**ADAC Project:** Development of Propeller Driven Long Range Autonomous Underwater Vehicle (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards

- Project Principal Investigator(s): PI Dr. Jim Bellingham (WHOI), Co-PI/PM Amy Kukulya (WHOI), Co-PI Brett Hobson (MBARI)
- Lead Institution: WHOI
- Supporting Team: Dr. Chris Reddy (Project Scientist)
- Student Participation: Hiring
- Project Champion: Kirsten Trego, HQ USCG MER
- Project Support: Jeff Wheeler, CG-731
- Project Advocates: CAPT Tom Meyer, CG-761, Dr. Robyn Conmy, EPA USEPA/NRMRL/RTEB, USCG Research and Development Center, Dr. Jay Choy BSEE/Oil Spill Preparedness Division
AUV Odyssey on the R/V Palmer of Anvers Island.

January 1993.
ADAC Project (LRAUV): Description and Baseline

- Project Description: To develop an Autonomous Underwater Vehicle (AUV)-based approach leveraging a small, reliable COTS 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 and minimize logistical support and operate autonomously.

- Research Method: Our approach is to leverage an existing Long-Range AUV developed at MBARI (the Tethys LRAUV), and to modify that system to operate under ice. Attractive features include its extended endurance (one to three weeks), comparatively small size (the standard vehicle is 125 kg dry), and its ability to be operated by a remote support team via an Iridium communication link, all by using commercially available off-the-shelf sensors (COTS).
**LRAUV: Research Methods**

- **Prior:** Selected, integrated and tested oil detection sensor; designed arctic science payload and identified arctic payload; integrated sensors on COTS REMUS and conducted mapping/training exercise; developed LRAUV mission simulations

- **Current:** Finishing EE and ME BOMs and fabrication; building subassemblies; building Arctic LRAUV at MBARI

- **Projected:** Bench test and water test LRAUV @MBARI; Accept vehicle delivery from MBARI to WHOI; Develop documentation and wiring diagrams for Arctic payload; Conduct open water field trials @WHOI; Train members of USCG; Finalize transition plan
LRAUV: Methods

Observation requirements for the AUV system include:

• Ability to map in 3D
• Extended unattended deployment (days to weeks)
• Detection and quantification of dissolved particles and fluorescent material.
• Environmental characterization: e.g. CTD, currents.
• Remote operation of the vehicle is enabled by Iridium.

• Operators interact with the vehicle via an Iridium satellite link, recovering data snippets in near real-time and sending new mission commands to the vehicle as desired. Communications with the vehicle are possible when it surfaces – or communicated through an Arctic buoy, at intervals that are determined by the operator. Over several years of operation, a web-based operator’s portal has been developed (http://aosn.mbari.org/TethysDash/) which includes a display of science and engineering data.

• On a secure portion of the site, there is a command interface and a variety of utilities such as an alert page, where operators can configure alerts to be sent to email or mobile phones on certain conditions.
Project (LRAUV): Schedule and Metrics

Current year research schedule, milestones and metrics:

• ML4-1: Fabricate LRAUV
  A. Complete Design of Arctic Payload: November 2017
  B. Complete Bill of Materials (BOM): November 2017
  C. Order/Fabricate Parts: December 2017 (85% complete)
  D. Assemble Platforms: Begin 13 November and continue through March 2018

• ML5-1: Complete water testing of LRAUV
  A. Conduct sea trials at MBARI: April 15
  B. Pass factory acceptance test and deliver to WHOI: 30 April
  C. Conduct extensive testing of software and payload at WHOI: 1 June
  D. Conduct training Demo at WHOI: 15 June
• ML5-2: Process the data and fine tune navigation algorithms from testing missions, June 30

• ML5-3: Finalize vehicle documentation, 30 June
  A. Complete manual to include schematics and operational protocol/planning
Project LRAUV: Planned Research Outcomes

• Planned outcomes of the research: Completed and operational 300-meter rated LRAUV 300 vehicle with a science/oil mapping payload capable of unattended surveys up to three weeks in open ocean and Arctic ice conditions (with primary batteries). LRAUV will be capable of adaptation to incorporate new payloads and mission scenarios. LRAUV will give the USCG the latest and proven AUV technology not currently available to them for quick response and mitigation.

Please identify concluded research identification:

• Once project is completed...LRAUV can be more efficiently fabricated and, if demand exists, move to commercialization. One or more systems will allow for broader based use whether as a deliverable to the government, or a WHOI operated vehicle that can ‘respond’ and ‘deploy’ as a crisis occurs.
• Additionally, monies are being allocated to WHOI by BSEE, through NOAA, for sensor development and acquisition for oil mapping and characterization for REMUS AUVs. These sensors can also be integrated onto LRAUV at small costs.
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
  - Available to the government on a royalty-free basis
  - Can be readily replicated for the USCG
  - Has a proven vehicle design and proven reliability
LRAUV: Transition Plans

- Transition options 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)
Ecosystem of Robotics Companies

Research institutions have spawned a growing network of robotics companies.

July - Entrepreneurship Leadership Forum for Marine Robotics (WHOI, CMR)
Documentation

ROS (Robot Operating System) provides libraries and tools to help software developers create robot applications, provides hardware abstraction, device drivers, libraries, visualizers, message-passing, package management, and more. ROS is licensed under an open source, BSD license.

ROS:
- **Install**
  - Install ROS on your machine.
- **Getting Started**
  - Tutorials, technical overview, and links to getting help. Also, check out the @ROScheatsheet.pdf
- **Contribute**
  - How to contribute to the ROS community, such as submitting your own repository. See the c ROS PR; for what others are doing. There are active Special Interest Groups where you can find more focused discussions about topics within ROS.
- **Support**
  - What to do if something doesn't work as expected.
- **Mirrors**
  - Mirrors of this wiki.

Software:
- **Core Libraries**
  - APIs by language and topic.
- **Common Tools**
  - Common tools for developing and debugging ROS software.
- **Search Software**
  - Search the 2000+ libraries available for ROS.
• Strawman 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. As USCG develops expertise, full operational capability can be transitioned. Additional vehicles can be built on demand.
WHOI AUVs have a long history of commercialization and transition into militaries
Aligning Investments

• Vehicle R&D
  • Massachusetts State: “Robots to the Sea” project created DunkWorks accelerated prototyping/advanced manufacturing center established (initial funding $700k out of $5M). Bellingham
  • Moore Foundation: seed funding for “Meta-Modular Vehicles” (initial funding 200k). Bellingham
  • Eastman Chemical Co.: informal collaboration on additive manufacturing materials for marine vehicles. Bellingham

• Oil spill sensing:
  • BSEE: REMUS observations near Taylor platform (August 2017) Kukulya.
  • BSEE: Integrating suite of sensors for REMUS, including holocam (proposed 650k). Kukulya
Feedback...

- What needs improvement of is missing?
  - Sensing of oil against the ice or on seafloor
  - Bathymetric sonar
  - Water sampling
  - Lower vehicle costs
  - More operational time for shake-down and training
  - Ice buoy

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