ADAC Year 5 Annual Meeting
ADAC Project Briefing
(LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards

A presentation by
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ADAC Project (Name): (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards

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- Woods Hole Oceanographic Institution
- Supporting Team: Daniel Gomez-Ibanez, Sean Whelan
- 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
LRAUV: Description and Baseline

• **Project Description**: To develop an Autonomous Underwater Vehicle (AUV)-based approach leveraging a small, reliable system, called the Tethys Long-Range AUV (LRAUV). The LRAUV is helicopter portable, carrying an environmental mapping payload, allowing rapid response to provide situational awareness and damage mitigation for first responders/USCG.

• **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 LRAUV: Relevance and Method

• **Relevance to DHS and USCG:** This project’s goal is to create a rapidly deployable platform for oil spill characterization in ice-covered oceans that has minimal logistical overhead. 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 maximize operational capability, minimize logistical support and operate autonomously.

• **Research Method:** Our approach is to leverage an existing 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 team remotely.
Tethys LRAUV Specifications

**Short Nose**

- Mass: 110 kg (240 lb) dry weight
- Size: 0.3m (12”) diameter, 2.47m long
- Speed: 0.5 – 1.2 m/s plus hover
- 400 Ah energy, ~1.1 Ah/hr, ~3 km/hr, .83 m/sec ~15 days, 1000 km

**With 3G ESP Nose**

- Mass: 160 kg (354 lbs)
- Size: 3.18 m long
- Speed: 0.5 – 1.0 m/s plus hover
- 400 Ah energy, ~1.5 Ah/hr, ~2.5 km/hr, 11 days, 670 km

Core sensors: DVL/ADCP, Fluorometer/Backscatter (Wetlabs), CTD (Seabird), PAR, O2

Iridium, GPS, WiFi and Cellular in mast

Backup argos and VHF

Buoyancy Engine allows neutral drift in water column - 1 Liter

Efficient low-speed propeller

Paired Rudder and Elevator Control Surfaces

Core sensors: DVL/ADCP, Fluorometer/Backscatter (Wetlabs), CTD (Seabird), PAR, O2

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Buoyancy Engine allows neutral drift in water column - 1 Liter

Efficient low-speed propeller

Paired Rudder and Elevator Control Surfaces

6 kWh rechargeable, 11 kWh expendable

Shifting Mass allows controlled angle of attack during flight

3G ESP Sampler Module

Load Control System

18 configurable channels isolates load, circuit breaker, ground fault detection

Short Nose

With 3G ESP Nose
Why is **LRAUV** a smart choice?

- Uses commercially available off-the-shelf sensors (COTS) to easily merrily data.

- Has a proven variable ballast system and mass shifter making it the only propeller-driven AUV in the world that can drift, hover and accurately navigate to tell you exactly where an anomaly is.

- Has reliably operated remotely for weeks at a time for more than eight years
Project LRAUV: Schedule and Metrics

YR5 Accomplishments:

- Integrated arctic/oil science payload on LRAUV; 100%
- Conducted open water testing and plume mapping/training exercise at MBARI (September 27, 2018); 100%
- Developed LRAUV mission simulations with Bulgar site current data 100%
- Designed arctic buoys (LBL, USBL, ACOMMS, WiFi, RF, Iridium, thermistor) 100%
- MBARI is performing further offshore testing of vehicle; Ongoing
- Implementation and testing umodem and USBL functionality (WHOI/MBARI/Intuaware); 65%
- Implementing LBL navigation capability; 5%
- Building three* arctic buoys; 99%
- Developing firmware for buoys for three subsurface capabilities (LBL, USBL, ACOMMS) 40%

LRAUV can be launched from a cell phone
Project LRAUV: Schedule and Metrics

• Current year research schedule and milestones:
  • Planning **Santa Barbara Seeps** Expedition for June 80%
  • Develop mission macros for plume mapping 50% always ongoing as we learn
  • **Build vehicle boat launcher** 0% not in SOW
  • Planning under-ice expedition 5%
  • Evaluate data, software enhancements, training: June 30 2019...
  • Low cost vehicle evaluation: June 2019...
  • Transition Plan: June 2019...
Project LRAUV: Relevance and Method

Projected - Perform low cost vehicle study at DunkWorks

- **Reduced Cost Vehicle Fabrication:** Using WHOI’s maker space known as Dunk Works, the WHOI LRAUV team along with designated student interns accomplished the following in order to reduce vehicle costs:

- Evaluate LRAUV BOMs and identify machined parts that can be 3D printed with less people labor and less expensive materials.

- Produce drawings and prototypes of vehicle components, such as chassis, end comes, end caps, vehicle shells, etc.

- Evaluate third party licensing of the LRAUV with MBARI approval.

(Demo goes here)
Project LRAUV: Scientific Metrics

- Current year metrics:
  - Ability to map environment in 3D;
  - Detection and quantification of dissolved particles;
  - Determine the physical ocean environment (and determine acute/critical variables, such as assessing hypoxia of the water column in/near spill area);
  - Take CTD measurements;
  - Simulator fidelity for development, mission testing, and operator training.

Heat Maps from Sea Owl
Project LRAUV: Metrics

Current year metrics:

- Navigation performance:
  - Drift rate: percentage of distance traveled. Target: < 0.5%
  - Error bounding: can navigation drift be constrained, e.g. by ranging from a fixed beacon (arctic buoys /image).
Project LRAUV: Metrics

- Current year metrics:
  - Performance-specific measures:
    - Detection level of oil: measured in terms of minimum sensitivity Target: < 80 ppb.
    - *Range and endurance: Target: 300 km on secondary (chargeable) batteries, >twice that on primary (disposable).
    - Adaptive sampling performance- mapping of spill extent: Target: Area coverage 1000 km² per vehicle deployment (lane spacing TBD, e.g. 30 km x 30 km, 1 km grid).
  - Operator ease of use:
    - Logistical footprint: number of operators required on site, number of kilograms to be transported. Target: 2-3 and < 600kg.
    - Ease of mission configuration: time to specify grid survey: Target: < 1 hr.
    - Ease of remote interaction: training time required for operators: Training: < 1 week.
Tethys Dash accessible from anywhere: https://okeanids.mbari.org/dash3/#/data
Planned outcomes of the research:

- A portable Long Range AUV, for under-ice 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 7/8 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.)
LRAUV: Key Accomplishments

The MBARI/WHOI team has combined the best AUV technologies from two successful AUV systems to make a custom Arctic capable platform:

- Designed custom LRAUV and vehicle agnostic arctic buoys; (WHOI)
- Built an operational LRAUV for oil detection; (WHOI/MBARI)
- Developed Vehicle current modeling simulator; (ADAC/WHOI/Intuaware)
- Evaluated COTS sensor packages (split beam, multibeam, methane, optics); (WHOI)
- Performed two vehicle demonstrations to stakeholders (WHOI, MBARI);
- Presented and published two IEEE papers on our research; (WHOI)
- Built collaborations with EPA, NOAA and BSEE; (WHOI)
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
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)
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.
LRAUV Ready for questions

- **What needs improvement or is missing?**
  - Sensing of oil against the ice and seafloor
  - More sensor payloads—Bathymetric sonar, Cameras, Water sampling
  - Lower vehicle costs, 3D print internal chassis
  - More operational time for shake-down and training
  - Software development (behaviors)

- **Who should we connect with to improve odds of success?**
  - Engage with USCG operators early
  - Broaden R&D support
  - 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?