseline for an AUV to meet the unique demands of Arctic operations that requires a minimal logistical footprint, a small operational team and oil detection and mapping capability.
- **Project Description:** To develop an Arctic-capable **long-range Autonomous** Underwater Vehicle (AUV) that is helicopter portable, carries an environmental **mapping** payload, allowing **rapid** response while providing situational **awareness** and damage **mitigation** for first responders/USCG.

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Project LRAUV Relevance and Method

- **Relevance to DHS and USCG:** We characterize the challenge as the 'last seat in the helicopter' problem: If first responders are operating at the far end of their logistical support capability, the system must be able to fill that void.
- **Research Method:** Our approach leveraged an existing base Long-Range AUV developed at MBARI (LRAUV), and enhance the system to detect oil and operate under ice. LRAUV offers extended ranges (one to three weeks), and can be operated by a team remotely and monitored by anyone, anywhere.
 - Next up:
 - Prior (where you have been)
 - Current (where you are at)
 - Projected (where you want to go)



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ADAC LRAUV Updates

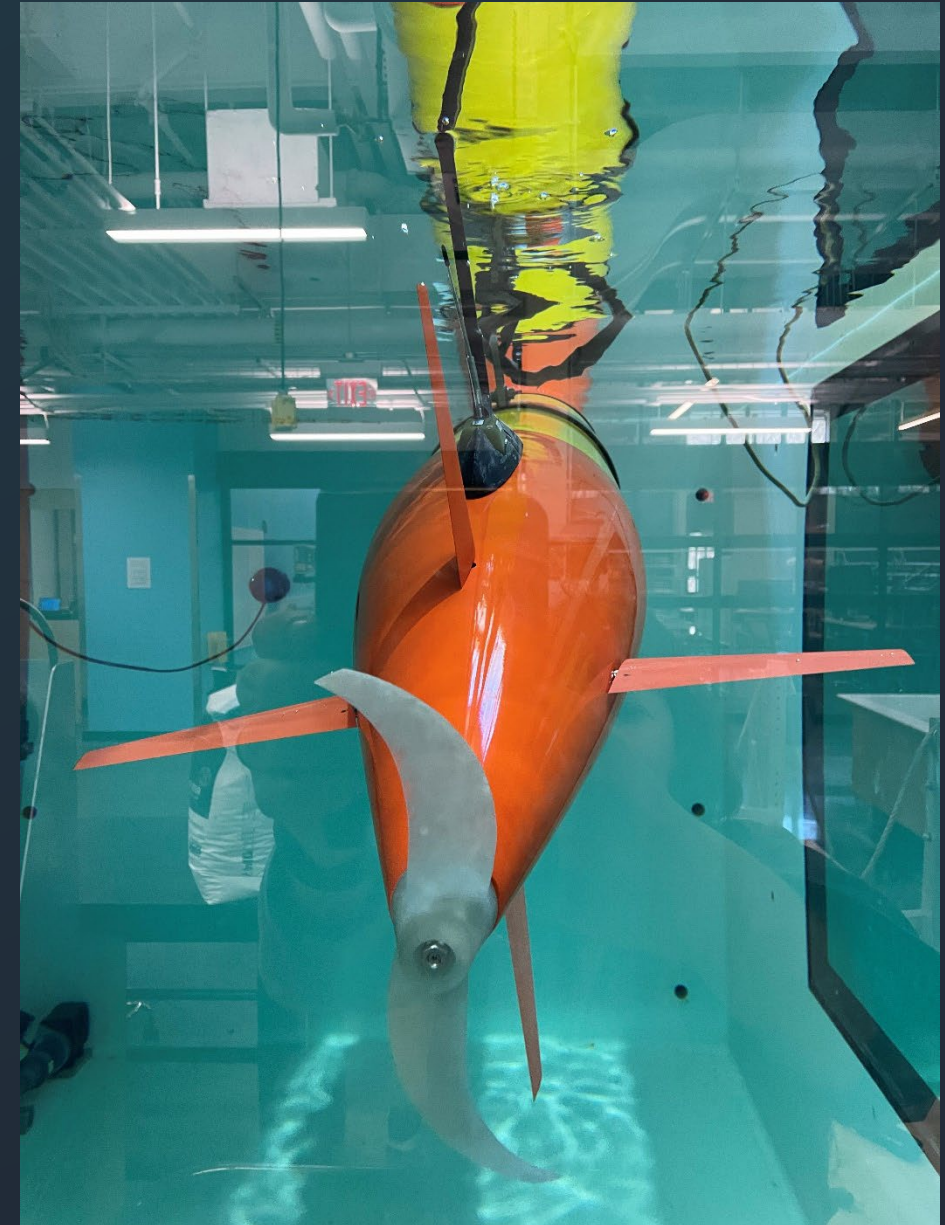
- Backseat- wireless joystick driving (Co-op project)
 - Now works over cell for longer range
 - Backseat- Sidecar Action Manager development, allowing sensors and behaviors to be developed in a vehicle agnostic way so capabilities can be leveraged across platforms (students, software engineers)
- LRAUV backseat computer system health monitor ROS node
- LRAUV Software Simulation
 - Hardware in the loop to test things like oil spill simulations
 - Currently set up with Burger Oil field Simulation
 - Lab tests are successful and now needs open water testing for Arctic demo preparation



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LRAUV Updates:

- Ran 3 over-the-horizon missions.
- Completed 450 km mission offshore (shipless) X 2
- Conducted two virtual Stakeholder training sessions
- Developed new software behavior missions (>20) for docking, undocking, no surfacing, new sensor configurations
- Provisional Patent



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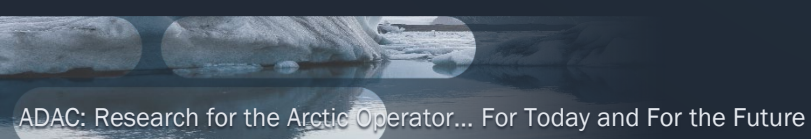
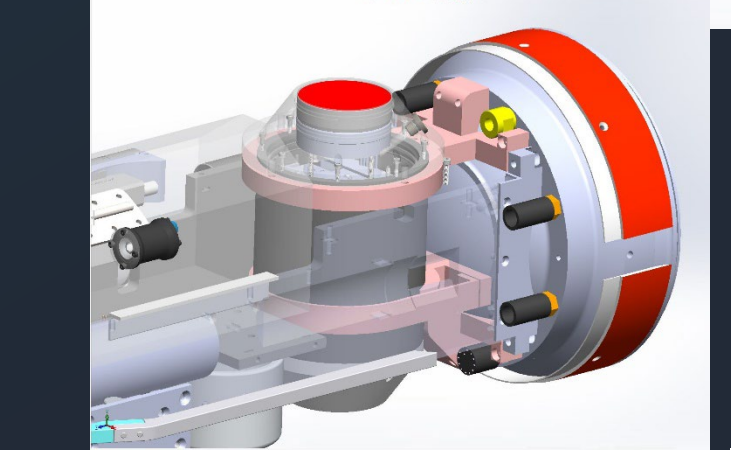
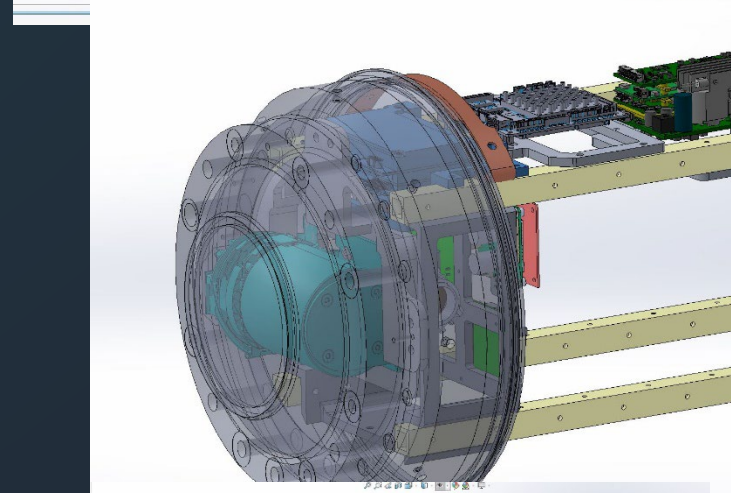
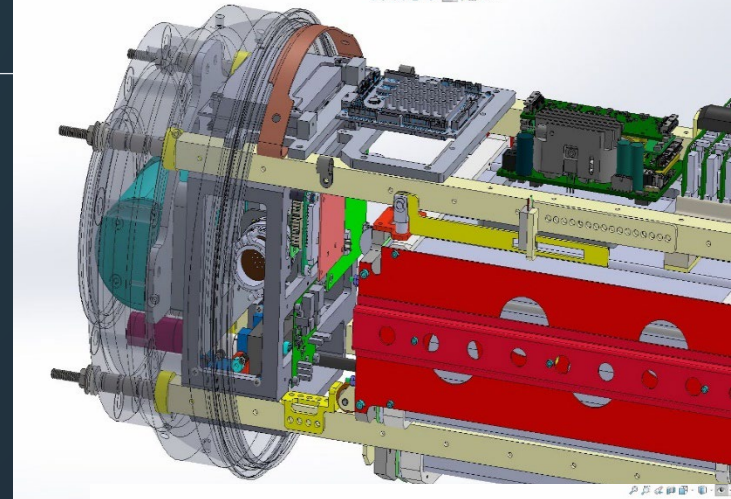
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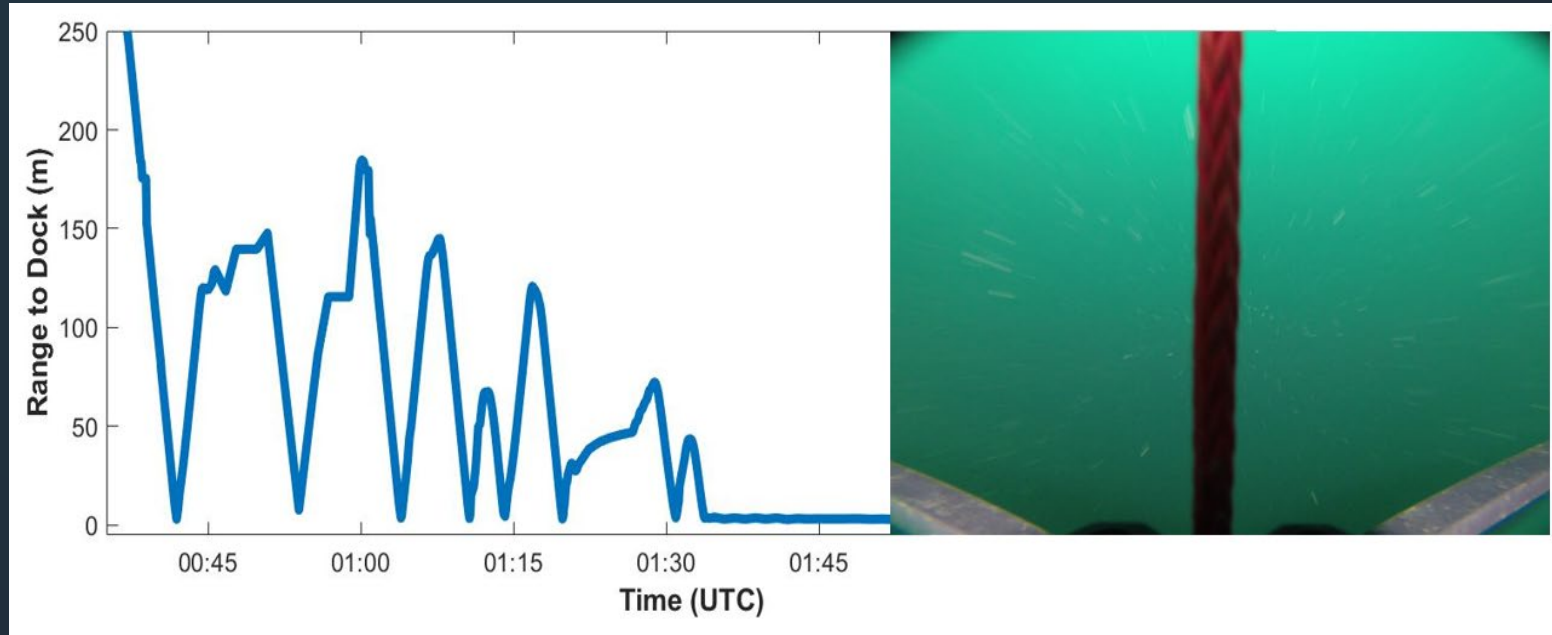
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Where we are at:

- Developed LBL (filter updates implemented)
- Integrated multibeam on Stella
- Completed Stella Build!
- Refined docking (extreme cold tolerant gearbox installed and tested successfully)
- Developed onboard sim mission for plume tracking tests
- Updated plume tracking algorithm (MBARI testing)
 - Burger Oil field Sim tested on vehicle in lab
- Built second docking nose (for Stella)
- Working on software for GPS, time, timing (1 PPS), for IMU and sonar, new PIC board- Completed and bench testing
- All updated wiring for new sensors and config complete
- Built vehicle in a box, Proxima (for rapid testing)



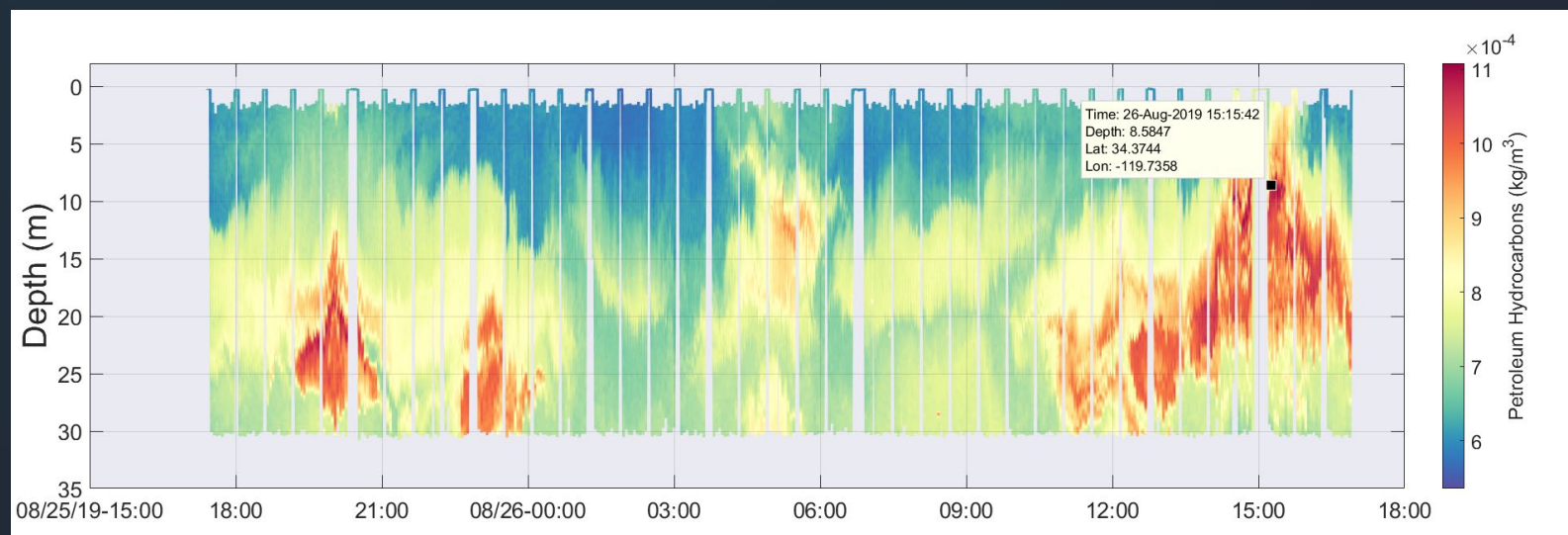
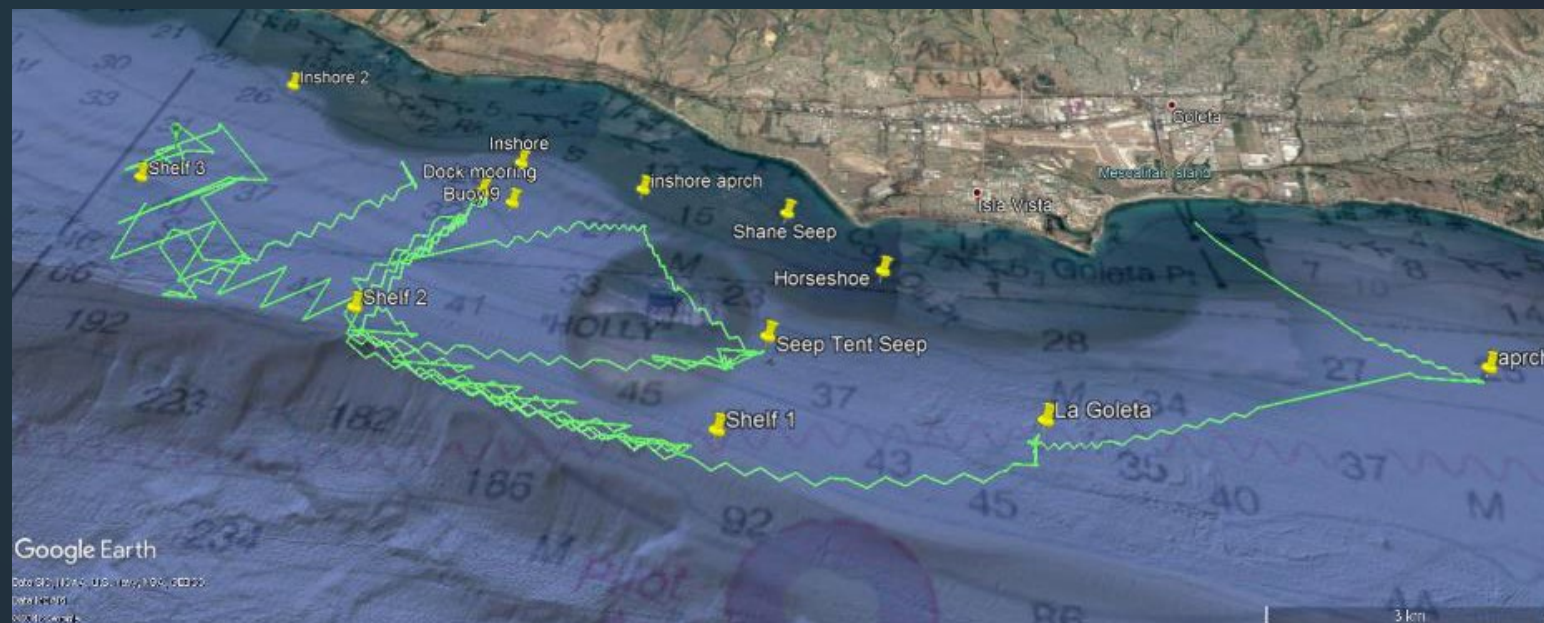
DOCKING PAYLOAD COMPLETED



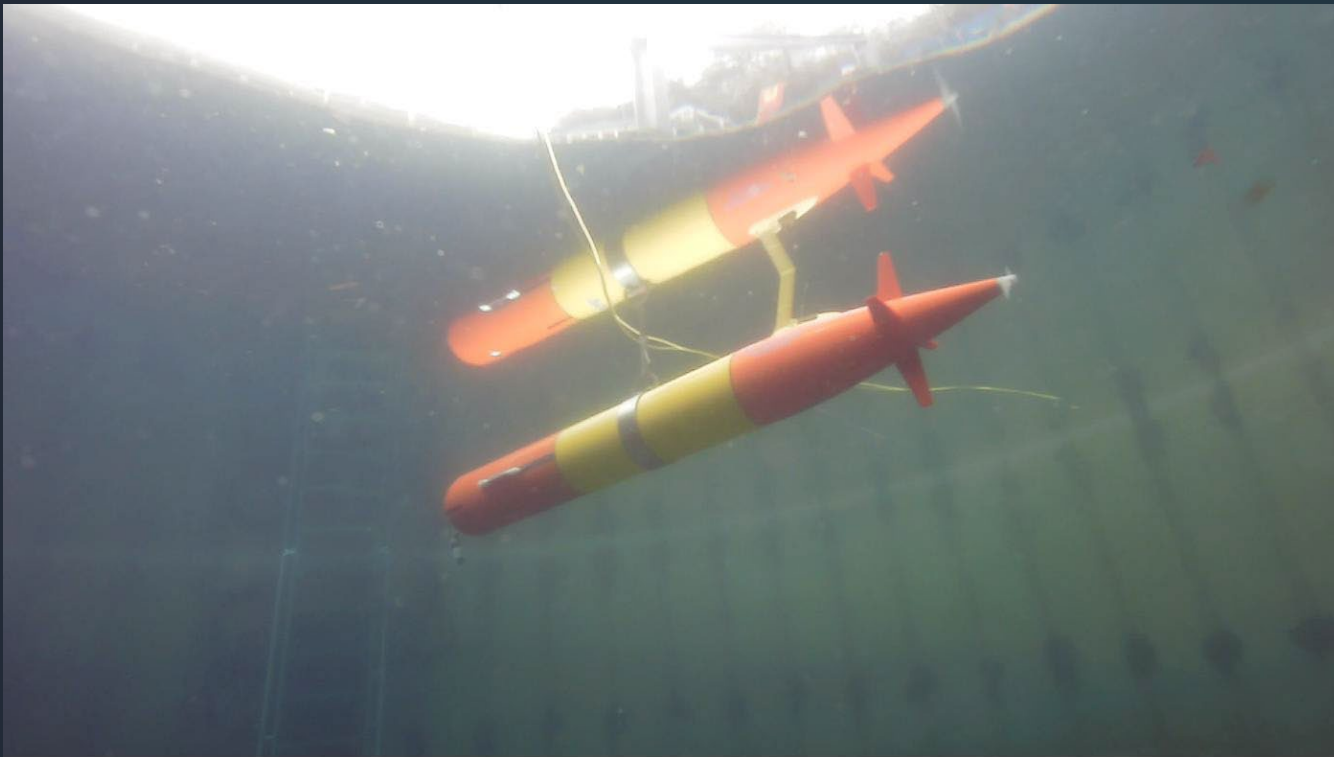
Polaris homes to the Acoustic Gateway Buoy using a USBL. Then it uses the Dynamic Docking Module (pictured left) to hook and latch onto the buoy anchorline. This conserves energy while awaiting new missions or recovery.

OIL SPILL MAPPING

Polaris uses the SeaOwl UV-A sensor to detect dissolved petroleum hydrocarbons in the water using optical backscatter.



Introducing STELLA!



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The WHOI Scibotics Team leveraged WHOI's Innovation Center to build, integrate and test sensors and Stella with lots of MBARI synergistic collaboration



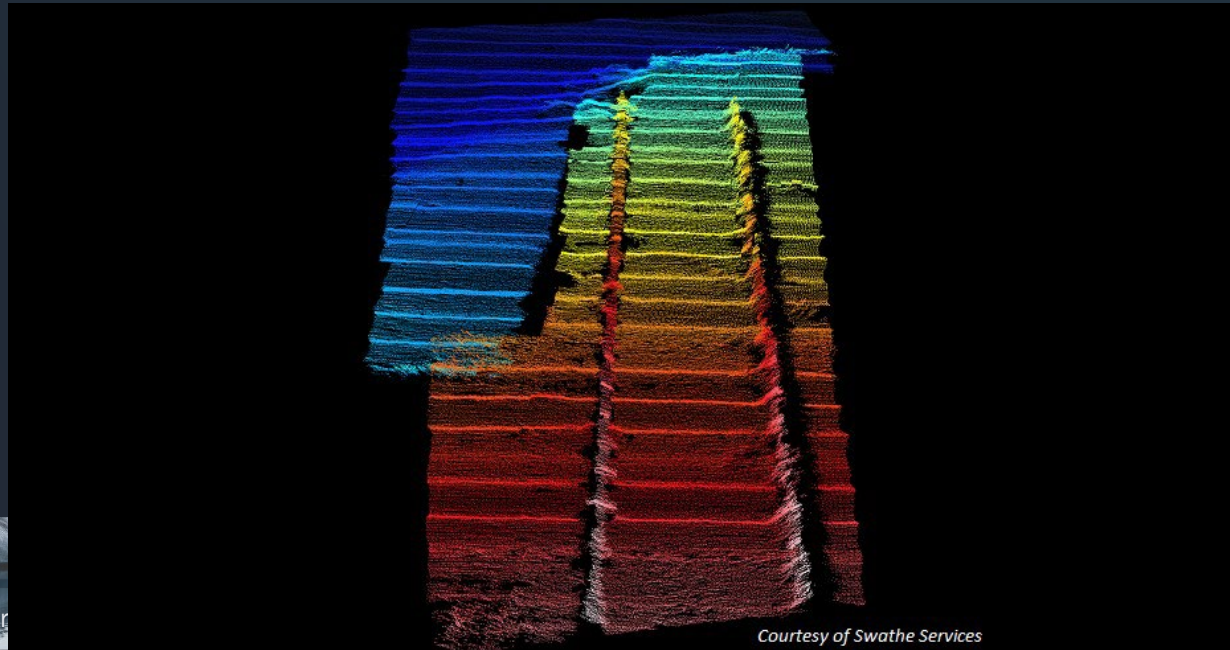
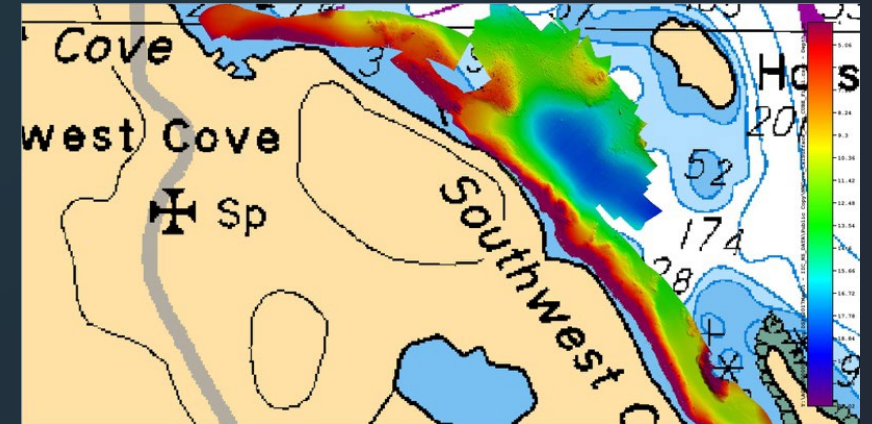
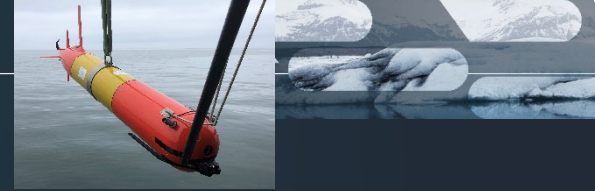
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Polaris & Stella have interchangeability

- Seafloor mapping
- Bathymetry charts
- Shipwreck search/map
- Under-ice and glacier mapping
- Under-ice and in water oil/gas detection

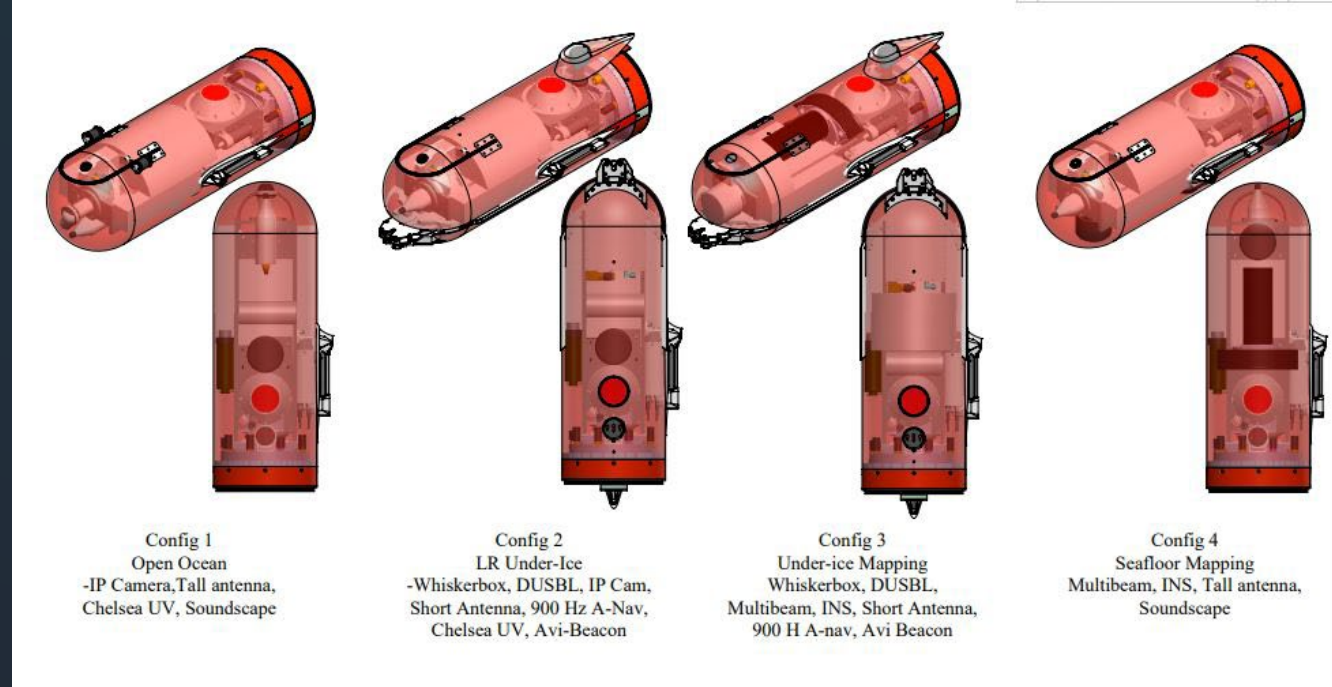


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Courtesy of Swathe Services

Where we are going:

- Two LRAUV vehicles with four nose configurations:
 1. Open water science standard sensors, tall antenna, Chelsea UV, Soundscape
 2. LR under-ice with Whiskerbox, DUSBL, short antenna, Chelsea UV, Avi-beacon with room for camera, 900 Hz A-Nav
 3. Under-ice mapping, Whiskerbox, DUSBL, Multibeam, INS, short antenna, 900 Hz A-Nav, Avi Beacon
 4. Seafloor mapping, Multibeam, INS, tall antenna, soundscape



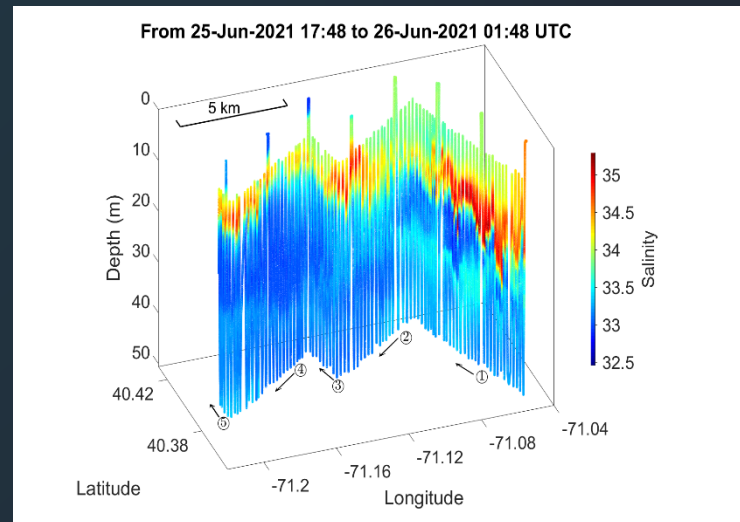
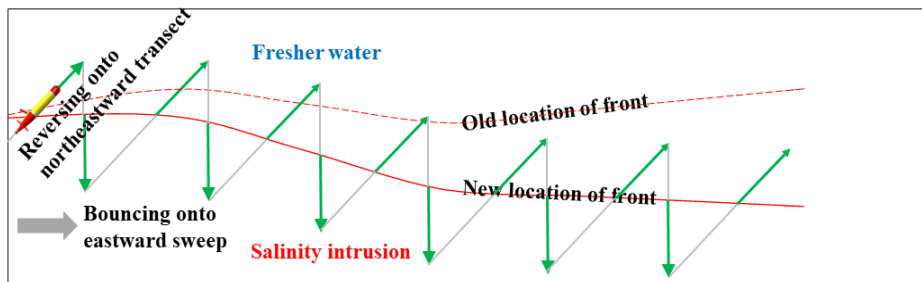
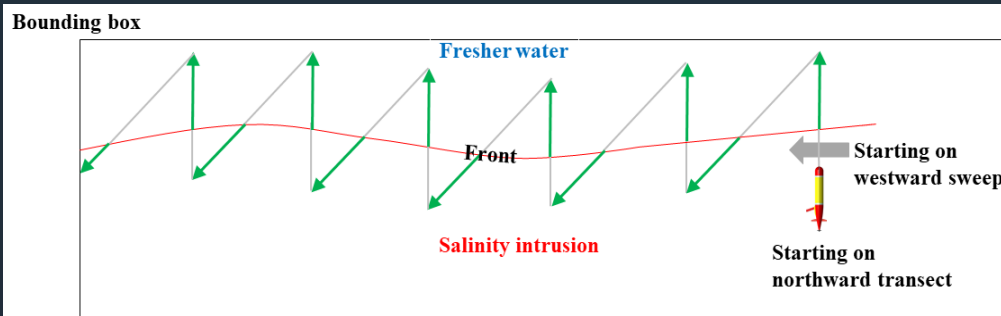
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Leveraged funding from NSF project to develop and test 2D front tracking algorithm Choose your Proxy



Snapshot from LRAUV camera capturing squid in a salt intrusion

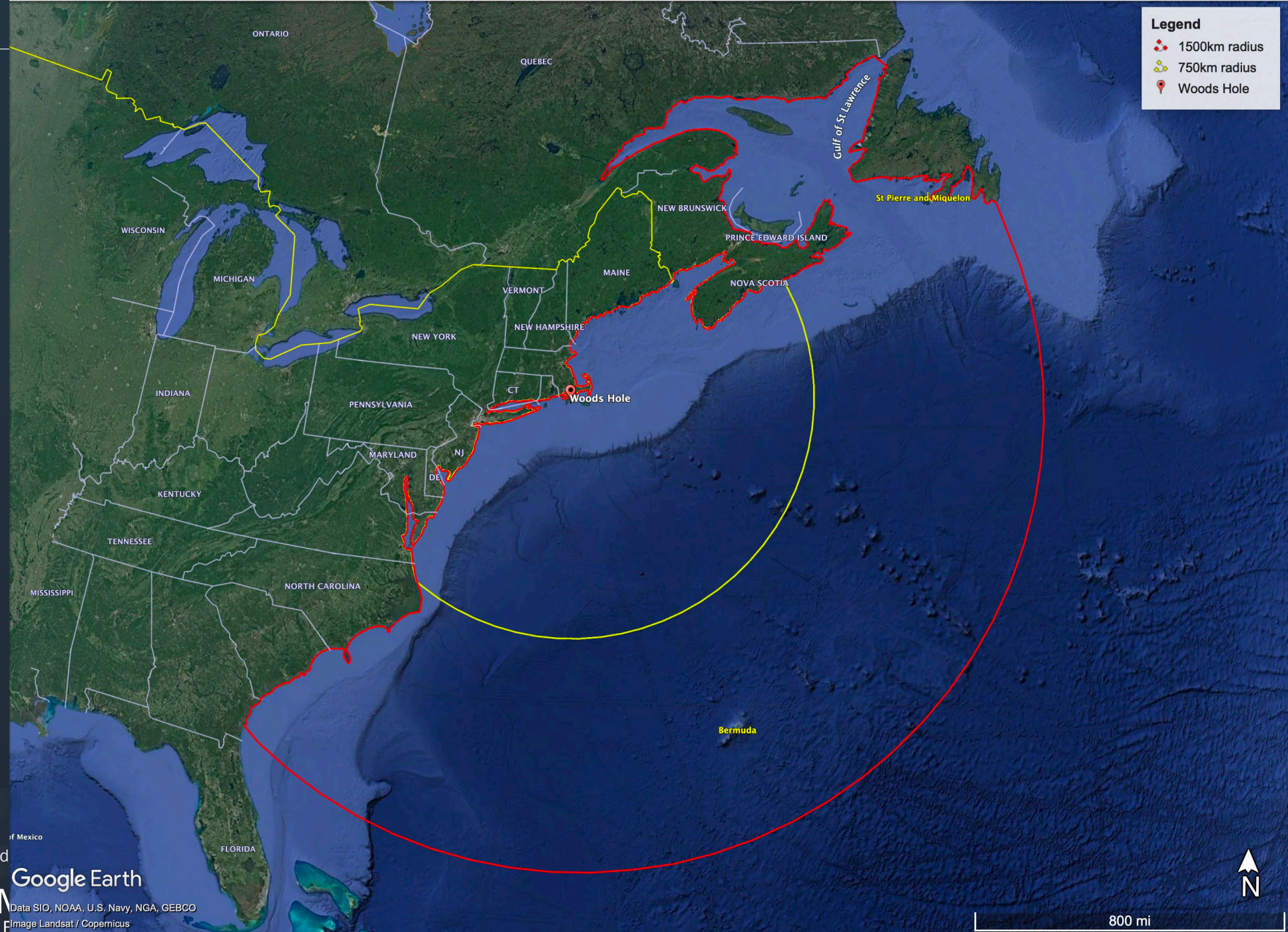
Illustration of the AUV's horizontal zigzag tracks alternating in westward and eastward sweeps between a western bound and an eastern bound. Over the duration of the sweeps, the front moved southward. On every instance of front detection, the vehicle continues flight for a prescribed distance (marked green), and then turns an oblique angle to fly back to the other water column. When the AUV reaches the western bound, it reverses course.



In one mission on 25 June 2021, LRAUV *Polaris* detected and passed through the salinity-intrusion front five times. Front detection on each transect is shown in Fig. 8, with corresponding transect numbers.

(Figures courtesy of Yanwu Zhang, MBARI and not for distribution)

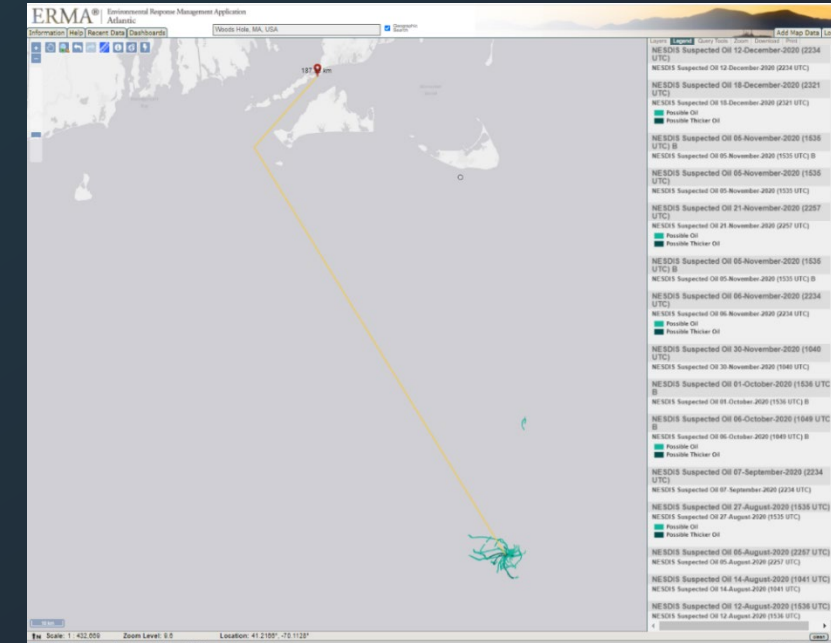
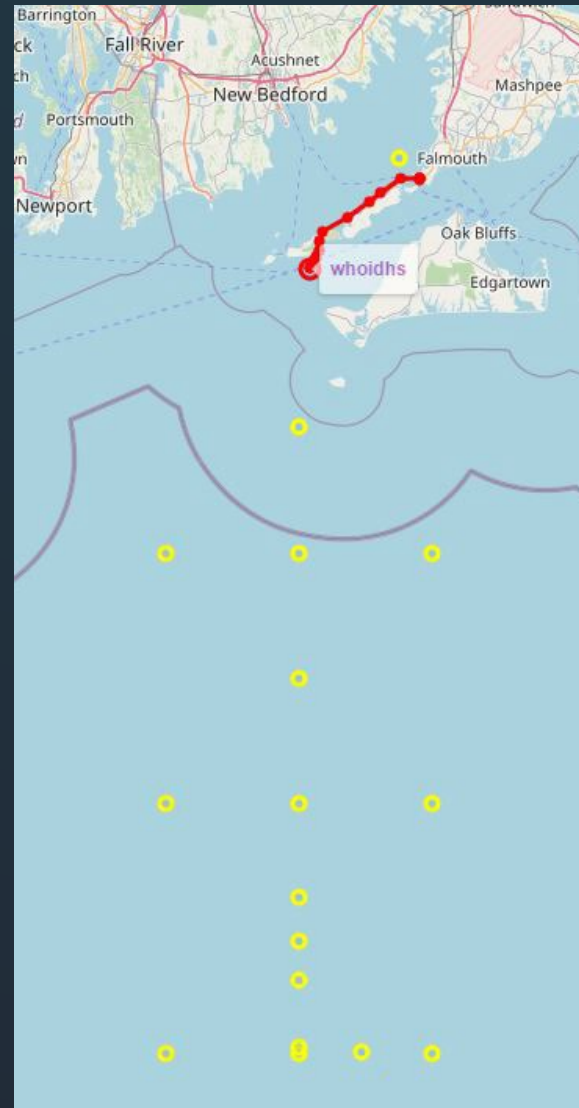
What you can expect: Bermuda, anyone?



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Long-range adds versatility: Wreck 1487

- Overview of over-the-horizon mission – Shipless Operations

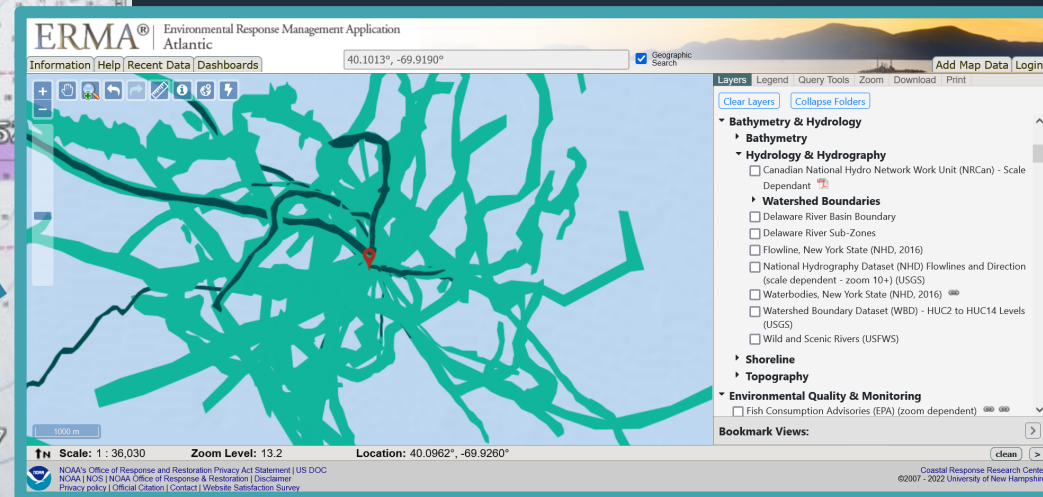
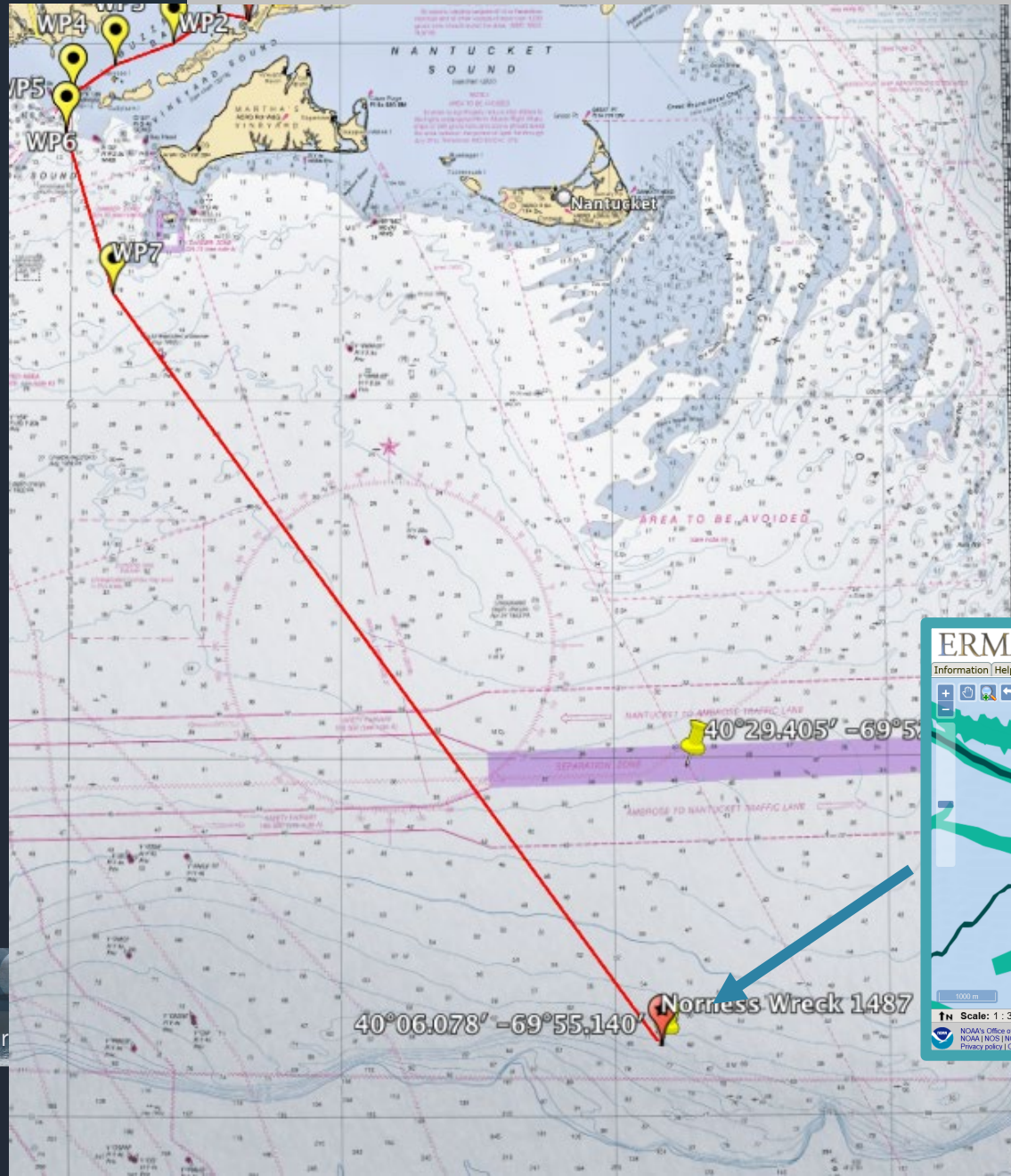


188 km from Woods Hole shipwreck actively leaking oil...in LRAUV wheelhouse (Scott Lungren (NOAA))

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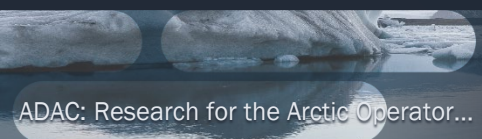
Long-range adds versatility: Wreck 1487

- 13 day mission out to the shelf break and back with LRAUV
- Started out as a find-the-oil mission
- A Nor'easter hit the area and we reprogrammed to yo-yo to collect storm impact data on T&S



Where we are going: Growing Applications!

- Fly away capability with rapid response for oil spills, sunken ships (etc.), pipe leaks, seafloor mapping, habitat monitoring, measuring soundscapes (weather, whales, etc.), long-range shipless surveys, open ocean, fresh water and under-ice capabilities over-the-horizon data relay, 24/7 operator response
- Center of Expertise
- Go to for help...it's already happening...USCG, NTSB, NOAA, USGS, Science community...



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Project LRAUV: Schedule and Metrics

- ✓ Fabrication of a second platform (Stella) Conducted Arctic Readiness Testing, *over-the-horizon testing, docking and acoustics*
 - ✓ Three buoy system completed- one buoy is HF, two LF
 - ✓ Docking/Undocking reliability ~60% and a new cold weather gear box has been switched out
 - ✓ Comms reliability (antenna/buoy/Dash)
- ✓ Provide training and familiarization of LRAUV to USCG
- ✓ Develop software for *improved operator system interface*
 - ✓ Backseat is integrated, new sensors can be integrated.
 - ✓ Multibeam is integrated
 - ✓ Inertial navigation is integrated
 - ✓ Dash operator Portal is complete at LRAUV.WHOI.EDU and receives monthly updates/improvements

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Project LRAUV: Planned Research Outcomes

Planned outcomes of the research:

- A helicopter portable Long Range AUV, for under-ice and over-the-horizon shipless anomaly and oil detection with deployable Arctic buoys for aided navigation, remote communication and docking; around-the-clock expertise available and training with a TRL 6/7 system ready for low-rate manufacturing and payload capability expansion.

Additional research identification:

- Service for hire
- Interest in commercialization
- Interest in scientific community to use and develop tech (BSEE, EPA, NOAA, etc.)
 - (more vehicles, deeper ratings, recharge capabilities)

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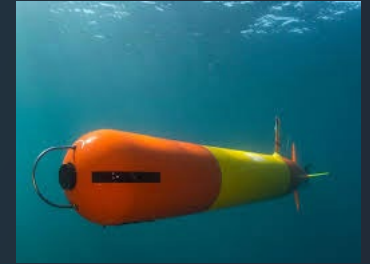


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- **What** needs improvement or is missing?
 - Sensing of oil against the ice and seafloor and high latitude testing
 - More sensor payloads-Echosounders, Cameras, Water sampling, energy harvesting
 - More operational time for shake-down and training
 - Software development (behaviors) and backseat autonomy
 - System upkeep funding
 - LARS for helicopter---have ideas
 - How can we be ready and respond to current events?
- **Who** should we connect with to improve odds of success?
 - Engage with USCG operators early and frequently
 - Broaden R&D support
 - Be a part of oil spill technology and response meetings
 - Need to coordinate field operations with first responders and fill technology gaps that are identified
 - Continue to connect with alternative funding sources like ONR, NOAA and BSEE to help fund operations and sensor development (methane, what else?)
 - **Need more vehicles**



Input on future from you: Do we need 2, 5, 10 vehicles?

Transition...

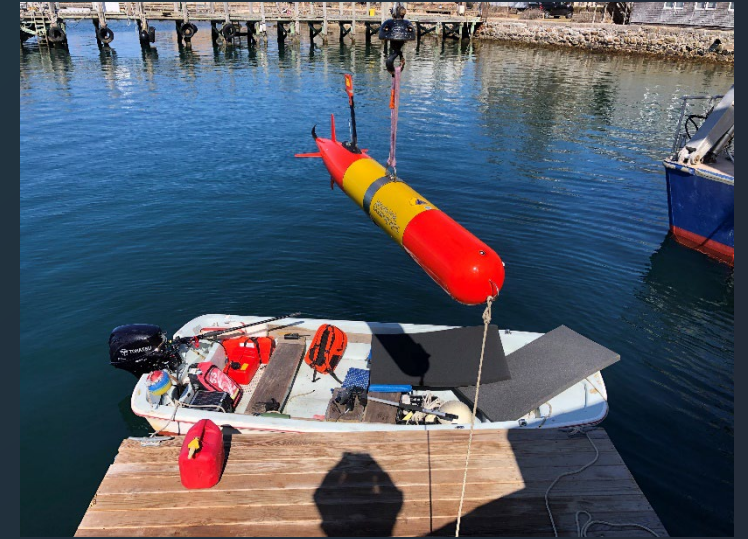


- Persistent observations on the order of weeks and spanning 10s–100s of km
- Relevant observations require comprehensive sensing capabilities and investment

Project LRAUV: Transition Plans

Two-Stage Transition Plan:

1. Build one or more systems to support USCG complete with successful open-water and under-ice demonstrations. WHOI trains USCG operators with support funding. WHOI can support USCG on site or remotely via iridium vehicle communications as needed. 24 hr support possible.
2. Commercialize resulting platform: Based on lessons learned from (1), prepare the system for commercialization by accessing WHOI CMR fabrication resources. LRAUV was not designed for efficiency of manufacturing and rapid prototyping, therefore revisiting AUV design is a top priority.



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Project LRAUV: Transition Plans

Pathway to Transition:

- *Create an operational system that the USCG can use for characterizing spills in ice-covered ocean environments. Transition advantages of the LRAUV platform:*
 - Contains commercially available sensors
 - Can be replicated for the USCG
 - Has a proven vehicle design and proven reliability
 - Sensor commonality



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Project LRAUV: Transition Plans

Transition Plan includes the following:

- **Facilities:** WHOI operates facilities for fabrication, testing, logistics (on-ice support) and platforms such as ALVIN
- **Service for-Hire:** Operators and AUV's such as the REMUS are available for hire and also have been transitioned into both the Navy and commercial sectors
- **Hardware Builds:** WHOI has a history of replicating systems and training end users
- **Commercialization:** Demand for WHOI built systems may occur through spin-off companies or through licensing the technology to a commercial entity. (example: Hydroid Kongsberg with REMUS and Bluefin from MIT, Bellingham)

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LRAUV Ready for questions

