Arctic Domain Awareness Center (ADAC)

A DHS Science and Technology Office of University Programs,

Center for Maritime Research

ADAC Annual Performance Report for Program Year 3

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ADAC submits the below report to U.S. Department of Homeland Security, Science and Technology Directorate Office of University Programs. *This ADAC Program Year 3 report complies with terms and conditions of ADAC Cooperative agreement to the University of Alaska Anchorage.* Additionally:

...
• ADAC certifies no Patentable Inventions during the budget period.
• ADAC has reviewed existing Center’s Information Protection Plan and Researcher Safety Plan. ADAC offers no new updates to these existing documents.

I. SUMMARY REPORT ON ADAC’s STRATEGIC VISION AND ACTIVITIES

ADAC Program Year 3, a year of refining and advancing relevant research in science and technology, arrayed to U.S. Coast Guard and other DHS Arctic maritime missions.

The Arctic continues to gain strategic importance nationally and globally. Among its many missions, the United States Coast Guard (USCG) provides the nation’s visible presence across America’s maritime reaches in the Arctic. This includes providing security to U.S. National Interests in the Arctic, effective law enforcement in ecologically sensitive waters and safety to mariners operating in some of the most challenging seafaring regions on the planet.

In January 2017, the International Maritime Organization (IMO) Polar Code, following years of careful coordination, enacted important safety measures designed to protect current and future Arctic maritime operations. In early May 2017, following 2 years of leading the Arctic Council and advancing a number of policy improvements to international Arctic cooperation, the United States transitioned the Chairmanship to Finland. The IMO Polar Code and recent advances in international Arctic cooperation provide useful mechanisms to help the United States and other cooperating nations to provide for a safer and more secure Arctic. These measures are particularly important as interest and activity across the region continues to rise.

Economic interest of the Arctic continues to advance. Consistent with leveraging seasonal diminished levels of sea ice across the Arctic basin, industry efforts to conduct resource extraction, fisheries, destination tourism and shipping in the Arctic region continue to gain strength.

As trends indicate, human activity across the Arctic continues to rise in diversity and volume. As more people come to the Arctic, the overall preparedness of those who come appears to be declining resulting in increased activity for the U.S. Coast Guard to conduct search and rescue, humanitarian assistance missions or to respond to disaster. Additionally, as more people come to the Arctic, the reasons for their arrival become more diverse resulting in increased need for vigilance in enforcing laws and regulations.

As a U.S. Department of Homeland Security, Science and Technology Office of University Programs, (DHS S&T OUP) Center of Excellence in Maritime Research, the Arctic Domain Awareness Center (ADAC) orients science and technology, research and development to support the USCG as they conduct their statutorily assigned missions in the Arctic.

This report describes the 3rd year of project work by ADAC conducted from 1 July 2016 to 30 June 2017. In addition to specific details on individual projects, the report also provides a recap of Center activities.
for this period. This report corresponds to reflect results in overall program and individual projects approved by DHS S&T OUP in ADAC’s Program Year 3 Workplan.

ADAC’s principal customer is the USCG. ADAC investigates operational shortfalls and gaps and orients research activity to support USCG needs, particularly related to USCG missions in support of Arctic search and rescue, humanitarian assistance, disaster response and security matters. While principally oriented to the USCG, ADAC also seeks to support other DHS maritime mission needs in the Arctic. As a university-hosted research venue, ADAC supports student education. Through the Center’s Fellows Program, ADAC provisions student research, internships and entry into the Homeland Security Enterprise (HSE).

ADAC’s approach is to align the Center’s research agenda with U.S. national, DHS, and USCG Arctic strategies and strategy implementation plans. ADAC notes existing strategies may change and DHS strategy for the Arctic remains in development. As the U.S., DHS and USCG strategies adapt (as well as associated strategy implementation plans); ADAC will seek to conform Center research activities to these changes.

At the core, ADAC strives to benefit the U.S. Coast Guard Arctic operator and corresponding command echelons. The goal of ADAC’s research is to improve the quality and accuracy of operational decisions, improve mission effectiveness, and/or reduce risk. Ultimately, ADAC’s efforts are to conduct research and deliver solutions to assist USCG in saving lives, reducing property loss, preserving and protecting national resources, and secure the maritime approaches to the U.S. Arctic shorelines.

As specified in ADAC’s Program Year 3 Workplan, the University of Alaska (both Anchorage and Fairbanks campuses) serves as the Center’s hub. ADAC’s hub connects to an array of partner and contributing universities and industry research associates. Throughout Program Year 3, ADAC worked diligently in cultivating a collaborative network with federal, state, local and tribal agencies, and international colleagues seeking to advance Arctic maritime research.

As stated in prior year research reports, ADAC’s Program Year 3 research and development conducted by the Center will not only serve the USCG and other DHS maritime missions, but will also benefit a number of ADAC partners and collaborators as well as support the public good. As planned and conducted, ADAC’s vision, mission and strategy approved for the Center in Program Year 3 was as follows:

**Vision:** The DHS Center of Excellence providing networked and mission-focused support to the USCG Operator in the High North. ADAC seeks to become a national center of Arctic maritime research.

**Mission:** ADAC’s mission is to develop and transition technology solutions, innovative products and educational programs to improve situational awareness and crisis response capabilities related to maritime challenges posed by the dynamic Arctic environment.

**Strategy:** The Center’s strategy for ADAC Program Year 3 initiated on 1 July 2016 was to advance knowledge in relevant science and technology through conducting research and development in close
collaboration with mission agencies and end users. The Center also sought to develop future leaders for the DHS enterprise through structured and well-led programs.

**ADAC’s specific research activities approved for Program Year 3.** ADAC started Program Year 3 on 1 July 2016 with management approval. The Center received further project approvals on 12 July 2016 and corresponding DHS S&T OUP Notice of Award on 25 July 2016 for the following research:

- Community Based Observer Networks for Situational Awareness (CBONS-SA);
- High-Resolution Modeling of Arctic Sea Ice and Currents (HIOMAS);
- Arctic Oil Spill Modeling (AOSM);
- Identifying, Tracking and Communicated Sea-Ice Hazards in an Integrated Framework;
- Arctic Information Fusion Capability (AIFC);
- Low Cost Wireless Remote Sensors for Arctic Monitoring and Lifecycle Assessment;
- Development of Propeller Driven Long Range Autonomous Underwater Vehicle; (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards.

ADAC received subsequent approval for the following project on 25 October 2016:

- Ice Condition Index (ICECON) for the Great Lakes.

ADAC received Integrated Education Outreach (and Workforce Development) approval on 25 October 2016 with the following project approvals:

- Minority Serving Institution (MSI) and Significant Minority Enrollment (SME);
- Integrated Arctic Maritime Education (Principally oriented via Summer Research Interns).

ADAC received the following final project approval for Year 3 on 11 January 2017:

- Arctic Education Implementing the Arctic Strategy in Training.

**ADAC’s partner Academic/Research Institutions.** The following universities or research institutions contributed to ADAC’s Center efforts or individual research projects in Program Year 3:

- Maine Maritime Academy (MMA);
- Texas A&M University (TAMU);
- USCG Academy Center of Arctic Study and Policy (CASP);
- University of Alaska Anchorage (UAA);
- University of Alaska Fairbanks (UAF);
- University of Idaho (UoI);
- University of New Mexico (UNM);
- University of Texas, El Paso (UTEP);
- University of Washington (UW);
- Woods Hole Oceanographic Institution (WHOI);
- Monterey Bay Aquarium Research Institution (MBARI).

**Industry Partners.** The following are the industry or business enterprises who contributed to ADAC’s Center efforts or individual research projects in Program Year 3.

- ASRC Federal Mission Solutions (ASRC FMS);
A summary of ADAC Activities. The timeline below provides a list of major Center activities conducted throughout Program Year 3: The majority of these activities comport to ADAC’s long-range schedule, established in the Center’s SHS S&T OUP approved workplan. This summary highlights ADAC’s management strategy to engage and iterate research initiatives with the Center’s principal customer, the U.S. Coast Guard, as well as other members of the U.S. Federal, State and international government officials. The Center also collaborated with the community of Arctic maritime research, prepare and conduct activities expected of DHS S&T OUP, while accomplishing planned research and developing students to serve in the Homeland Security Enterprise.

18 July – 5 August 2016: ADAC hosted a U.S. Air Force Academy Summer Intern. Intern conducted a 3-week interdisciplinary course of study between UAA and UAF, which included orientation training facilitated by ADAC to Joint Base Elmendorf-Richardson.

21 July 2016: ADAC Principal Investigator and Executive Director conduct radio interview with KUAC FM 89.9 at ADAC facilities at UAA, Anchorage, Alaska.

27 July 2016: ADAC hosted U.S. Customs and Border Protection (CBP) Intel Division delegation for comprehensive information briefings. These briefings resulted in follow-on requests for continued program and research project updates. Accordingly, ADAC has provided periodic updates to CBP.

3 August 2016: ADAC provided information briefing to U.S. Northern Command/North American Aerospace Command (USNORTHCOM/NORAD) Maritime Domain Awareness conference (via video conference). Briefing resulted in several follow-on teleconferences with USNORTHCOM J-8 Science and Technology Directorate on ADAC’s program progress.

27 July 2016: ADAC Arctic Information Fusion Capability project re-establishes Community of Interest weekly teleconferences. AIFC Project Manager hosted these weekly teleconferences over the remainder of Program Year 3.

8 August 2016: ADAC hosted discussions with U.S. Northern Command Deputy Commander, LTG Dan Hokanson.

10 August 2016: ADAC conducted its first Year 3 Customer’s and Partner’s Roundtable via teleconference. The Center received positive and constructive feedback from key USCG “customers” at HQ USCG, USCG RDC, Pacific Area and District 17. ADAC also received favorable feedback from the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), Federal Bureau of Investigation (FBI), The
Oceanographer of the Navy Offices, U.S. Office of Naval Research (ONR), U.S. National Ice Center, Canada Department of National Defense and State of Alaska, plus a number of fellow universities.

15-16 August 2016: ADAC participated in DHS S&T OUP Research and Technology Transition Workshop, University of Minnesota, Minneapolis, Minnesota.

18 August 2016: Co-investigator of Arctic Information Fusion Capability (AIFC) project at UAF departed the project. AIFC project continued with single PI at UAA and established AIFC Project Manager at ASRC Federal Missions solutions.

22 August 2016: ADAC established a full time Education Outreach and Workforce Development Director, Ms. Clarice Conley. This addition aided efforts to improve Center’s student support.

22-23 August 2016: ADAC participated in Exercise Arctic Chinook, a joint USCG/DoD sponsored Search and Rescue exercise in direct support of the U.S Chairmanship of the Arctic Council. Execution was an interagency evolution, with international, state, local and tribal participants, with international observers.

22-26 August 2016: ADAC’s Community-Based Observer Network for Situational Awareness (CBONS-SA) conducted field test near Tin City, Alaska. Field test supported the usefulness of High Fidelity Observers reporting observations using Field Information Support Tool (FIST) in remote regions with no existing communications.

25 August 2016: ADAC hosted HQ USCG Assistant Commandant for Capabilities (CG-7), RDML John Nadeau and his executive assistant, CAPT Tom Meyer. ADAC provided baseline understanding of Center research endeavors to a key USCG customer.

30 August 2016: ADAC submitted Center’s Program Year 2 Annual Report to DHS S&T OUP Program Manager.
7 September 2016: ADAC participated in University of Alaska Fairbanks comprehensive collaboration with Sandia National Laboratories. These briefings established mutual interest between ADAC and Sandia in seeking joint research opportunities. Throughout Program Year 3, ADAC continued a collaborative dialogue with Sandia Laboratories, to include discussions in Sandia supporting ADAC’s planned Arctic Summer Internship, planned for June 2018 at Point Barrow Alaska.

7 September 2016: ADAC released Arctic IoNS Rapporteur’s Report and DHS S&T OUP approved Request for Proposal (RFP) to a wide array of academic and industry research networks assisted by DHS S&T OUP communications. The Rapporteur’s Report provided a comprehensive overview of ADACs 21-22 June 2016 Arctic IoNS workshop to identify research gaps/questions centered around mass rescue operations from disabled cruise ship in the Arctic. The associated RFP provided a funding opportunity for academic and industry researchers to respond to USCG validated research questions presented in the Rapporteur’s Report.

13 September 2016: ADAC hosted collaboration meetings with National Space and Aeronautics Administration’s Arctic Collaborative Environment team (NASA-ACE). Following the meeting, NASA proceeded to develop a Memorandum of Understanding with DHS S&T regarding collaboration with ADAC.

22 and 23 September 2016: In accordance with approved Program Year 3 work plan, ADAC conducted its first Program Year 3 Quarterly Review.

26-27 September 2016: ADAC finalized prior planning and participated in USCG Academy’s Center of Arctic Study and Policy (CASP) Governing the Waves International Workshop on Best Practices in Maritime Governance at Bowdoin College, Brunswick, Maine. ADAC provided in-kind support and facilitation for the workshop along with fiscal assistance from University of Alaska.

28 September 2016: ADAC conducted sub-recipient on-site visit at Maine Maritime Academy in Castine, Maine.

Figure 2. ADAC ED receiving instruction by Maine Maritime Academy Cadet on Icebreaker duties associated with understanding of IMO Polar Code certification requirements.

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29 September 2016: ADAC conducted sub-recipient on-site visit at Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts and conducted technical planning for Long Range Autonomous Under Water Vehicle (LRAUV) proof of principal test, Buzzards Bay, Massachusetts.

5 October 2016: ADAC met with National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration and mutually agreed utilize NOAA’s Arctic Environmental Management Application (Arctic ERMA) as part of the Center’s Arctic Information Fusion Capability end-to-end project.

11 October 2016: ADAC conducted a Center overview to Bureau of Ocean Energy Management (BOEM), Department of the Interior via teleconference.

13 October 2016: ADAC conducted a Center Program Year 3 Project Champions overview teleconference. This teleconference was in response to a request by USCG Project Champions to have a dedicated teleconference apart from the larger Customer’s and Partner’s Roundtable venue.

14 October 2016: ADAC received 12 proposals responding to the disabled cruise ship scenario Arctic IoNS RFP. Following, the Center reviewed and provided the proposals to DHS S&T OUP Program Manager for review. ADAC subsequently provided a scoring rubric and proposed reviewers for the science review portion to assess the proposals.

20 October 2016: ADAC conducted Customer’s and Partner’s Roundtable via teleconference.

26 October 2016: ADAC hosted HQ USCG Arctic Planners to provide a comprehensive Center overview at ADAC facilities in Anchorage, Alaska.

31 October 2016: ADAC conducted a Center overview briefing to White House Director of Office of Science and Technology Policy and the White House Arctic Executive Steering Committee in Washington, DC. This was in response to a request ADAC received from the Executive Director of the Arctic Executive Steering Committee.

1 November 2016: ADAC participated at Maritime Security Center, Stevens Institute, Annual Meeting, at Ronald Reagan Building, in Washington, DC.

2-3 November 2016: ADAC planned and conducted LRAUV Proof of Principal Demonstration with WHOI and USCG Research and Development Center, in Woods Hole, Massachusetts. Demonstration met or exceeded planned test objectives.

4 November 2016: ADAC participated in USCG Research & Development (R&D) Center Roundtable meeting in New London, Connecticut. The roundtable advanced both ADAC and USCG R&D Center’s mutual interests in Arctic related research to include discussions on USCG’s Vertex studies and ADAC’s LRAUV project.
7 November 2016: ADAC conducted a roundtable with U.S. National Ice Center (USNIC) in Suitland, Maryland. Ice Center director and staff signaled strong interest in ADAC partnership. Subsequent to the meeting, the USNIC director agreed to serve as an ADAC Executive Counselor.

9-10 November 2016: ADAC conducted its Annual meeting in Alexandria, Virginia. ADAC leadership, project leads, selected research teams, and student fellows presented major facets of ADAC’s research portfolio. Meeting attended by representatives of HQ USCG, USCG R&D Center, USCG Pacific Area, NOAA/National Weather Service, Office of Naval Research, U.S. Navy Office of Oceanography, DHS S&T Borders and Maritime Division, DHS S&T Office of University Programs, DHS Policy and United States European Command. Remote participants included Arctic maritime researchers at a number of U.S. and Canadian universities. Several industry members also participated. Keynote speaker for the Annual meeting was HQ USCG Deputy Commandant for Operations, VADM Charles Ray.


16 November 2016: ADAC participated in the National Maritime Intelligence Integration Office (NMIO) Global Maritime Forum at the University of Washington in Seattle, Washington. Forum participation established a request for information and collaboration by NMIO Deputy Commander, Harry Schmidt, CAPT, USCG.

6 December 2016: ADAC established Ms. Malla Kukkonen as the Center’s Communications and Administration Officer.

Figure 3. Dr. Jim Bellingham, ADAC LRAUV Principal Investigator from Woods Hole Oceanographic Institution (on the left) and Dr. Larry Hinzman, ADAC Research Director at ADAC’s Annual meeting in Alexandria, Virginia.
7 December 2016: ADAC provided a comprehensive program update to NASA-ACE via teleconference.

9 December 2016: ADAC submitted comprehensive package for project literature and science information to DHS S&T OUP Program Manager in support of ADAC’s Biennial Review.

19 December 2016: ADAC participated at initial planning conference for Oceans 17, an academic and technical exchange forum planned for September 2017 in Anchorage, Alaska.

20 December 2016: ADAC presented on Center research activities to USCG District 17 Commander and key staff via teleconference.

4 January 2017: ADAC participated in University of Alaska hosted briefings including ADAC research to Commander, Alaskan Command, 11th Air Force and Alaska NORAD Region.

9 January 2017: ADAC provided planning construct and participated in HQ USCG DCO-X hosted scoping meeting in support of a future Arctic 2030+ workshop.

20 January 2017: ADAC hosted VADM Fred Midgette, Commander, USCG Pacific Area and RADM Mike McAllister, USCG District 17 Commander for orientation briefings on ADAC research activities.

Figure 4. ADAC briefing to VADM Fred Midgette, Commander, USCG Pacific Area and RADM Mike McAllister, USCG District 17 Commander, January 2017.

30-31 January 2017: ADAC hosted first meeting of Year 3 with Executive Counselors in support of Center’s mid academic-year Quarterly Review.

![Figure 5](image.png)

Figure 5. ADAC Quarterly Review with Executive Counselors, January 2017.

1-2 February 2017: ADAC served as a facilitator to EarthX Workshop on Arctic Maritime Domain Awareness for New and Emerging Security Threats workshop hosted by the Center for Resilient Communities, Arctic Research Consortium for the United States in Washington, DC.

3 February 2017: ADAC met with HQ USCG 5PW, 926, 751, MER and Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) Executive Director.

6 February 2017: ADAC submitted current project summaries and future project concepts for Biennial Review Federal Coordinating Committee (FCC) to DHS S&T OUP Program Manager.

15 February 2017: In association with CBONS-SA project, ADAC conducted sub-recipient site visit at Aleut International Association in Anchorage, Alaska.

21 February 2017: ADAC conducted sub-recipient site visit at University of Idaho, Moscow, Idaho.

23 February 2017: ADAC hosted a Customer’s and Partners’ Roundtable.

2-10 March 2017: ADAC provided a series of methane plume modeling from Arctic Oil Spill Modeling researchers to NOAA offices in Anchorage to assist analyzing a significant methane leak on a pipeline connecting shore facilities to an oil platform in Cook Inlet, Alaska. ADAC research was reportedly helpful for NOAA offices in characterizing and identifying hazards from the methane leak.
7 March 2017: Departure of ADAC Education and Workforce Development Director Ms. Clarice Conley. ADAC established tentative assignment of Center’s Communications and Administration Officer Kukkonen to conduct Education and Administration activities. Additional assistance for Center communications obtained from contracted work with staff from UAA’s Business Enterprise Institute (BEI) and BEI’s Applied Environmental Research Center (AERC).

8 March 2017: ADAC provided comprehensive update to Commander Alaskan Command, 11th Air Force and Alaska NORAD Region as a guest speaker at ALCOM Arctic Speaker series.

15 March 2017: ADAC participated in DHS S&T OUP Biennial Review Federal Coordinating (FCC) Committee meeting at HQ USCG in Washington, DC. Feedback from the Biennial Review included positive marks for Center leadership, activities and outreach. In a prepared package delivered to all members of the DHS S&T OUP FCC, ADAC presented 25 White Papers identifying a number of potential Arctic research opportunities, aligned with research questions posed in original DHS S&T Center of Maritime Research Funding Opportunity.

Following the Biennial Review, DHS S&T OUP Program Manager notified ADAC that the following projects would discontinue at the end of Program Year 3:

- Identifying, Tracking and Communicated Sea-Ice Hazards in an Integrated Framework
- Low Cost Wireless Remote Sensors for Arctic Monitoring and Lifecycle Assessment
- Real-time Storm Surge, Coastal Flooding, and Coastal Erosion Forecasting for Arctic Alaska
- Arctic Information Fusion Capability (AIFC)

20 March 2017: ADAC hosted Congressional Delegation escorted by USCG Congressional Affairs to overview briefings on Center activities followed by a staffer led question and answer session.

Figure 6. ADAC briefings to U.S. Congressional Staff Delegation escorted by USCG Congressional Affairs.
22-23 March 2017: ADAC supported Interagency Arctic Research Policy Committee (IARPC) stakeholder meeting at UAA, Anchorage, Alaska.

24 March 2017: ADAC presented briefing regarding Science and Technology in support of Arctic operations and participated at UAA’s first Arctic Research Day in Anchorage, Alaska.

14 April 2017: ADAC presented Center overview and on Arctic S&T research at the Center for Collaborative Systems for Security, Safety, and Regional Resilience (CoSSaR) at the University of Washington in Seattle, Washington.* (see other references and note below regarding travel expenditures on page 21.)

13 April 2017: ADAC ED serves as a panelist at Arctic Encounter Symposium (AES) in Seattle, Washington. ADAC participated in the same panel with HQ USCG Senior Arctic Advisor.*


4 May 2017: ADAC Customer’s and Partner’s Roundtable. In addition to project review, ADAC conducted a “research idea” brainstorming session.

7 May 2017: ADAC presentation to USEUCOM International Legal Symposium (via Video Conference).

10 May 2017: ADAC conducted ADAC Fellows Student Research Poster session as part of the Arctic Interchange events at the University of Alaska Fairbanks (UAF) in Fairbanks, Alaska.

Figure 7. A flyer from the Arctic Encounter Symposium in Seattle, Washington, 13-14 April 2017.

Figure 8. ADAC Fellows presenting at the ADAC Student Research Arctic Interchange, 10 May 2017, University of Alaska Fairbanks.
11-12 May 2017: Hosted Arctic 2030+ Workshop as part of the Arctic Interchange events at the University of Alaska Fairbanks. The workshop was sponsored by USCG Headquarters Office of Emerging Policy (HQ USCG DCO-X) and facilitated by the RAND Corporation’s Homeland Security Operational Analysis Center (HSOAC) with additional facilitation provided by United States Coast Guard Academy’s Center for Arctic Study & Policy (CASP). ADAC provided planning support by compiling an advance Literature Review, conducting a plenary session presentation, and assisting with logistics coordination, workshop facilitation, breakout group recording. After the workshop, ADAC produced a comprehensive workshop Rapporteur’s report to HQ USCG DCO-X, including a series of research questions for HQ USCG consideration.*

![Figure 9. Arctic 2030+ Workshop at the University of Alaska Fairbanks, 11-12 May 2017.](image)

16-18 May 2017: ADAC participated at Canada- USA (CANUS) Maritime Stakeholders Conference at the National Maritime Intelligence-Integration Office (NMIO) in Suitland, Maryland.*

18 May 2017: ADAC ED met with DHS S&T Borders and Maritime in Washington, DC to discuss potential research gaps and seams, important to Borders and Maritime Division related to the Arctic.

31 May 2017: ADAC presented remotely (via WebEx) at the Arctic Patrol and Reconnaissance Forum in Copenhagen, Denmark.

1 June 2017: ADAC Program Change Request completed to establish Monterey Bay Aquarium Research Institute (MBARI) as co-investigator and research partner with WHOI for the LRAUV project.
5 June 2017: ADAC submitted “Version 1.0” (first draft) of Center Program Year 4 Workplan to DHS S&T OUP Program Manager.

6 June 2017: ADAC conducted Final Program Year 3 Quarterly Review.

8 June 2017: ADAC conducted a teleconference with Ukallaysaaq Tom Okleasik, Vice-President of Corporate Affairs of the Sitnasuak Native Corporation based in Nome, Alaska. The teleconference with Mr. Okleasik was a follow-up from the Arctic 2030+ workshop and how such a workshop framework could be useful to learn “local and placed based” vantages discussed during an Arctic Alaska Native conference.


22 June 2017: ADAC provided detailed Arctic Information Fusion Use Case Demonstration to AIFC Project Champion at HQ USCG with interaction to USCG D17 AIFC Project Coordinator via WebEx. AIFC Project Champion and USCG D17 Project supporters stated strong interest and advocacy to advance demonstration research to create capability for USCG watch standers.

26 June 2017: Arctic Information Fusion Engine Demonstration to HQ USCG and NMIO via WebEx. Fusion Engine demonstration successfully met planned meteorological information fusion objectives.

30 June 2017: ADAC concluded Program Year 3. Projects discontinued per decision of DHS S&T OUP Biennial Review, or completed as per Program Year 3 plan transitioned to onward monitoring and advocacy by ADAC via University of Alaska institutional support.

1-30 June 2017 (the end of the reporting period): Conducted ADAC Fellows 10-week Summer Internships for all Center Fellows. Additionally, ADAC began working with Center’s first Minority Serving Institution Student (MSI) Fellow from Tougaloo College, Mississippi.

*Travel and participation funding accomplished via resources other than DHS S&T OUP provided funds.

The following report maps ADAC’s results for the period of performance from 1 July 2016 through 30 June 2017 in comparison to the Center’s Program Year 3 Workplan approved by DHS S&T OUP. Accordingly, the remainder of the report addresses the following:

- Center management efforts.
- Performance reports on each project, including:
  - Explanations of changes from the Workplan.
II. SUMMARY OF CENTER MANAGEMENT EFFORTS

The overall effort for ADAC leadership and research teams was compliance and vigorous execution to meet objectives, schedules, milestones metrics, and deliverables as described in the approved workplan.

ADAC’s strategy and strategy implementation construct in the Center’s approved Program Year 3 Workplan drove Center leadership efforts enabling leadership to establish a series of “lines of effort” to prioritize and comprehensively accomplish myriad activities with a very small Center staff. The following material outlines the ADAC strategy implementation plan and subsequent summary results for Center management activities.

**ADAC Program Year 3 Strategy implementation:** ADAC leadership enacted a comprehensive “implementation plan” to deliver on the Center’s Program Year 3 strategy. The following paragraphs provide a summary of results from this strategy implementation plan.

- Finalized a new Center management construct initiated in ADAC Program Year 2;
- Solicited specific inputs from customers and partners on scheduled basis. Periodic Customer’s and Partner’s Roundtables, ADAC’s Annual Meeting, and Project Champion teleconferences contributed to gaining inputs from USCG over the course of Program Year 3;
- Increased the number of Center partners and collaborators;
- Expanded research activities to include approved projects from the 2016 Arctic Related Incidents of National Significance (Arctic IONS) workshops and advanced initial planning for a Program Year 4 Arctic-related IONS workshop;
- Conducted a Medium and Long Term Environment (MaLTE) workshop, sponsored by Headquarters USCG based oriented to an Arctic futures scenario;
- Solicited and provided White Papers to DHS S&T OUP that advance science and technology relevant to the Arctic region to address DHS mission knowledge gap;
- Executed projects to advance Arctic maritime domain awareness, maritime technology, and Arctic specific education;
- Participated in DHS S&T OUP sponsored activities, such as the Research and Technology Transition workshop at the University of Minnesota;
- Conducted Education Outreach and Workforce Development; which included quarterly reviews with DHS S&T OUP Education Outreach and Workforce Development program managers;
- Conducted numerous outreach efforts presenting and participating at a number of Arctic related forums and symposiums and establishing a significant effort in strategic communications across federal departments and agencies, academic institutions, industry, state and local entities. ADAC extended complementary efforts to international engagement;
- Prepared and executed a DHS S&T biennial review.
The following paragraphs outline associated personnel, management and communications summaries, providing additional details in support of overall ADAC management efforts.

**Center personnel summary.** ADAC’s leadership team had two transitions during the course of the Program Year 3. In August 2016, Ms. Clarice Conley joined the ADAC team as the Education and Workforce Development Director. Ms. Conley departed the team in early March 2017. In December 2016, Ms. Malla Kukkonen joined the team as the Communications and Administration Officer. Following Ms. Conley’s departure, Ms. Kukkonen transitioned to an interim status of Education and Administration Manager, which was subsequently, formalized via UAA personnel actions. Consequently, ADAC gained communications assistance via personnel assigned to UAA Business Enterprise Institute (BEI) and BEI’s Applied Environmental Research Center. As of the end of Program Year 3, ADAC accredited leadership is comprised of the following:

- Douglas Causey, PhD, Principal Investigator, University of Alaska, Anchorage (UAA)
- Larry Hinzman, PhD, Research Director, University of Alaska Fairbanks (UAF)
- Randy Kee, Maj Gen (Ret) USAF, MS, Executive Director, UAA
- Heather Paulsen, MBA, Finance Director, UAA
- LuAnn Piccard, MSE, PMP, Project Management Director, UAA
- Malla Kukkonen, MSS, Education and Administration Manager, UAA

**ADAC’s Executive Counselors, a successful development of external advisors for the Center.** Commencing with Program Year 3, ADAC established its Executive Counselors team, which collectively and individually, proved very helpful in support of Center activities. ADAC’s Executive Counselors participated in teleconferences as a group and individually conducted additional engagement. The ADAC Executive Counselors served in an unfunded/pro-bono status. The Executive Counselors advised ADAC leadership on overall strategy for the Center efforts, connected ADAC to greater research collaboration (such as invitation to participate in Arctic research workshops) and provided advice for individual Center projects. Following are ADAC’s Executive Counselors who participated in the Center’s Program Year 3 efforts:

- Tom Barrett, VADM (Ret), USCG, President, Alyeska Corporation, Anchorage Alaska. Admiral Barrett is a former USCG Vice Commandant and District 17 Commander.
- Paul Hubbard, PhD, Canada Department of National Defense, Ottawa Canada.
- John Farrell, PhD, Executive Director, U.S. Arctic Research Commission, Washington D.C.
- Ruth Lane, CDR, USN, Director, U.S. National Ice Center, Suitland Maryland.
- Mike Faust, (Ret), Former Vice President of Exploration, Conoco-Phillips Corporation, Anchorage Alaska.

**ADAC Affiliated researchers.** ADAC maintained affiliations established in Program Year 2 with Dr. Jeremy Mathis and Dr. Nicole Kinsman. Dr. Mathis and Dr. Kinsman are full time NOAA employees, and receive no compensation for their affiliation. ADAC added a new affiliated researcher in Program Year 3, Ms. Brenda Dunkle who is seeking a Ph.D. and conducting research on Arctic related decision support processes. Ms. Dunkle receives no compensation in her affiliated activity. At the close of Program Year 3, ADAC was in final coordination with NOAA to establish Dr. Mathis as ADAC’s Science Advisor.
ADAC Student Fellows. The Education and Workforce Development section of this report provides a comprehensive review of ADAC student activities. Based on two distinct funding streams in Program Year 3, ADAC had two categories of student Fellows. In summary, ADAC initiated Program Year 3 with student Fellows funded via DHS S&T OUP Supplemental Career Development Grant (CDG) funding. ADAC received approval for Education Outreach and Workforce Development funding approximately mid-way into Fall Semester 2016.

Following approval of Education Outreach and Workforce Development, ADAC conducted recruitment for the remainder of the semester placing newly recruited students into fellowships at the start of Spring Semester 2017. Most ADAC Fellows participated in projects associated with ADAC DHS S&T OUP approved Program Year 3 Workplan. Upon graduation, ADAC Fellows seek employment within the Homeland Security Enterprise (HSE).

ADAC Fellows participated in every aspect of the Center in Program Year 3. This included project research, participating and presenting in USCG forums, such as Arctic Chinook in August 2016. Fellows were instrumental to a number of ADAC events, such as the Center’s Annual meeting in Washington, DC and ADAC’s quarterly review with Executive Counselors. Fellows helped the Center prepare for major events such as the ADAC hosted Arctic 2030+ workshop held at UAF in May 2017. ADAC Fellows also conducted two poster presentation seminars, one at UAA with a university audience, and a second at UAF to an international research audience. At the close of spring semester 2017, ADAC graduated, the Center’s first Fellow, and is employed with the HSE (with Transportation Security Administration). ADAC’s Program Year 3 closed with all current Center fellows participating in one of two required 10-week summer internship programs.

Summary of Center research management processes. ADAC executed the approved Program Year 3 Management Workplan. Included in this were weekly teleconferences between ADAC leadership and DHS S&T OUP Program Manager and Program Coordinator. ADAC conducted weekly “all hands” calls available to the entire ADAC research team also providing written products to inform members who were unable to join the teleconference. ADAC leadership periodically joined research project leads for project teleconferences with HQ USCG Project Champions. ADAC’s Finance Director conducted monthly fiscal reviews and provided summary updates during ADAC’s Quarterly Review meetings. During Program Year 3, ADAC conducted sub-recipient monitoring of awards established in Program Year 1. Additional details are as follows:

Quarterly Reviews. ADAC Quarterly Reviews proved critical for Center leadership oversight of research project’s activities allowing a long-range, scheduled opportunity for research teams to present and discuss research, schedule, milestones metrics, and technology development. ADAC’s Executive Counselors participated in ADAC’s mid-year Quarterly Review, which also served to help prepare ADAC for the DHS S&T OUP Biennial Review.

Reporting. Integral to ADAC research management was significant involvement of Center leadership with research project leads in drafting the ADAC Program Year 2 Report; preparing and presenting for the Annual Meeting in Washington DC.; drafting and submitting literature and customer relevancy related documents and summaries for the DHS S&T OUP Biennial Review; and preparing the ADAC Program Year 4 Workplan. Accomplishing these tasks resulted in close collaboration between ADAC research teams and Center leadership.
Sub-recipient site visits. ADAC conducted sub-recipient site visits of sub awards established in Center Program Year 1. Accordingly, ADAC accomplished program and fiscal monitoring for the following ADAC sub-recipient teams:

- Woods Hole Oceanographic Institution;
- Maine Maritime Academy;
- University of Idaho;
- Aleut International Association

DHS S&T OUP Biennial Review. A principal focus for the Center was to prepare as a center, including excellent presentation of ADAC’s research projects, for the DHS S&T OUP Biennial Review. Preparation and execution for the Biennial Review required extensive coordination between Center leadership and research teams and associated interaction with HQ USCG Project Champions. Following decisions in discontinuing research projects as previously discussed ADAC leadership and research teams continued to execute research agendas as planned for each project for Program Year 3. In accordance with the Center’s research-to-capability transition process, ADAC initiated efforts for commercialization within the private sector, supported efforts to publish research and advocated research to find transition partners for projects either discontinued or completed at the end of Program Year 3.

Continued monitoring and advocacy for ADAC Program Year 2 concluded projects. ADAC leadership continued to work with prior ADAC research teams on projects either concluded at the end of Program Year 2 or not funded in Year 3, via University of Alaska provided Institutional support. The purpose of continued advocacy was to continue efforts to seek successful transition of ADAC sponsored research to either new research sponsorship or commercial transition. Accordingly, monitoring and advocacy continued for prior ADAC research projects with the following results:

- **SmartCam (Computational Photometer).** On-going SmartCam research continues as part of Embry Riddle Aeronautical University “DroneNet” investigations. SmartCam research team at Embry Riddle Aeronautical University is preparing a follow-on proposal to NASA.
- **Real-Time Storm Surge and Coastal Flood Forecasting for Western Alaska.** UAA College of Engineering continues to advance model refinement of ADAC sponsored research for the Norton Sound and Yukon-Kuskokwim River Delta. Project has transitioned to a new Alaska Coastal Forecasting research project funded by the Alaska District of the U.S. Army Corps of Engineers.
- **Monitoring Intentional and Unintentional Catastrophic Events: Detecting sea ice and oil spills through measurement of the H2O and C isotope geochemistry in winds.** UAA College of Arts and Sciences submitted a follow-on research proposal to National Science Foundation to build on ADAC sponsored research from Program Years 1 and 2.

Summary of ADAC’s efforts in communications. ADAC’s Program Year 3 communications significantly advanced from prior years. As presented in Section I of this report, ADAC conducted a sustained level of specific engagement to HQ DHS, across the USCG, other federal departments and agencies, academic and industry research institutions, State of Alaska, local, tribal and with international collaborators. In addition to Center leadership engagement activities conducted via teleconference, in person meetings, symposiums, workshops, etc., ADAC communications endeavors, describing center activities, research
advancements and individual achievements made significant improvements in Program Year 3. The below paragraphs provide additional details for ADAC’s comprehensive efforts in communications.

**ADAC Video Shorts.** Late in Program Year 3, ADAC began producing video shorts and publishing them on “You Tube” in order to highlight Center activities, research, and people. The inspiration for creating these videos originated from reflecting on remarks made by DHS S&T OUP Director at the monthly OUP Director’s calls in January 2017, urging OUP Centers to work harder at messaging their research. These videos have helped advertise ADAC work to previously under-reached audiences, particularly among university students. These videos have helped connect ADAC to students and additional research collaborators. DHS S&T OUP Center of Excellence established leader for Communications, Ms. Eleanore Hajian, has highlighted ADAC’s Video Shorts, as an effective communications approach to all DHS S&T OUP CoE communicators. URL: https://www.youtube.com/channel/UCnlcKAIpk7SvXyzL7_ToL4g

![Figure 10. Opening screen shots of ADAC Video Shorts Published in Program Year 3.](image)

These video shorts have received compliments from the DHS S&T OUP Communications Manager and from a number of Arctic focused researchers and customers in the USCG. Due to cybersecurity firewalls in the USCG Coast Guard IT networks, YouTube is not accessible on Coast Guard computers. Personnel have to view these videos via personal computer systems. Collaborators from the U.S. Interagency Arctic Research Planning Committee have been particularly supportive of these video shorts.

**Project Vignettes.** In concert with DHS S&T OUP Calendar Year reporting, ADAC created a series of vignettes as a way to assist DHS S&T OUP in providing updates on specific projects in a succinct manner. ADAC created these vignettes and presented to DHS S&T OUP Communications lead for each current ADAC research project and education activity. These vignettes helped to quickly explain ADAC research activities suitable for a number of ADAC collaborators as well as members of the USCG. Below is an example for ADAC’s LRAUV project.
IARPC Collaborative Network. In March 2017, Center leadership established an ADAC research network at the U.S. Interagency Arctic Research Policy Committee (IARPC) interactive collaborative portal. This collaborative network serves to assist the Center in communicating about current and future activities and opportunities. Achieving an IARPC Collaborative Network connects ADAC research to the community of U.S. Arctic scientific research community, enabling ADAC to reach audiences more comprehensively than before. Such access is important to further research idea generation, advertise ADAC activities and opportunities and establishes the center as a recognized institution across the United States.

ADAC Facebook Site. Throughout Program Year 3, ADAC has continued to advance messaging about Center activities and research endeavors via Facebook. As many university students invest much of their daily life in social media, advancing ADAC’s Facebook site allows increased access to students to aid recruitment of Center Fellows, while serving as another outlet to communicate ADAC activities and opportunities. URL: https://www.facebook.com/ADACAlaska/
Quarterly newsletters. ADAC published Quarterly Newsletters throughout Program Year 3. These publications highlighted significant Center activity by highlighting various research projects, interaction with key ADAC customers and partners, and importantly “showcased” ADAC student Fellows and their contributions. ADAC’s Quarterly Newsletters provide a scheduled update to inform of recent Center activities, research updates and advertise coming events to the community of ADAC’s customers, transition partners and research collaborators. In Program Year 3 ADAC published newsletters in July and October 2016, February and May 2017. The following is an example of May 2017’s front and back cover of the ADAC Quarterly Newsletter.

Figure 13. ADAC’s Quarterly Newsletter, May 2017.

Updates and improvements to ADAC’s Web page. URL: http://adac.uaa.alaska.edu/
Throughout Program Year 3, ADAC made improvements to the Center’s “.edu” Web page. ADAC’s webpage describes the Center, while serving as the repository of Center activities, reports, workplans, specific research, current and prior newsletters, student events, and other items of interest. This product is now a source containing the Center’s significant research documents and associated research materials. The Webpage serves to provide details about ADAC to Center customers, transition partners and collaborators, including prior and current endeavors.

Figure 14. ADAC’s Webpage banner, February 2017.
The Center and associated research teams successfully conducted fundamental and applied research in Maritime Domain Awareness and Maritime Technology to achieve the following:

- **Advanced Arctic Domain Awareness research areas by increasing the science of knowledge and understanding.** As described in project research in Program Year 3, ADAC advanced research helpful to improve USCG Arctic operator coordination, control and decision making;
- **Conducted research in Maritime Technology to provide needed capability to support and effect increased Domain Awareness for the Arctic region;**
- **Participated, contributed and conducted forums to learn Arctic operator needs, while soliciting science and technology communities to generate ideas and then work ideas into future research proposals and projects;**
- **Provided responsive requests to information and research to the operator community.** ADAC’s support to provide a series of methane plume modeling from Arctic Oil Spill Modeling researchers to NOAA offices in Anchorage, regarding a pipeline methane leak in Cook Inlet, Alaska was an illustration of the Center’s desire to be helpful in times of concern or need.
- **Presented and published findings and research conclusions;**
- **Initiated efforts to transition research consistent with DHS and USCG needs;**
- **Initiated efforts to seek commercialization or other transition pathways for discontinued or completed ADAC research that does not meet USCG mission needs.** Accordingly, this activity seeks to transition research no longer funded by DHS S&T OUP to other partners to maximize prior DHS S&T OUP research investment.

### III. ADAC PROJECT DESCRIPTIONS

#### Theme 1 – Maritime Domain Awareness

**PROJECT:** Community-Based Observer Networks for Situational Awareness (CBONS-SA)

**Project Team and Champions**

**Project PI:** Dr. Lilian Na’ia Alessa.

**Lead Institution:** University of Idaho (UI).

**Supporting Team:** Dr. Andrew Kliskey (UI), Ms. Jessica Veldstra, Aleut International Association (AIA), James Gamble (AIA), Amos Oxereok (AIA - Village of Wales), Eddie Ungott and Edward Ungott (AIA - Village of Gambell), Laresa Syverson (AIA - Village of Unalaska), Lance Kramer (AIA - Kotzebue), Perry Anashugak (AIA - Utqiagvik / Barrow), Leo Naboyshchikov (Kestrel Technology Group), Brian Conroy (Nova Corporation). Undergraduate intern students Amy Kaucic (UI), Ethan Mahakam (UI).

**Collaborators:** The CBONS-SA core team (at UI, Kestrel Technologies, and NOVA DINE) collaborated with partners in the US Coast Guard and Arctic coastal communities to recruit observers. In addition to
assisting in identifying and selecting individual observers, the Aleut International Association (AIA) was critical in bridging the gap between University, Agency, and Communities. Project team mediated day-to-day contact with observers through AIA, and they acted as trainers and troubleshooters for observer-side technological and reporting protocol issues. In the Year 3 Workplan, Project team proposed the State of Alaska National Guard and Emergency Management as collaborators. CBONS-SA team investigated this collaboration but determined desired research association as infeasible, and declined further efforts.

Program Year 3 Project Champion(s): Mr. Hank Blaney, CG-255

Student Involvement: Two University of Idaho undergraduate students served as ADAC Fellows in support of the CBONS-SA project in Program Year 3. Students were recruited from a class on “The Resilient Landscape” taught by CBONS-SA personnel at the University of Idaho and they worked out of the Center for Resilient Communities laboratory. Amy Kaucic assisted CBONS-SA project leads by aggregating, sorting, and preparing archived observations for analysis by team members. This involved working through the database of CBONS-SA reports from observers in remote communities and classifying them. Ethan Mahakam assisted CBONS-SA project leads as a student fellow on what environments are amenable to successful implementation of CBONS methodologies. This included research on what type of facilities and environments might be conducive to future USCG-CBONS team collaborations, and primarily identified large port districts in close proximity to international borders. Both UI ADAC Fellows intend to seek employment in either DHS or DOD enterprises after completing professional internships as part of their degree programs.

Project Description

Abstract: This project is establishing a community-based observing network and system (CBONS) to acquire fine scale, local data on a range of variables critical to USCG operations (Savo et al. 2016, Alessa et al. 2015). Variables include those associated with environmental change, subsistence activities/habitats and vessel transits. A systematic and quality assured CBONS enhances the Coast Guard’s ability to respond to Arctic-related Incidents of National Significance (Arctic IoNS). CBONS data are useful to enhance the preparedness of Arctic coastal communities, which can greatly increase the effectiveness of USCG in the Arctic while potentially reducing costs in the long term (Alessa et al. 2015). The data are used to generate community maps consisting of areas critical to culture and subsistence which will allow the Coast Guard to operate in ways that protect livelihoods and traditional lifeways. Finally, CBONS data are potentially useful to enhance the precision of data from other Arctic Observing Networks (AON) by placing them in situational contexts.

Baseline: The baseline for this project is the existing data intake forms and database, which demonstrates integration of community-based sea ice observations with NOAA’s Arctic ERMA (Environmental Response Management Application) - a web based GIS tool for emergency responders. The baseline for CBONS-SA at the start of Program Year 3: one Aleutian community, one Bering Sea community, and one Bering Strait community that apply standardized protocols for trained observers and demonstrates near real-time transmission of observations, representing TRL-7.

Relevance to DHS: CBONS-SA demonstrates the development of a successful protocol for the acquisition of fine-scale, local resolution data on environmental changes, subsistence patterns and habitats and current local conditions. Acquisition takes place in austere marine environments and their upload in real-time or near real-time may enhance the USCG ability to prepare for and respond to incidents of national significance, including search and rescue/humanitarian and disaster response.

Purpose of Research: The purpose of the CBONS-SA is to utilize distributed human observers as sensors to systematically observe and document Arctic environmental and globalization changes, which are of significance to USCG operations. By placing them in sociocultural and economic contexts, USCG may be able to anticipate, plan and respond to these changes through electronic reporting from observers to USCG command centers.

Methodology: The research design of CBONS-SA includes several steps: a) recruiting and training high fidelity observers, b) coordination of data intake forms with communities, USCG and Kestrel Technology Group (KTG), c) coordinating native data formats with those from other data streams from instrumented observations and datasets, d) demonstrating data feeds through field-based and modeling proof-of-concepts.

Further details include:
1. Determine, test and develop new data relays with Field Information Support Tool (FIST).
2. Perform field-based and model interoperability tests with CBONS-SA data.

Project Results

Key Accomplishments in Year 3: CBONS-SA completed expansion of the network to four active observing communities – Gambell, Kotzebue, Unalaska, and Utqiaġvik. This was five High Fidelity Observers, supported by research team at University of Idaho, coordinators at Aleut International Association and research partners at NOVA-DINE and Kestrel Corporations. These communities applied standardized protocols for trained observers and demonstrated near real-time transmission of observations. This network research represents TRL-7. Note, research team reported TRL-7 at the close of Program Year 2, and in Program Year 3, this technology readiness level remained at TRL-7, while research area expanded to additional communities. Additionally, the austere location communications system (FIST) served as a HFO communications system validation via the field tests conducted at Tin City during Exercise Arctic Chinook in August 2016. In ADAC Program Year 2, CBONS-SA network comprised two observers in the community of Gambell on St. Lawrence Island in the northern Bering Sea, and one observer in Unalaska on the eastern Aleutian Islands and one observer in Wales in the Bering Strait. During Program Year 3, the network was expanded to include one active observer in Kotzebue on the Chukchi Sea (in February 2017) and one active observer in Utqiaġvik (formally known as Barrow) on the
Beaufort Sea in May 2017 (Figure 15). In order to bring new observation communities to operational status, it was necessary to select suitable observers in the communities (in conjunction with community representatives), to train the selected observers, and to run some preliminary observing exercises with the observers. Figure 16 represents the current complement of CBONS-SA observers, number of observations in Program Year 3 and associated period of performance.

Throughout ADAC Program Year 3 CBONS-SA observing occurred in conjunction with the Field Information Support tool (FIST). A one-week proof-of-concept for the integration of CBONS-SA with FIST (referred to as the “mini-exercise” in the ADAC Year 3 Plan) occurred in August 2016 in conjunction with Exercise Arctic Chinook at Wales and Tin City, Alaska (Milestone 1) – the AAR Field report (provided as Year 3 Report Appendix).

Observers in Unalaska, Kotzebue, and Utqiagvik undertook observing using FIST from the time of their observing periods (Figure 16). Due to technical issues with internet connectivity in Gambell, the project transitioned from manual recording with internet upload to FIST based during the Program Year 3.

Testing of FIST in Gambell during Program Year 3 resulted in the following conclusions:

- Cellular connectivity in Gambell is only 2G and very unreliable and not sufficient for sending observations with photos;
- Wi-Fi is only available through satellite and very expensive to set up a new connection;
- WISP Wi-Fi is not sufficient for sending any reports. We recommend that any community with these issues should use the app primarily through the InReach connection, with the understanding that no photos should be expected with the observations.
FIST software enabled transmission of data acquired through the CBONS-SA program by using the FIST tool for “forward fusion” on the FIST portal (Metrics 1 and 2) as a temporary repository, while awaiting establishment of an information fusion capability for ADAC. The FIST portal software development was a critical component for integration with other components of ADAC (Milestone 2). The project initiated use of FIST to standardize communications protocol, to gain user defined information in austere communications environments, and to connect field observations to USCG command centers. Figure 17 describes the reporting metrics used and the number of corresponding observations.

<table>
<thead>
<tr>
<th>Reporting metric</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of obs. (including testing)</td>
<td>606</td>
</tr>
<tr>
<td>Total number of obs. captured using FIST</td>
<td>456</td>
</tr>
<tr>
<td>Total number of obs. captured using manual approaches</td>
<td>141</td>
</tr>
<tr>
<td>Total number of obs. captured using FIST and InReach upload</td>
<td>308</td>
</tr>
<tr>
<td>Total number of notable* obs.</td>
<td>383</td>
</tr>
<tr>
<td>Average number of obs. per month</td>
<td>83</td>
</tr>
<tr>
<td>Average number of obs. per month captured using FIST</td>
<td>63</td>
</tr>
<tr>
<td>Average number of notable* obs. per month</td>
<td>53</td>
</tr>
</tbody>
</table>

*Notable observations refer to all observations captured during typical hunting and fishing excursions excluding observations capture das part of training exercises.

**Breakdown by observation type**

<table>
<thead>
<tr>
<th>Breakdown by observation type</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental (biological/ecological)</td>
<td>366</td>
</tr>
<tr>
<td>Environmental (physical/ice/atmosphere)</td>
<td>296</td>
</tr>
<tr>
<td>Vessels/boats transiting</td>
<td>26</td>
</tr>
<tr>
<td>Humans encountered</td>
<td>2</td>
</tr>
<tr>
<td>Suspicious events</td>
<td>3</td>
</tr>
<tr>
<td>Search &amp; Rescue</td>
<td>1</td>
</tr>
</tbody>
</table>

*Key Stakeholder Engagement in Program Year 3:* The CBONS-SA research team met extensively across operationally oriented networks, including HQ USCG, NOAA, NWS, Alaska State Troopers, Alaskan...
Command, State of Alaska National Guard, and USCG D17. Further, the CBONS-SA project engaged numerous Arctic research professionals over the Program Year 3 including:

- Mr. David Boyd, USCG Pacific Area; in teleconferences and ADAC Annual Meeting
- Dr. Martin Jeffries, Assistant Director for Polar Sciences, Executive Office of the President (Office of Science and Technology Policy);
- Mr. David Kennedy Senior Advisor to President, Arctic Executive Steering Committee (NOAA);
- Dr. Jeremy Mathis, Director, Arctic Research Office with NOAA;
- Dr. Simon Stephenson, Director, Polar Programs at the National Science Foundation.

These engagements provided external assessment of the CBONS-SA project, including a vetting of the procedures used, enabled closer alignment of the CBONS-SA project with national and international observing efforts, and achieved a greater degree of interoperability between these different observing efforts.

**Key publications [Peer-reviewed]:**


**Key reports/developments/presentations***

- Arctic 2030+ Workshop, Arctic Interchange, University of Alaska Fairbanks, May 11-12, 2017.

*Note: CBONS-SA researchers did not use DHS S&T OUP funds to participate or present at these forums.*
References cited

Changes from initially approved Workplan: In order to allow establishment of AIFC framework, the research team uploaded the CBONS-SA observations to the FIST portal that was accessible to Arctic Environmental Response Management Application, and therefore is readily discoverable to USCG D17 watch standers.

Project Progress against Milestones:

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete expansion of the network to three communities from central Aleutians to Chukchi Sea. March-May 2017.</td>
<td>Achieved – We maintained the network through Year 3 with active observers in the Native Village of Gambell on St. Lawrence Island in the northern Bering Sea and the Native Village of Unalaska on the eastern Aleutian Islands. We expanded the CBON-SA network to Kotzebue in the Chukchi Sea in Feb 2017 and to Utqiagvik in the Beaufort Sea in May 2017 representing four communities from central Aleutians to Beaufort Sea.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Standardize/harmonize CBONS-SA protocols across all communities. May 2017.</td>
<td>Achieved – We standardized the CBON-SA protocols via FIST and are in place across all communities in the expanded network.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Demonstrate the utility of a CBONS-SA to field operator decision support in near real (minutes lag) and real (seconds lag) using a handheld device.</td>
<td>Achieved – A one-week proof-of-concept for the utility of CBON-SA with FIST occurred in August 2016 in conjunction with Exercise Arctic Chinook at Wales and Tin City, Alaska.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>

Project Progress against Metrics:

<table>
<thead>
<tr>
<th>METRIC</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of successful image and data relays both real-time and delayed-time: 12 per month.</td>
<td>Achieved: See summarized observation reports (Figures 16 and 17)). Total data relays = 606; Total FIST data relays = 383. FIST data relays per month = 63.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Inter-rater reliability of observers across network:</td>
<td>Achieved: 99.7% (# of Verified / # of Verified + # of verified false);</td>
<td>N/A.</td>
</tr>
</tbody>
</table>
### Analysis of CBONS-FIST Field Test After Action Report:

Between August 22 2016 and Friday August 26 2016, a proof-of-concept field test for Community Based Observation Networks (CBONS) enabled by the Field Information Support Tool (FIST) was conducted in Wales and Tin City, Alaska. The field test focused on proving the utility of CBONS as enabled by the FIST system within the mission areas of Austere Field Reporting, Humanitarian Assistance / Disaster Relief, Search and Rescue, Community Engagement, Command / Control / Communication Operations, and Maritime Domain Awareness. One of the primary aims of the CBONS FIST field test was to submit field reports and establish a functional Forward Operating Base/Control Center within a notional scenario of a disabled cruise ship off the coast of Wales, Alaska while using minimal equipment that could be easily carried to any site in the area of operation.

Mr. Amos Oxereok, a CBONS high fidelity observer and Wales Alaska native, Mr. Leonid Naboyshchikov, a FIST Sr. Analyst, and CBONS-SA PI Dr. Lilian Alessa, herein known as the “CBONS-FIST Team”, conducted field-testing the CBONS-FIST system in Wales Alaska and surrounding areas (Oxereok/Naboyshchikov) and the Joint Base Elmendorf Richardson (JBER) Joint Operations Center, Anchorage, Alaska respectively. The CBONS-FIST Team conducted testing the functionality of the FIST system within the austere environment while keeping in mind the operational objectives of the CBONS program.

The CBONS-FIST team successfully submitted 76 field reports to the live Fusion Portal, of which 16 were characterized as “High” or “Critical” Alarm. The team submitted eight additional field reports to the Forward Operating Base/Control Center. The CBONS-FIST team successfully submitted or received 39 messages to/from the HQ support in Anchorage, Alaska and Orlando, Florida. The CBON-FIST team identified three areas of technological improvement for this mission set. The CBONS-FIST team and supporting staff classify this field test very successful both operationally and conceptually.

### Project Year 3 Outcomes, Output and TRLs:

**Project is at TRL-7**
Project Year 3 Objectives:

- **Develop a quality assured and precise local-scale community based observing network and system to monitor on-going environmental changes, cultural and subsistence habitats and vessel transits.** Apply tested protocols for HFOs and demonstrates real-time transmission of observations. The project achieved this objective with the four-community CBONS-SA network maintained in Year 3 – see Project Progress against Milestones (Milestone 1) and Project Progress against Metrics (Metrics 1 and 2) above.

- **Develop data streams to be interoperable with satellite and buoy data so that rapid ingests can occur via hand-held field information tools.** The project achieved this objective with continued development, refinement and testing of CBONS-SA data capture and upload enabled by FIST – see Project Progress against Milestones 2, Metrics 2 and 3.

- **Assess CBONS communities’ existing response capacity (preparedness) and training/development needed to potentially establish a subset as first responders in a more coordinated fashion than currently exists.** The project achieved this objective with the successful field-testing of CBONS-SA enabled by FIST in conjunction with USCG Exercise Arctic Chinook in August 2016 – see Milestone 3 and in the ADAC Year 3 Annual Report Appendices, AAR - CBONS-SA FIST Field-test Report) (provided separately)

Program Year 3 Results: At the close of Year 3, the CBONS-SA network comprised one Aleutian Islands community, one northern Bering Sea community, one Chukchi Sea community, and one Beaufort Sea community. Trained High Fidelity Observers from these communities demonstrated sufficient capability to apply standardized protocols for near real-time transmission of observations.

FIST System Program Year 3 outputs:

- Set up and configured the FIST Core Package on an Amazon Web Services cloud computing server, as provided by ADAC, within 3 (three) work weeks of the start of the project.
- Provided the FIST Gather APK for 10 (ten) field users within four workweeks of the start of the project.
- Provided the FIST Fusion Portal access for 10 (ten) portal operators work within weeks of the start of the project.
- Provided four customized “Gather” long form development opportunities within six workweeks of the start of the project.
- The FIST team provided programmer availability for customization, research, and development work (not to exceed 120 person-hours) within 26 (twenty-six) workweeks of the start of the project.
- The FIST team provided the equivalent of one workweek training for 20 (twenty) users within eight workweeks of the start of the project.
- The FIST team purchased and provided set-up DeLorme InReach SE 2-Way Satellite Communicator hardware unit within three workweeks of the start of the project.
- The FIST system set-up an account on DeLorme Enterprise portal for ADAC within 2 workweeks of the start of the project.

Unanticipated Problems and Plans for Addressing Them: None reported.
**Transition Plans.**

**Transition Plans and Progress Made:** CBONS-FIST research concluded in Program Year 3 that community based HFOs equipped with an effective communications device capable to relay timely observations from austere and remote locations in the Aleutians, Bering, Chukchi and Beaufort regions, provided data relevant to USCG Arctic operators. However, input from USCG operational community was providing stipends to community based HFOs could potentially create a programmatic burden in excess of available funding. Accordingly, ADAC’s CBONS-FIST Year 4 research plan is to take the research and lessons learned from Program Years 1, 2 and 3 to create an Arctic Community-Based Observer Service prototype. This Community-based Observer Service prototype transitions away from the Year 3 established HFOs (credentialed by Village Elders) to HFOs from three volunteer sources (as a collateral duty): Arctic localized mariners (such as Alaska fishing industry), Bureau of Ocean Management Off shore personnel, and established Village Public Safety Officers that respond to Alaska State Troopers. An additional volunteer source could potentially be from the “Alaska Scout” initiative, a project conceived by the Alaska National Guard, creating an Alaska Arctic Native observer and response project similar to the Canadian Ranger program. The Alaska Scout initiative is currently with the State of Alaska legislature in Juneau.

CBONS-FIST investigation has demonstrated the construct of providing training, observing protocols and austere communications equipment to selected observing teams is feasible and suitable. Transitioning concluded research is now a matter of establishing an observer service prototype, conducting validation of the prototype and determining if the selected prototype meets USCG operational needs and an acceptable programmatic cost.

The project consulted with State of Alaska to determine if a future Alaska Scouts Program could serve as a potentially feasible/suitable transition destination. The outcome of these discussions was that an ASP is clearly not feasible in the near term due to insufficient funding for the ASP initiative. At the same time, the project consulted with Canada’s JTF-N concerning lessons learned from Canada’s development of their Ranger observer program. The Canadian Ranger program as structured adequately supports CBONS. In Program Year 3, collaboration between HQ USCG CBONS-FIST Project Champion, USCG Senior Arctic Advisor, USCG R&D Center and USCG D17 focused on determining an affordable and sustainable Community based observer service.

USCG Project Champion and USCG D17 Arctic planner noted the investment of FIST, which enabled HFOs to provide timely reports from austere locations as particularly useful. Future transition of CBONS-FIST to an observer service hinges in prototyping capable HFOs at a sustainable cost.

**PROJECT: High-Resolution Modeling of Arctic Sea Ice and Currents**

**Project Team and Champions:**

**Project PI:** Dr. Jinlun Zhang.

**Lead Institution:** University of Washington.

**Supporting Team:** N/A.
**Collaborators:** None

**Program Year 3 Project Champion:** Dr. Jon Berkson, CG-WWM.

**New Project Champions Established by DHS S&T OUP and HQUSCG at end of Program Year 3:**
Champion (continuing): Dr. Jon Berkson, CG-WWM.

**Student Involvement:** No students involved.

**Project Description**

**Abstract:** This ADAC project aims to develop an accurate, High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) for modeling and predicting sea ice and currents in the Arctic Ocean. This system is to be calibrated and validated using a range of available sea ice and ocean observations and then used for (near) real-time hindcast and daily-to-seasonal forecast of Arctic Ocean currents, sea ice, and change.

Accurate, high-resolution predictions of ocean currents and sea ice conditions will enhance the Coast Guard’s ability to prepare for and respond to oil spills in the Arctic Ocean. The prediction data will also allow the Coast Guard to more safely and reliably conduct search and rescue missions. While ADAC seeks to transition HIOMAS to the U.S. National Ice Center, the Center also seeks that HIOMAS data will eventually be transmitted to ship captains via the NOAA’s Arctic Environmental Response Management Application (ERMA), in order to promote safer maritime transportation. Finally, the data are useful as forcing inputs to drive other models such as wave and oil spill models.

**Baseline:** There are sea ice-ocean models on global or regional scales. These models can simulate ocean velocity, temperature, salinity, and sea ice thickness, concentration, and drift. Most of the models have relatively coarse horizontal resolution (> 10 km), although there are a number of models with higher resolution (< 10 km). A rather common difficulty in high-resolution modeling is the overestimation of ice thickness resulting from the simulation of excessive ice deformation. This challenge can affect the prediction of sea ice and upper ocean currents. Accordingly, the project team developed a robust HIOMAS that realistically simulates sea ice without causing spurious ice thickness buildup. The research team proved this aspect in latest test results. The HIOMAS is configured such that it can be easily refined to a higher resolution (≤ 4 km) if computing resources permit.

**Relevance to DHS:** This ADAC project aims to develop an accurate, High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) for modeling and predicting sea ice and currents in the Arctic Ocean. Accurate, high-resolution predictions of ocean currents and sea ice conditions will enhance the Coast Guard’s ability to prepare for and respond to oil spills in the Arctic Ocean. The prediction data will also allow the Coast Guard to more safely and reliably conduct search and rescue missions. In Program Year 3, ADAC’s Arctic Information Fusion Capability (AIFC) effort supported upload of HIOMAS to NOAA’s Arctic Environmental Response Management Application (ERMA) to promote safer maritime transportation. Integrating HIOMAS to Arctic ERMA allowed USCG D17 watch standers improved
situational awareness of Arctic Ocean drift, sea ice presence, movement and thickness. Finally, the data are useful in forcing to drive other models such as wave and oil spill models.

**Purpose of Research:** In order to serve the needs of USCG and other Arctic stakeholders, this project strives to develop a robust and accurate HIOMAS to predict Arctic sea ice and ocean conditions on time scales from days to months. HIOMAS research focuses on the prediction of spatial distribution of ice motion and thickness, ice internal stress and pressure, and fraction of thick ridged or multi-year ice, plus prediction of retreat and advance of ice edge. All of these factors are relevant to the Arctic operators. The project uses a range of satellite and *in situ* sea ice and ocean observations for model calibration and validation, in order to improve model performance in both hindcast and forecast. The project researcher is examining forecast performance through skill evaluation and uncertainty analysis to identify areas for further improvement. Skill evaluation and uncertainty analysis assists forecast accuracy. The project researcher developed HIOMAS in a way that is useful for operators to respond rapidly to urgent search and rescue needs.

**Methodology:** The research community has created a number of sea ice-ocean models developed for Arctic forecast. These models can simulate ocean velocity, temperature, salinity, and sea ice thickness, concentration, and drift; however, most of the numerical models have coarse horizontal resolution, often much coarser than 10 km, while very few models have high resolution, higher than 10 km. A rather common difficulty in high-resolution modeling is the overestimation of ice thickness resulting from the simulation of excessive ice deformation. This would obviously affect the prediction of sea ice and upper ocean currents.

In order to overcome this difficulty, the project team developed a robust HIOMAS based on the Pan-arctic Ice–Ocean Modeling and Assimilation System (PIOMAS) with higher resolution. As described in prior ADAC annual reports, PIOMAS is a well-established system that consists of an efficient, stable solver for sea ice dynamics. Worldwide, scientists, sea ice enthusiasts, and some media organizations use PIOMAS Sea ice output. The project investigation determines and validates whether HIOMAS is able to simulate sea ice without causing spurious ice thickness buildup. HIOMAS is configured such that it can be easily refined to a higher resolution (≤ 4 km) if computing resources permit. HIOMAS is being calibrated and validated using a range of available sea ice and ocean observations and then used for (near) real-time hindcast and daily-to-seasonal forecast of Arctic Ocean currents, sea ice, and change.

**Project Results**

**Key accomplishments in Program Year 3:** In Program Year 2, the project researcher developed a version of HIOMAS with advanced sea ice and ocean model components and 6 km horizontal resolution. The project year 3 plan was to refine HIOMAS with even higher horizontal resolution targeting 2 and 4 km resolutions, depending on computer resources. *The project achieved this key goal.* As a result, the project researcher developed three different versions of HIOMAS with three different horizontal resolutions: 6, 4, and 2 km resolutions. This allows choice based on available computer resources. For example, the 2 km resolution HIOMAS is too time consuming to run on the existing University of Washington’s Polar Science Center computer cluster, so project research mainly focuses on the 4 km resolution HIOMAS. They have been using the 4 km resolution HIOMAS to conduct hindcast and daily to
seasonal forecast at the beginning of each month. However, it is straightforward to run the 2 km resolution HIOMAS if more powerful computing is available. On the other hand, the 6 km resolution HIOMAS would be useful for prediction runs with limited computer resources.

The project researcher found that there is no spurious, excessive ice thickness buildup in areas such as the Beaufort Sea in all three versions of HIOMAS when compared to NASA, “Ice Bridge” Sea ice thickness observations. The project researcher achieved similar results by comparing HIOMAS simulated sea ice thickness field with the Navy’s Arctic Cap Nowcast/Forecast System (ACNFS) simulated field. Figure 18 reflects the comparison: HIOMAS ice thickness is much lower than ACNFS ice thickness in most of the Beaufort Sea.

In addition to conducting daily to seasonal forecasts, the project research assessed forecast skills by comparing with satellite observed sea ice concentration and edge location. This allows reduced prediction bias by adjusting model parameters during the prediction phase. As of June 30, 2017, the Technology Readiness Level (TRL) for this project is Level **TRL6**.

**Key Stakeholder Engagement in Program Year 3:** Through ADAC work with DHS, USCG HQ, NOAA, NWS, Alaskan Command, State of Alaska National Guard, and USCG D17, the project PI highlighted HIOMAS modeling efforts to an array of Federal and State of Alaska operators. The project PI obtained helpful feedback from Dr. Phil McGillivary, the Coast Guard Science Liaison, Dr. Glen Watabayshi at NOAA’s Office of Response and Restoration, and Mr. Todd Mudge at ASL Environmental Sciences Inc. on how to better serve the Arctic operators. The project PI continues to work in close collaboration with scientists at the NOAA/NWS/NCEP Climate Prediction Center in an effort to improve NOAA’s daily to seasonal Arctic sea ice forecast, which distributed HIOMAS to NOAA/NWS field offices regularly. Experience and insights resulting from this collaboration contributed directly to HIOMAS development and informed key stakeholders for the project.

**Key Publications (Peer Reviewed):**


**Key publications/developments/presentations:**

- Mahoney, A. R., and J. Zhang (2017), High-resolution prediction and real-time observations of Arctic sea ice and currents, Alaska marine Science Symposium, 23–27 January 2017, Anchorage, AK, USA.
- Zhang, J. (2017), High-resolution prediction of Arctic sea ice and currents, Sea Ice Workshop, 12–13 July 2017, Seattle, WA, USA.
Arctic coastal and marine environments and their potential contribution to Arctic maritime domain awareness: A case study in northern Alaska, *Arctic Observing Summit Special Issue, submitted*.

- Working on a manuscript to examine sea ice properties in high-resolution sea ice models.

**Changes from initially approved work plan:** None

**Project Progress against Milestones:**

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion of HOMAS at even higher resolution, targeting 2–4 km, depending on computer resources.</td>
<td>Achieved.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Complete model calibration and validation using:</td>
<td>Achieved.</td>
<td>N/A.</td>
</tr>
<tr>
<td>a. Satellite ice concentration data from the National Snow and Ice Data Center (NSIDC),</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Buoy drift data from the International Arctic Buoy Program (IABP), and</td>
<td></td>
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<tr>
<td>c. Available HF Radar-derived current data from collaborating investigators of this project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. NASA IceBridge sea ice thickness data.</td>
<td></td>
<td></td>
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</tbody>
</table>

**Project Progress against Metrics:**

<table>
<thead>
<tr>
<th>METRIC</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model resolution at locations of high interest. Current resolution: 6 km, target 2-4 km, depending on computer resources.</td>
<td>Achieved. Three model configurations completed with horizontal resolutions of 6, 4, and 2 km for the whole Arctic Ocean. This allows choice based on available computer resources.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Mean prediction error in ice concentration (percent). Current estimate: 50%; target: 30% (or better).</td>
<td>Achieved. Range of mean prediction error in ice concentration: 0% to 30%.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Mean prediction error in ice thickness (m). Current error: 1 m; target 0.4 m (or better).</td>
<td>Achieved. Range of mean prediction error in ice thickness: 0 m to 0.4 m.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>
Mean error in ice drift velocity estimates (m/s). Current error: 0.05 m/s; target 0.02 m/s (or better).

Achieved. Range of mean error in ice drift estimates: 0 m/s to 0.02 m/s.

N/A.

### Program Year 3 Outcomes, Output and TRLs:

Project is at TRL-6

![Figure 18](image)

**Figure 18.** (a) Sea ice thickness (m) simulated by the 4 km resolution HIOMAS and thickness observations from the NASA IceBridge program collected during March and April of 2014 through 2015.

In Figure 18 (a), the blue line indicates equality and the red line represents the best fit to the observations. The number of total observation points, observed and modeled mean values, model bias (mean model–observation difference), and model–observation correlation (R) are listed. The mean model bias is 0.28, which is within the error range of the performance metrics. The model-observations correlation is 0.77, indicating that the model captures ~59% of the variance of the observations. Figure 18 (b): Point-by-point differences in ice thickness (m) between model results and observations at the locations of the observations; red (blue) color indicates that the modeled ice is thicker (thinner) than the observed. Ice thickness results from the 6 and 2 km resolution HIOMAS are similar to those from the 4 km resolution HIOMAS.
Figure 19. HIOMAS (left) and ACNFS (right) simulated sea ice thickness for April 30, 2016.

Figure 19 shows that both the HIOMAS and ACNFS models have ~4 km horizontal resolution for the Arctic Basin. In comparison with ACNFS, HIOMAS does not create excessive sea ice thickness in the Beaufort Sea.

Unanticipated problems and plans for addressing them: None.

Transition Plans

Transition Plans and Progress Made: ADAC leadership, the HIOMAS investigator, and other project investigators (in particular, Arctic Oil Spill Modeling) worked in Year 3 to advance transition pathways for HIOMAS. As reported, HIOMAS has been discoverable via NOAA programs such as Arctic Environmental Response Management Application (ERMA). In Year 3, ADAC initiated coordination with the U.S. National Ice Center in order to establish a specified Plan of Action and Milestone (POAM) to transition HIOMAS as an operational model at USNIC no later than 30 June 2019. This includes undergoing USNIC information assurance requirements and model evaluation.

Further investigation is needed to discern if applicability to General NOAA Operational Modeling Environment (GNOME) and any DHS or USCG application as desired by HIOMAS USCG HQ Project Champion.

Currently, transition for HIOMAS has three separate avenues of approach:

- Become an operational model within USNIC (most definitive pathway)
- Establish a transition to formally integrate within NOAA via Arctic ERMA and/or GNOME (with results readily useable to USCG);
- Integrate to a U.S. Coast Guard system resulting from ADAC follow-on research associated with Arctic MDA and information fusion.
In Program Year 3, ADAC’s AIFC team coordinated HIOMAS updates to Arctic ERMA. This was in response from request by USCG D17 to support their watch standers center efforts to improve Arctic Maritime Domain Awareness (Arctic MDA). Providing periodic HIOMAS updates to Arctic ERMA assisted D17 with precision Arctic Ocean currents, sea ice presence, thickness and movement. Integrating HIOMAS into Arctic ERMA, (as part of a suite of capabilities sought in AIFC’s research to advance Arctic MDA) was in accordance with ADAC AIFC Program Year 3 Workplan.

**PROJECT: Arctic Oil Spill Modeling (AOSM)**

**Project PI’s:** Dr. Tom Ravens and Dr. Scott Socolofsky

**Lead Institutions:** University of Alaska Anchorage and Texas A&M University (TAMU)

**Supporting Team:** Dana Brunswick (UA) and a Postdoctoral researcher (TAMU).

**Collaborators:** Glen Watabayashi and Catherine Berg, NOAA Office of Response and Restoration.

**Program Year 3 Project Champions:** LT Rebecca Brooks, CG-MER (Primary); Mr. Jerry Popiel, USCG D9 IMPA (Secondary); and H. Blaney, CG-255 (Secondary).

**New Project Champions Established by DHS S&T OUP and HQ USCG at end of Program Year 3:** Ms. Kristen Trego, CG-MER.

**Student Involvement:** The project supported a graduate student (Dana Brunswick) and Postdoctoral researcher (Dr. Chris C.K. Lai), who worked with co-PI Scott Socolofsky (Texas A&M Univ.). He modified the Texas A&M University oil plume model (TAMOC) to include surface buoyant plume dynamics and worked on the coupling between TAMOC and both the GNOME model and the new Arctic Oil Spill Calculator (AOSC). The graduate student worked with PI Ravens and had primary responsibility for the intermediate and “far field” oil transport calculations within AOSC.

**Project Description**

**Abstract:** The team is working to develop techniques to estimate the spreading of oil released under ice (due to a well blowout or due to a ruptured pipeline) or among ice (due to a ship grounding). For the under-ice oil release from a well blowout or a ruptured pipeline, the approach involves coupling output from the oil plume model developed by Texas A&M University with simple analytical density current models to arrive at forecasts of oil spreading. For oil released near the surface, project team adopted approaches derived from the research literature that are compatible with NOAA’s GNOME oil spill model (General NOAA Operational Modeling Environment).

The goal is to develop a tool to forecast the spreading of oil in the immediate aftermath of a spill event (i.e., within 24 or 48 hours of the spill), accounting for the character of the spill (e.g., well blowout or pipe rupture), the release rate or amount, and the environmental conditions (ice concentration, water
The tool produced – referred to as the “Arctic Oil Spill Calculator” – is an “in-house” platform for developing and testing algorithms. In Program Year 4, we will incorporate the algorithms into GNOME.

**Baseline:** The USCG relies on the General NOAA Operational Modeling Environment (GNOME) oil spill model and NOAA for expert guidance when responding to an oil spill. At the beginning of this project, the existing GNOME oil spill model was not Arctic-capable (e.g., it did not yet account for sea ice). The existing GNOME oil spill model also did not yet include an oil plume module so that it could not readily address sub-surface well blowouts and sub-surface pipeline ruptures. In ADAC Program Years 1 and 2, AOSM researchers engaged with NOAA’s leading oil spill modelers (Glen Watabayashi and Catherine Berg), and provided guidance and suggestions on general ways to incorporate ice into GNOME. In part, based on this guidance, the new GNOME model, (under development) accounts for sea ice by assuming if the coverage is 20% or less, the oil moves with winds and currents. If the coverage is 80% or more, then it moves entirely with the ice. For concentrations between 20% and 80%, movement interpolates linearly.

In ADAC Program Years 1 and 2, ADAC acquired under-ice roughness data from the Beaufort and Chukchi Seas. These data are important for forecasting the movement and spreading of oil released under ice, and it constitutes additional baseline data. Shell Corporation originally provided the Arctic under-ice roughness data available to this project. The AOSM project also benefitted from significant analysis and processing by ADAC collaborator Dr. Andy Mahoney (UAF).

In ADAC Program Year 3, co-PI Dr. Scott Socolofsky (Texas A&M University) joined the ADAC Arctic Oil Spill Modeling team. The plume modeling expertise developed by Texas A&M University also constitutes significant baseline data.

Over the last five years, Dr. Socolofsky developed the Texas A&M Oil Spill Calculator (TAMOC). TAMOC is a comprehensive model for predicting the nearfield behavior of subsea oil spills (Socolofsky et al., 2015). Dr. Socolofsky developed TAMOC via support from an array of sources, including the U.S. National Science Foundation, the Gulf of Mexico Research Initiative (GoMRI), the Bureau of Safety and Environmental Enforcement (BSEE), Chevron Energy Technology Company, and Shell Oil Company.

The AOSM researchers note, when oil and gas are released below the surface, these substances rise and entrain ambient seawater to form a plume; the nearfield region of a spill extends until the buoyant effects of the oil, gas, and seawater mixture are exhausted. For the Deepwater Horizon/Macondo Canyon accident, the nearfield dynamics were responsible for the deep intrusion layer that formed at 1100 m depth in the Gulf of Mexico (Socolofsky, et al., 2011), as well as for transport of oil to the surface close to the response zone (Ryerson, et al., 2011). In shallow, ice-capped regions such as the Chukchi and much of the Beaufort Seas, the nearfield plume extends from the spill to the ice bottom surface. The plume model predicts the mixture density of oil, gas, and seawater that will intrude laterally under the ice. The plume model also predicts the mass flow rate of oil and gas.

**Relevance to DHS:** In accordance with U.S. law, the Coast Guard is the designated Federal On-Scene Coordinator to oversee & coordinate the response to discharges of oil in the coastal zone. During such a
response, the USCG relies on forecasts of oil transport to inform and manage the response. The National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration (ORR) provides scientific support to the Coast Guard, including forecasting and modeling of oil transport and to provide them to USCG during a response in a format that enables response decisions. To do this, NOAA uses their General NOAA Operational Modeling Environment (GNOME), a computer software package to predict oil transport in the marine environment. At the start of ADAC, the GNOME model was not capable of simulating the interaction of oil with ice; hence, it was not capable of making accurate oil transport forecasts in the Arctic domain. ADAC is developing oil spill models appropriate to Arctic conditions and incorporating our findings into the GNOME model. Thus, the relevance of this research makes it possible for NOAA to provide USCG reliable forecasts to use during a response to an Arctic oil spill event.

**Purpose of Research:** The objectives of the proposed research are to develop an “Arctic Oil Spill Calculator” (AOSC) that provides short-term (24 and 48 hour) forecasts of an oil spill event in the Arctic. Such forecasts are currently not available to first responders. The oil spill forecasts will provide projections of the location of the spill, the extent of oil spreading (longitudinal and transverse spreading), and the oil plume density and thickness as a function of the nature of the spill event (e.g., well blowout, pipeline rupture, ship grounding). Forecasts will also include the oil release rate or amount, and the environmental conditions (e.g., ice concentration, water depth and velocity, etc.). AOSC is serving as an in-house platform for the development and testing of Arctic oil spill algorithms planned for later incorporation into the GNOME oil spill model.

**Methodology:** In this project, the team developed a forecasting tool – the Arctic Oil Spill Calculator – which forecasts critical oil spill information (e.g., location, horizontal extent, thickness, and concentration) 24 and 48 hours into the future. The Calculator accounts for sub-surface releases due to well blowouts and pipeline ruptures as well as near-surface releases due to ship groundings. It accounts for the presence of ice and the under-ice roughness. It accommodates oil spill events in the Chukchi and Beaufort Seas.

In order to estimate the horizontal spreading of near-surface oil spills in seas with ice concentrations between 0% and 100%, researchers supporting MATLAB² developed a random walk oil-spreading model initially ignoring the presence of ice. The random walk model was a function of the ocean horizontal diffusivity, wind speed and direction, and ocean surface velocity at the spill location. In the second step, modelers reduced spreading in accordance with the ice concentration, incorporating rules of thumb developed in the oil spill literature (e.g., Dickins and Buist 1975).

For a subsurface release of oil due to a well blowout or a pipeline rupture, we employed a different methodology. We used the Texas A&M University Oil Plume Model to generate the initial (nearfield) condition of the oil plume, covering the period from the oil release from the blowout or pipeline rupture

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² MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions expressed in familiar mathematical notation.
to the arrival of the plume at the underside of the ice. As appropriate, researchers input Chukchi Sea or Beaufort Sea oil reservoir properties and hydrocarbon constituents into the model ensuring realistic plume simulations. The Texas A&M model generated the plume density, plume volumetric flow rate, plume horizontal extent, and oil mass flow rate all as a function of vertical position. The model also determined the plume momentum and the likely reflection at the under-ice surface.

![Depiction of oil plume and buoyant density current on underside of ice](image)

*Figure 20. Depiction of oil plume and buoyant density current on underside of ice, assuming smooth ice, and stagnant ice and water.*

Based on the plume model outputs, we developed a density current model to forecast the subsequent spreading of the oil plume (Figure 20). A key parameter of the density current model used to forecast oil plume spreading was the frontal velocity, $u_f$, for which modelers gain a nominal estimate from the classical result (Meiburg and Kneller 2010, Meiburg et al. 2015):

$$u_f = Fr (g' h)^{1/2}$$

In detail: $Fr$ is the Froude number (a function of $\rho_o/\rho_1$ and/or $h/H$); $h$ is the density current front height. $H$ is the total fluid depth beneath the ice, $g'$ is the reduced gravity ($= g \Delta \rho/\rho_o$), $g$ is the gravitational acceleration; $\rho_1$ is the density of the plume. $\rho_o$ is the ambient density, and $\Delta \rho$ is the difference between the ambient density and the plume density.

In order to determine the variation in density current velocity and height in the flow direction, the team employed a depth-averaged or shallow water (SW) density current model. For a subsurface oil release into stagnant water under smooth and stagnant ice, the plume had radial symmetry. Researchers estimated plume spreading (at 24 and 48 hours) based on the frontal velocity and the elapsed time. For
a subsurface oil release into stagnant water with significant under-ice roughness (defined as roughness greater than the steady state density current thickness), the spreading extent will be determined based on ice cavity volume and plume volumetric flow rate, following Cox and Schultz, 1981). In the event of a subsurface release into moving water/ice, the plume will be elongated and relatively narrow. The team estimated the longitudinal spreading based on the water/ice velocity and the elapsed time, and estimated the lateral spreading based on the frontal velocity described above.

**Project Results**

**Key Accomplishments in Program Year 3:**

*Finalization of the development of the Arctic Oil Spill Calculator.* The Calculator is a MATLAB-based program that calculates the movement and spreading of oil released near the surface accounting for ice concentration, and under ice accounting for under-ice roughness. The Calculator is an in-house test bed for developing and testing Arctic oil spill algorithms before integration into GNOME.

*Validation of the Arctic Oil Spill Calculator for surface releases.* The team calibrated and validated the Arctic Oil Spill Calculator by comparing observations and calculations of the trajectory and spreading of an experimental 2009 oil spill in the Barents Sea in marginal ice conditions (80% ice). The spill volume was seven cubic meters, the duration of the experiment was 6 days, and the process moving the oil was ice drift, driven by wind and ocean current. The observed and an example AOSC-calculated trajectory shown in Figures 21(a) and 21(b) below. For this calculation, the team assumed the horizontal diffusion coefficient to be 100 cm2/s, the windage as 2.5 to 3.5%, and wind drift as 2% of wind speed with a 30-degree clockwise shift in direction. For this example, the maximum observed and calculated north-south distance on the trajectory was about 49 and 59 km, respectively. Figure 22 shows observed and calculated spreading.

*Validation of Texas A&M Oil Spill Calculator (TAMOC).* The team validated the ability of the TAMOC to predict the densities of the three phases of interest (seawater, oil, and gas). Additionally, the team also evaluated the ability of the model to predict two relevant parameters indicative of plume behavior: the width of the plume and the separation height.
Figure 21. (a) Observed and (b) AOSC-calculated trajectory of the 2009 Barents Sea experimental oil spill.

Figure 22. Observed and calculated oil spill area over 5 days of the experimental Barents Sea spill.

**Modeling of five oil and gas spill scenarios.** The team modeled five oil/gas spill scenarios including one surface release and four sub-surface releases. Below provides basic information about each of the “five scenarios:”

a. A surface oil release at Utqiaġvik (formerly Barrow) Alaska, due to a vessel rupture.

b. A subsurface oil release at Utqiaġvik, due to a vessel rupture or blowout.

c. A subsurface oil release at Northstar Island (North Slope Alaska) due to pipeline breach.

d. A subsurface oil release at Burger, Alaska (Chukchi Sea) due to a well blowout.

e. A subsurface gas leak in Cook Inlet Alaska.
Scenarios “a”, “b” and “e” are described in more detail below. Full descriptions of all of the scenarios is included in the University of Alaska Anchorage, Master in Civil Engineering Thesis written by Dana Brunswick.

Scenario a: surface oil release at Utqiagvik (formally Barrow): The first scenario (scenario “a”) addressed a surface release of 120,000 m$^3$ of Prudhoe Bay Crude. Model inputs for this scenario are provided in Figure 23 and other figures communicating the environmental conditions are provided in the University of Alaska Anchorage Master’s Degree Thesis of Dana Brunswick. During the time of the spill, the ice concentration was 9/10 over most of the domain. The wind was moderate (6-10 knots), and it blew from the east and southeast. Ocean currents flowed toward the north. These “movers” moved the spill seaward as shown in Figure 24. After the two-day period, the AOSC-calculated spill area was about 340 km$^2$ and the spill thickness was about 4 mm.

<table>
<thead>
<tr>
<th>Location</th>
<th>Utqiagvik, AK, [Lat = 71.5, Lon=156.8333]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release date</td>
<td>2016-05-04 13:00 (AKST)</td>
</tr>
<tr>
<td>Spill size</td>
<td>120,000 m$^3$ (750,000 bbl)</td>
</tr>
<tr>
<td>Oil type</td>
<td>Prudhoe Bay Crude</td>
</tr>
<tr>
<td>Release location</td>
<td>surface</td>
</tr>
<tr>
<td>Current</td>
<td>HYCOM (Figure 35, Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Wind speed</td>
<td>GFS (Figure 33, Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Windage</td>
<td>1-3 %</td>
</tr>
<tr>
<td>Persistence</td>
<td>.25 hr</td>
</tr>
<tr>
<td>Ice drift</td>
<td>HIOMAS (Figure 42, Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Ice concentration</td>
<td>NOAA (Figure 37, Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Modelled duration</td>
<td>48 hours (2 days)</td>
</tr>
<tr>
<td>Time step</td>
<td>15 minute</td>
</tr>
<tr>
<td>Number of particles</td>
<td>100</td>
</tr>
<tr>
<td>Bin size</td>
<td>1001 m x 1002 m</td>
</tr>
</tbody>
</table>

Figure 23. AOSC inputs for scenario “a”: Surface Oil Release near Utqiagvik, Alaska.

---

Scenario “b”: subsurface oil release at Utqiaġvik: The second scenario (scenario b) addressed a subsurface oil release at Utqiaġvik, Alaska due to a near-bottom vessel rupture or well blowout. The period and environmental conditions are the same as in scenario a. For a subsurface release, the nearfield spill data on plume density and mass flowrate are provided by the Texas A&M Oil Spill Calculator (TAMOC), and the far field solution is provided by AOSC’s analytical density current models described later in this report. Researchers provide AOSC and TAMOC data inputs for scenario b in Figure 25.

<table>
<thead>
<tr>
<th>Location</th>
<th>Utqiaġvik, AK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lat = 71.5, Lon=-156.83333</td>
<td></td>
</tr>
<tr>
<td>Release date</td>
<td>2016-05-04 13:00 (AKST)</td>
</tr>
<tr>
<td>Spill size</td>
<td>120,000 m³ (750,000 bbl)</td>
</tr>
<tr>
<td>Oil type</td>
<td>Pt Thompson crude</td>
</tr>
<tr>
<td>Release location</td>
<td>subsea</td>
</tr>
<tr>
<td>Water depth</td>
<td>45.72 m (150 ft.)</td>
</tr>
<tr>
<td>Current</td>
<td>HYCOM (Figure 35 Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Wind speed</td>
<td>GFS (Figure 33 Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Windage</td>
<td>1-3 %</td>
</tr>
<tr>
<td>Persistence</td>
<td>.25 hr</td>
</tr>
<tr>
<td>Ice drift</td>
<td>HIOMAS (Figure 42 Dana Brunswick MSCE Thesis)</td>
</tr>
<tr>
<td>Ice concentration</td>
<td>NOAA (Figure 37)</td>
</tr>
<tr>
<td>Modelled duration</td>
<td>48 hours (2 days)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Time step</td>
<td>15 minute</td>
</tr>
<tr>
<td>Number of particles</td>
<td>100</td>
</tr>
<tr>
<td>Bin size</td>
<td>1001 m x 1002 m</td>
</tr>
<tr>
<td>Plume type</td>
<td>Stratified</td>
</tr>
<tr>
<td>GOR</td>
<td>0 (oil only)</td>
</tr>
<tr>
<td>Initial droplet size</td>
<td>Maximum stable diameter 23.5 mm</td>
</tr>
<tr>
<td>Diameter of release orifice</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

*Figure 25. AOSC and TAMOC inputs for scenario “b”: Subsurface Oil Release near Utqiagvik, Alaska.*

After emission from the source, seawater is rapidly entrained in the plume. The water depth is very shallow so the aqueous dissolution of oil droplets in the near-field plume is limited; only 0.02% of solvable aromatics are predicted to aqueously dissolve before they reach the underside of the ice.

Output from the TAMOC nearfield plume model for this scenario is summarized in Figure 26.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average plume density</td>
<td>1024.6 kg/m³</td>
</tr>
<tr>
<td>Ambient seawater density</td>
<td>1025.1 kg/m³</td>
</tr>
<tr>
<td>Volume flow rate of water in the plume</td>
<td>184 m³/s</td>
</tr>
<tr>
<td>Mass flowrate of oil</td>
<td>1172 kg/s</td>
</tr>
<tr>
<td>Average plume temperature</td>
<td>271.5 °K</td>
</tr>
</tbody>
</table>

*Figure 26. Summary data on the TAMOC nearfield plume model for scenario “b”.*

Far field modeling of the thickness and spreading of the oil droplets on the underside of the ice (Figure 27) is dependent on the nature of the under-ice roughness. Based on historic ice draft data from near Utqiagvik, November ice draft ranges from 0.40 m to 6.64 m. In May, ice draft ranges from 2.55 m to 10.24. During the simulation of scenario b, the team used ice draft data from HIOMAS, and according to HIOMAS, ice draft ranged from 10 m depth (where there was landfast ice) to 2 m depth ice offshore. Based on the HIOMAS output, the team estimated that each square kilometer of ice held 15,700 m³ of oil with 40% of this area able to store oil.

The AOSC model predicts that the spill spreads out 5007 m between the point of emission at 45.72 m beneath the still water level (SWL) and the underside of the ice. The oil pools beneath the ice and distributes 120,000 m³ over 12 km², with a thickness of less than 1 mm. The concentration of ice is 9/10+. Thus, some of the oil will likely migrate to the water surface; however, the AOSC assumes that water surface is entirely ice covered and that oil is completely contained beneath the ice.
Scenario “e”: Gas leak in Cook Inlet: On February 7, 2017, a leak of natural gas, originating from a 52-year old underwater pipeline in Cook Inlet began. The pipeline, owned by Hilcorp, was delivering natural gas to oil platforms, and the company claimed that stopping gas flow without additional risks at the platforms served by the pipeline. The pipe had a nominal diameter of 8 inches and was leaking through a crack determined at the time the leak was fixed to be roughly three-sixteenth of an inch by three-eighth of an inch (4.8 by 9.5 mm). The gas released was almost pure methane. In the latest stage of this event, Hilcorp reduced the flow rate of gas in the pipe decreasing the quantity of leaking gas. NOAA provided the known/understood environmental factors, and AOSM modelers modeled the link, returning this information to NOAA.

Modelers based the simulations reported on the initial flow rate, which correspond to the prevailing situation during most of the event. Researchers simulated this scenario to provide insight into how much of the emitted gas aqueously dissolved and how much reached the sea surface. Figure 28 provides a summary of assumptions for scenario “e.”

<table>
<thead>
<tr>
<th>Release depth</th>
<th>24.4m (80 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release volume flow rate (gas) (at 15.5°C and 101325 Pa)</td>
<td>0.0714 m³ s⁻¹</td>
</tr>
<tr>
<td>Release duration</td>
<td>Several months</td>
</tr>
<tr>
<td>GOR</td>
<td>– (gas only)</td>
</tr>
</tbody>
</table>
Gas type | 99.4% CH₄ and 0.6% N₂ (mole percentage)*
--- | ---
Bubble initial size distribution | Assumed 5 mm
Model type | Stratified Plume Model
Water column profile number | 1
Diameter of the release orifice | 0.0063 m**.***
Release temperature | -1.5°C (= seawater temperature)
Latitude | 71.25139°N
Longitude | 163.19458°W

* Based on personal communication with Chris Barker (National Oceanographic and Atmospheric Administration), it appears that the gas also contained 0.7% of other compounds. Researchers neglected these miniscule levels of other compounds in these simulations.

** The estimated diameter of the release orifice, assumed circular was based on the equation at the top of page 30 of the ALOHA user manual, valid for choked flow leaking from a pipe. It appeared that the surface area of the release orifice reported after leak stoppage, corresponded closely to this estimated value.

*** The stratified plume model is started with the initial diameter assumed to be the diameter after flow establishment, which itself is assumed to be equal to 0.05 m (gas being expanding upon release, the increase of diameter in the flow establishment zone is larger than for scenarios 1 and 3 above).

**Figure 28. Assumptions for scenario “e”: Gas Leak in Cook Inlet.**

**Key Stakeholder Engagement in Program Year 3:** The project team participated in the ADAC “Customers and Partners” Roundtable, in order to inform and receive feedback on project progress. In particular, the project team engaged with key stakeholders at the NOAA Office of Response and Restoration (Glen Watabayashi, Catherine Berg, and Chris Barker), and with our project Champion LT Rebecca Brooks. The ADAC Oil Spill Modeling team actively engaged with NOAA during the 2017 Cook Inlet gas leak described in scenario “e”, above. In addition to the stakeholders listed above, project advocates include NOAA/NWS, USCG RDC, and USCG D17.

**Key Publications (Peer Reviewed):**
The research team published no peer reviewed journal articles in Program Year 3. However, three papers are in progress, with planned near term publishing:


Key publications/developments/presentations:

The research team presented its progress at the ADAC Annual Meeting in Washington, DC on 8 November 2016. Graduate student Dana Brunswick also presented project results at the April 28, 2017 Professional Development Seminar hosted by the UAA College of Engineering.

Changes from Initially Approved Work Plan: No significant changes from the approved work plan.

Project Progress against Milestones:

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop the Arctic Oil Spill Calculator algorithms for near-surface oil releases due to ship groundings and similar events, accounting for different concentrations of sea ice [Oct. 30, 2016].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Develop the Arctic Oil Spill Calculator algorithms for subsurface oil and gas releases making appropriate use of the Texas A&amp;M University plume modeling, incorporating appropriate Arctic reservoir data and oil pipeline data, and using appropriate density current models [Oct. 30, 2016].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Estimate the accuracy and precision of the Arctic Oil Spill Calculator (AOSC) using available field data on oil spills and using the GNOME model [March 30, 2017].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Implement the AOSC within the Arctic Information Fusion Capability (AIFC) and within Arctic ERMA [June 30, 2017].</td>
<td>Not completed.</td>
<td>Based on feedback from Glen Watabayashi (NOAA Office of Response and Restoration), it made more sense to implement AOSC within the existing GNOME model and provide modeled data.</td>
</tr>
</tbody>
</table>

Project Progress against Metrics:

<table>
<thead>
<tr>
<th>Description</th>
<th>Measure</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy of AOSC relative to the existing GNOME model in instances where AOSC and GNOME overlap.</td>
<td>The target accuracy is for the AOSC output to be within 50% of the GNOME result for 80% of the scenarios considered.</td>
<td>AOSC was in agreement with GNOME (within 50% of GNOME calculation) in all scenarios.</td>
</tr>
<tr>
<td>Accuracy of the Arctic Oil Spill Calculator (AOSC) using available field data on oil spills at specific times (when measured data are available).</td>
<td>The target accuracy is for AOSC output on oil spreading (at particular times) to be within 50% of observed spreading for 70% of the data sets considered.</td>
<td>AOSC was in good agreement with field data (within 20%) collected in the 2009 Barents Sea oil spill experiment.</td>
</tr>
<tr>
<td>Accuracy of the Texas A&amp;M Oil Spill Model (TAMOC) relative to measured data in shallow water applications.</td>
<td>The target accuracy is for TAMOC plume density calculations to be within 50% of measured data for 70% of the data sets considered.</td>
<td>Density of the three phases of interest (seawater, oil, and gas) were found to have an error of less than 2%</td>
</tr>
<tr>
<td>AOSC implemented within the Arctic Information Fusion Capability to support USCG and other DHS maritime missions and to provide decision support.</td>
<td>Implemented or not implemented.</td>
<td>As described in the milestones section, researchers did not implement AOSC to AIFC framework as it made more sense to focus on including its algorithms within GNOME, and make modeled data available via ADAC efforts in Arctic Information Fusion, to include any advances to including data in Arctic ERMA.</td>
</tr>
</tbody>
</table>

**Outcomes, Outputs and TRLs:**

**Project is at TRL-4**

In Project Year 3, researchers completed the Arctic Oil Spill Calculator (AOSC) using MATLAB software. The next step is to integrate the AOSC oil spill algorithms into NOAA’s GNOME model. Upon achieving GNOME integration, AOSM gains a fundamental operational status. As of June 30, 2017, the project ranks the AOSC at a technology readiness level of **TRL-4**. This assessment is based on the facts that (a) AOSC has been implemented and tested as a prototype, (b) AOSC has integrated a reasonable number of technology elements (oil spill processes), and (c) calculations have been demonstrated using full-scale data sets.

**Unanticipated Problems and Plans for Addressing Them:** The project team identified no major problems for either of the modeling components (TAMOC or AOSC) of the Arctic Oil Spill Modeling project. As challenges arise, the team communicates, as needed, through ADAC quarterly report presentations. Researchers also work with assigned USCG Project Champions.

**Transition Plans**

**Transition Plans and Progress Made:** The Arctic Oil Spill Modeling project has two major components: the subsurface transport model, which uses the Texas A&M Oil Spill Calculator (TAMOC), and the surface-tracking model, which is the Arctic Oil Spill Calculator (AOSC). NOAA has already adopted TAMOC as the subsurface module of GNOME, and NOAA is working with the University of Alaska to update GNOME with Arctic-capable algorithms from AOSC. While the model advances in AOSC are being included in the GNOME, these models need testing for Arctic scenarios. Transition includes
training NOAA staff for use of AOSM within GNOME. While AOSM modeling is well suited for GNOME, data from GNOME modeling supports USCG Federal On-Scene Coordinators in an Arctic oil spill. Accordingly, readily disseminating modeled AOSM data and fusing with other environmental data remains a key USCG MDA need, and potential key data source to access in new ADAC efforts in Arctic information fusion.

**PROJECT: Identifying, Tracking and Communicated Sea-Ice Hazards in an Integrated Framework**

**Project Team and Champions**

**Project PI:** Dr. Andrew Mahoney

**Lead Institution:** University of Alaska Fairbanks (UAF).

**Supporting Team:** Co-investigator Dr. Hajo Eicken (UAF), Technician Josh Jones (UAF).

**Collaborators:** Dr. Amy Merten (NOAA Office of Response and Restoration), Dr. Mark Ivey (Sandia National Laboratory), Dr. Tom Ravens (UAA, ADAC)

**Program Year 3 Project Champions:** HQ USCG CG-751 (Primary). HQ USCG CG-255 and USCG RDC (Secondary). ADAC acknowledges the following as project advocates: USCG RDC, USCG D17 and NOAA/NWS.

**Student Involvement:** The plan for Program Year 3 student involvement was to provide support for a Ph.D. student to conduct research into small-scale motion of landfast sea ice in the context of stability and safety of subsistence and commercial ice use. Unfortunately, education funds were not available to the project at the beginning of the academic year and the team arranged alternative funding support for the student, who successfully defended their thesis as described below. The team was fortunate to develop a collaboration with UAF Interdisciplinary Ph.D. student Jessica Garron, whose thesis tackles questions related to the incorporation of cutting-edge satellite-based oil spill detection techniques into Arctic oils spill response planning and policy. During year 3, Ms. Garron conducted a number of interviews with different Arctic operator groups to understand the usage of scientific data at different levels of decision-making. Additionally, two UAF undergraduate students (James Wall and Patrick Steckman) became involved in the project during the spring semester. Mr. Wall is majoring Homeland Security and Emergency Management / Civil Engineering and completed a project entitled “Environmental and Economic Security Challenges in a Changing U.S. Maritime Arctic” under the mentorship of Dr. Eicken. Mr. Steckman is majoring in Geography and Geospatial Science and Computer Engineering and completed a project entitled “Identifying best practices for display of vector ice motion data for different stakeholders and use cases.” Mr. Steckman was mentored by Dr. Mahoney and Mr. Dayne Broderson from the University of Alaska Fairbank’s Geographic Information Network for Alaska (GINA).
**Project Description**

**Abstract:** Increasing shipping and offshore activity together with emerging climate change-related threats to coastal and marine infrastructure related to traffic have greatly increased threats to environmental security in the maritime Arctic. In order to minimize and manage risks, hazards need identification and tracking. This project focuses on those hazards associated with ice in the ocean such as entrapment of vessels; structural damage to vessels and infrastructure; and risks to personnel and assets due to detachment of landfast ice.

During an Arctic emergency response, assets need safe and effective deployment in regions that are often remote and challenging. Involvement of local first responders will be a critical part of any Arctic response. Therefore, responders need a framework at the local scale to enhance and inform Arctic MDA and emergency response by identifying, tracking and communicating key environmental hazards in ice covered extreme maritime environment.

Predicting the real-time ice velocity from Utqiagvik (formally Barrow), Alaska will improve capabilities for ice hazard monitoring. As the northernmost point in the North American mainland, Point Barrow is often the last location along the Alaska coastline to open up to navigation and therefore represents a potential chokepoint for maritime operations in the U.S. Arctic. Making real-time data available to analysts will improve the ability of decision makers to assess hazards posed by sea ice in this location. Additionally, the project team demonstrated that the technology developed to track ice motion is transferrable to ship-based platform, where it is potentially useful to provide tactical information about ice conditions to crew.

**Baseline:** Currently, sea-ice hazards are evaluated based on available remote sensing data and ice charts, both of which have been shown to lack the temporal and spatial resolution to identify and track major sea-ice hazards (such as those listed above) at the tactical and operational level. Past work by the investigators and industry partners focused on the development of hardware and software solutions to extract relevant information about ice hazards from marine radar and other sensors available to or in use on USCG vessels and in coastal settings. In order to support USCG and other DHS maritime missions, these tools need to integrate into broader situational or maritime domain awareness contexts, to connect to stakeholder decision-support frameworks, and to tie into ice-ocean models relevant for emergency/spill response.

Sea ice information for maritime activity relies heavily on satellite data and much of the attention given to hazards posed sea ice has been focused toward thick ice and extreme ice features that can be identified from space [e.g., Barber et al., 2014]. Currently, sea-ice hazards are evaluated based on available remote sensing data and ice charts, both of which have been shown to lack the temporal and spatial resolution to identify and track major sea-ice hazards (such as those listed above) at the tactical and operational level. In this project, a broader set of hazards related to sea ice are considered, including those that require observations at higher temporal resolutions than can be achieved by polar orbiting satellites [Eicken et al., 2011; Eicken and Mahoney, 2014].
Past work by the investigators and industry partners focused on the development of hardware and software solutions to extract relevant information about ice hazards from marine radar and other sensors available to or in use on USCG vessels and in coastal settings [Jones, 2013; MV et al., 2013]. Marine radar is a robust technology that has been a mainstay of navigation for several decades and is capable of providing continuous situational awareness independent of weather or daylight. UAF researchers pioneered the use of coastal radar systems to study ice motion [e.g., Shapiro, 1975; Shapiro and Metzner, 1989]. Through numerous iterations of system design, UAF researchers have continued to use a coastal radar in Utqiagvik (formally Barrow) to improve understanding of the dynamics of landfast sea ice [Mahoney et al., 2007; Druckenmiller et al., 2009; Druckenmiller et al., 2010; Jones, 2013; Mahoney et al., 2015]. Recently, the Finnish Meteorological Institute (FMI) has pursued a parallel line of research using both coastal and ship-based marine radar to track ice motion and deformation in the context of ice engineering and MDA [Karvonen, 2016].

Relevance to DHS: Urgent information needs arise from increases in maritime and offshore resource exploration activities. Based on input from USCG D17, review of USCG Arctic Information Needs workshop report, and published guidance from USCG RDC, the ice hazards information products and the framework of a North Slope/Barrow ADAC Testbed developed through this project will meet these needs.

This research work addresses several of the 20 US MDA challenges identified by the USCG as well as USCG/DHS MDA mission elements. The research also addresses established information needs within the broader emergency and spill response community, including entities such as NOAA’s Office of Response and Restoration (ORR) with a mission to support USCG/DHS with respect to spill response. Moreover, interfacing observing system infrastructure with local and regional first responders directly addresses the needs of DHS’ “Responders of the Future” concept identified as a top challenge for the next decade. While ADAC acknowledges and complies with the decision to conclude this Integrated Ice Hazards project with the completion of ADAC Program Year 3, the Center and research team respectfully state that there is high value in continuing research on Integrated Ice Hazards to USCG Arctic operators.

Purpose of Research: The overarching purpose of this research is to develop new science and technology to identify, track, and distribute sea ice-related hazards efficiently to emergency responders and planners. To achieve this purpose, the research addressed the following questions:

- What ice conditions or events can represent hazards?
- How can we detect and track these ice hazards in an operational situation?
- How can we synthesize ice hazards data streams and communicate the information to stakeholders?

Methodology: As discussed in prior Integrated Ice Hazards Workplans and Annual Reports, the project method conforms to three activities: Ice hazard tracking with marine radar, detection of small-scale movement of landfast ice, and synthesizing and communicating sea ice and other Arctic MDA hazards information. The following paragraphs describe the methodology in detail.
I. Ice hazard tracking with marine radar. In March 2014, ice velocity information shown in Figure 29 from a coastal ice radar system operated by UAF in Utqiaġvik (formally Barrow), Alaska directly aided a successful search and rescue operation to recover personnel and equipment set adrift during a “landfast ice detachment” event.

![Image](image.png)

Figure 29. March 2014 ice velocity information from a coastal ice radar system operated by UAF in Utqiaġvik (Barrow) Alaska.

The research methodology builds on the hardware and software developed through CIMES by developing new post-processing steps to enhance the MDA content of the ice velocity data and to improving the usability of the data products. The research developed new data products such as ice divergence maps that were designed to identify regions where the ice cover is breaking apart or converging on itself. The research improved the usability of all data products by releasing them as near-real-time (< 1hr) feeds (when radar was operational) and providing georeferenced USCG and Arctic ERMA compatible data products (KML and Shapefiles).

In Program Year 3, researchers continued to refine the “ice divergence” data product, which requires careful treatment of errors and uncertainties in the ice velocity data. The team also applied the processing software developed for the Utqiaġvik coastal radar system to other modalities including ship-based marine radar, a land-based weather radar in Utqiaġvik, and spaced-based synthetic aperture radar.

II. Detection of small-scale movement of landfast ice.
Small-scale motion of landfast ice may be undetectable by conventional remote sensing techniques (including sea ice radar) but it can still render ice roads unsafe or cause damage to coastal and sub-sea infrastructure. Small-scale motion may also be a precursor to landfast ice detachment. In the work plan prior to Program Year 3, researchers planned to use the COTS Differential Global Positioning System (DGPS) receivers to evaluate whether they have required precision to detect small-scale deformation.
events indicative of landfast ice instability and potential threats to infrastructure. However, due to insufficient financial resources provided by the Center, this work did not progress as planned (see annual report for year 2). In Program Year 3, researchers instead built on an alternative satellite-based approach developed under other NSF-funded research activities. This approach uses interferometric synthetic aperture radar (InSAR) to measure cm-scale ice motion associated with cracking and destabilization of sea ice. Researchers combined this with estimates of surface roughness derived using polarimetric synthetic aperture radar (PolSAR) to produce maps of ice trafficability and identify regions of sea ice that are safest for surface travel, including the landing of aircraft.

**III. Synthesizing and communicating sea ice and other Arctic MDA hazards information.** In order to assess the value of hazards-related data products and to test methods for effectively communicating the information they contain, researchers developed a framework for an Arctic-specific MDA testbed in Utqiaġvik (formerly Barrow), Alaska. This ADAC testbed leverages existing community and scientific observing assets to develop a hybrid research-operational framework that addresses major challenges to MDA and effective emergency response in Arctic regions. The approach was first to produce a White Paper that would bring together stakeholders as co-authors to identify key gaps in Arctic MDA and identify the resources in Utqiaġvik required to close them (Eicken et al, 2016).

**Project Results**

**Key Accomplishments in Program Year 3:** The project team successfully implemented the ice-tracking algorithm on data from three new radar modalities that demonstrated the possibility to expand the technology beyond the use of coastal marine radar. The first new modality tested was a ground-based weather radar known as the X-band Scanning ARM Precipitation Radar (XAPR), operating near Utqiaġvik by the U.S. Department of Energy’s Atmospheric Radiation Monitoring (ARM) program. The second modality was a ship-based marine radar operating on the USCGC Healy. This required the subtraction of the vessel’s motion through the ice in order to derive the drift velocity of the ice over the ground. The third modality tested was satellite-based synthetic aperture radar (SAR), using open-access data from the European Space Agency’s Sentinel-1 satellite. We evaluated the capabilities of each of these methods and their value for Arctic maritime domain awareness (MDA) in a report submitted to project champions and ADAC leadership. Overall, we found that ship-based radars offered the best opportunity in the short-term for applying the technology and techniques developed in this project for enhancing Arctic MDA.

Working with nine co-authors from outside the project team and representing six different institutions, the team prepared a manuscript discussing the concept of a MDA Testbed in Utqiaġvik and the role of sustained Arctic observations in maintaining domain awareness in rapidly changing environment. A peer review journal, Arctic, accepted the prepared manuscript for publication and is listed in the key publications below.

PhD student Oliver Dammann successfully completed his thesis on Arctic Sea Ice Trafficability, which included the development of techniques for measuring small-scale movement and assessing the stability of landfast sea ice in the context of subsistence and commercial use of sea ice as a transportation platform. The project team lists the thesis and two resulting publications under key publications.
As of 30 June 2017, the project achieved TRL-6.

**Key Stakeholder Engagements in Program Year 3:**
Project PI Mahoney participated in all Customer and Partner Roundtable meetings throughout the year as well as the Annual Meeting in Alexandria, Virginia. Additionally, he communicated with USCG project champions in response to recommendations to consider the radar system operating in Prince William Sound to mitigate the hazard posed by iceberg in shipping lanes for the Port of Valdez. He included discussion of this system and comparison with the system operated by UAF in Utqiagvik in the “Arctic MDA Assessment for Alternative Radar Systems” report provided to the project champions in May. Additionally, PI Mahoney gave a webinar (listed below) on the use of coastal radar for sea ice monitoring to members of the National Weather Service Alaska Sea Ice Program.

**Key publications (peer reviewed or in-review):**

**Key publications/developments/presentations:**

**Changes from initially approved Work plan:** As described above, funding for student support was not in place in time for the beginning of the fall semester so we had to secure alternative support for PhD student Oliver Dammann. The team is pleased, however, to report that Dr. Dammann successfully defended his thesis in April 2017, which included the development of new techniques for analyzing small-scale motion and stability of landfast sea ice (see notes for milestone 4 above). The team also added additional student involvement to the workplan by mentoring and developing spring semester projects for two UAF undergraduate students, as described in the student involvement section above.

**Project Progress against each milestone:**

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
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<tbody>
<tr>
<td>1a. Development of ice velocity and hazards data products from additional radar-based modalities using algorithms and processing streams developed in years 1 and 2</td>
<td>Successfully applied ice tracking algorithm to data from 3 new radar modalities: i) ground-based weather radar; ii) ship-based marine radar; iii) satellite synthetic aperture radar</td>
<td>N/A.</td>
</tr>
<tr>
<td>1b. Assessment of MDA relevance for each data product with recommendations for further development.</td>
<td>Completed a MDA assessment for each new product, concluding that ship-based radar offers the best opportunity for short-term expansion of radar-based ice hazard tracking for enhancing Arctic MDA.</td>
<td>N/A.</td>
</tr>
<tr>
<td>2. Integration of ice radar-derived data feeds (ice velocity, divergence and ice edge position) into ADAC data fusion architecture for model validation.</td>
<td>Reformatted the archived ice velocity and divergence products into NetCDF format readily compatible with the ADAC data fusion architecture, but the data feed is currently offline due to hardware failure at the sea ice radar installation in Utqiagvik.</td>
<td>Necessary reformatting completed, but data feeds not integrated due to hardware failure. See below for more details.</td>
</tr>
<tr>
<td>3. Development of plan for tabletop exercise in Utqiagvik Testbed region to assess and inform design of ADAC data fusion infrastructure.</td>
<td>The basis for developing a tabletop exercise is presented in a journal article currently in press with journal <em>Arctic</em> and a paper submitted to the IEEE/MTS Oceans17 conference in Anchorage, Alaska in September. References for both these manuscripts are listed above.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>
4. Development of “ice stability” data products from satellite-based measurements of small-scale sea ice motion. | Developed and validated new satellite-based methods for detecting small-scale motion of landfast sea ice relevant for subsistence and commercial users of landfast sea ice. New methods described in detail via the PhD thesis of Dr. Oliver Dammann and associated peer-reviewed articles listed above. | N/A.

**Project Progress against each metric:**

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<tr>
<th>METRIC</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
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<tbody>
<tr>
<td>1. Development and assessment of new ice hazards data products from additional radar-based sensors. Targeted 2 new demonstration products</td>
<td>Developed 3 demonstration products, which are documented in MDA assessment document that was submitted to ADAC leadership and project champions</td>
<td>N/A.</td>
</tr>
<tr>
<td>2. Degree of overlap between ice hazards data products and model grid cells during validation time periods of interest. Team anticipates an overlap of &lt;25% (with &lt;10 days of overlap in time) after the first version of the grid has been set up and will begin to work towards overlap &gt;75% (with &gt;100 days’ overlap in time; both being constrained by coastal bathymetry and model resolution) after model grid is finalized.</td>
<td>In the current 4 km grid configuration of HIOMAS, there 100% spatial overlap of the radar’s ocean footprint with the model grid. The current timespan of HIOMAS data products exceeds that of the coastal ice radar, meaning we have 100% temporal coverage for archived data (2,543 days between 1/29/2009 and 3/9/2017).</td>
<td>N/A.</td>
</tr>
<tr>
<td>3. Planning document for ADAC Testbed planning providing implementation steps for key recommendations contained in year 2 whitepaper. Target is implementation plans for 5 out of 9 recommendations developed with input from</td>
<td>The following 3 recommendations are presented in a peer-reviewed paper currently in press with the Journal Arctic (listed above): 1: Implement a framework for an MDA Testbed on the North Slope of Alaska</td>
<td>N/A.</td>
</tr>
</tbody>
</table>
stakeholders and ADAC partners.

3: Conduct a survey of potentially relevant data sources, partners and contributors
5: Explore the potential value of Arctic ERMA in providing a framework for integration.

The basis of implementing recommendation 6 is presented in a paper submitted to the Oceans17 conference (also listed above):
6: Arrange for field and tabletop exercises that evaluate key aspects of an MDA testbed.

Additionally, recommendation 2 has been planned and implemented through interviews carried out by PhD student Jessica Garron (see above):
2: Survey and interview potential operational users to establish operational requirements.

Outcomes/output & TRLs:

Project is at TRL: 6

**Radar ice-tracking technology:** The research team demonstrated that the ice tracking technique developed for a coastal marine radar system is useful for a variety of different radar modalities including atmospheric weather radar, ship-based marine radar and satellite-based synthetic aperture radar. The following peer-reviewed articles (published previously) describe underlying software and hardware:


The team is currently in the process of transitioning long-term archiving and processing of future data streams to Axiom. Intellectual property remains held between at the University of Alaska.

**Mean velocity fields for model validation:** The team has produced daily and monthly mean velocity fields for the entire archive of radar data dating back to 2009. These data will be available in NetCDF format through Axiom.
**North Slope/Utqiagvik ADAC Testbed:** The two associated articles above, describe the basis for implementing and evaluating a MDA Test bed on Alaska’s North Slope.

**Unanticipated problems and plans for addressing them:** The UAF sea ice, radar system in Utqiagvik suffered a number of hardware and software failures this year, which resulted in several months of missing or low-quality data. Although ADAC DHS S&T OUP Cooperative Grant funding disallows resourcing for equipment maintenance costs, we were able to make some repairs using spare parts on hand from another unit.

**Transition Plans**

**Transition Plans and Progress Made:** For radar ice-tracking technology, the team transitioned long-term archiving and processing of current and any future data streams from University of Alaska Fairbanks to ADAC industry partner, Axiom Data Sciences. This includes the entire archive of daily and monthly mean velocity fields dating back to 2009 (all of which was finalized during Program Year 3) while processing new data as it was collected during Program Year 3. These data streams are now available in NetCDF format through a data maintenance plan administered by, Axiom Data Sciences. As previously described, ADAC leadership is seeking commercialization of developed radar software, based on assessment integrating ice movement indications on shipborne radar is a significant aide to navigation in ice-laden waters.

**PROJECT: Ice Condition Index (ICECON) for the Great Lakes**

**Project PI’s:** Dr. Tom Ravens and Dr. Andy Mahoney

**Lead Institutions:** University of Alaska Anchorage (UAA) and University of Alaska Fairbanks (UAF)

**Supporting Team:** Seth Campbell (graduate student, UAA) and Joshua Jones (research assistant, UAF).

**Collaborators:** US Coast Guard Districts 1, 9, and 17; US Coast Guard R&D Center

**Program Year 3 Project Champions:** Mr. Mark VanHaverbeke, USCG R&D Center

**New Project Champions Established by DHS S&T OUP and HQUSCG at end of Program Year 3:**
Champion: CDR William Woityra, CG-WWM; Support: Mr. Mark VanHaverbeke, USCG R&D Center

**Student Involvement:** The project is supporting a graduate student (Seth Campbell). He is assisting with the evaluation of the proposed ice condition indices and with the design of the ice index that ADAC will put forward.

**Project Description**

**Abstract:** In collaboration with the US Coast Guard and others, research team is developing an Ice Condition Index (ICECON) for the Great Lakes. The forecast index is up to 120 hours into the future.
making use of data from circulation and ice models developed by National Ocean and Atmospheric Administration (NOAA) Great Lakes Environmental Research Laboratory (GLERL). ICECON now-casts and forecasts will account for Icebreaker activity and its impact on overall ICECON. In parallel with the development of ICECON, the research will identify and adopt a vessel classification system, which will define a number of vessel classes and the ice-capability of ships in those classes (in terms of ICECON). This research was requested by USCG D9 to support their winter activities on the Great Lakes to increase safety and improve waterways management during period of ice coverage. The system will help the U.S. Coast Guard provide guidance and decision support to vessels (of a given class) which are planning a given transit. Successful development and implementation of ICECON should reduce the overall number of USCG rescues of vessels on the Great Lakes during winter months.

The overall ICECON Work Plan consists of six tasks. The research team conducted three of these during the last year. The team intends that the development of ICECON for the Great Lakes is an inclusive process that engages ice and maritime transportation experts from a range of organizations including (not exclusive):

- USCG R&D Center;
- National Oceanic and Atmospheric Administration (NOAA);
- U.S. National Ice Center (USNIC);
- US Army Corps of Engineers Cold Regions Lab (USACE CREL);
- Transport Canada;
- Canadian Ice Service;
- Finish Meteorological Institute.

Baseline: About 13 years ago, Transport Canada developed the “Arctic Ice Regime Shipping System” (AIRSS, Transport Canada 2003) in order to guide decisions on whether a ship (of a given class) should travel in ice (of a given condition). The system integrates information on Vessel Class (specifically the ice-capacity of ships) and ice condition (referred to as “Ice Regime” by Transport Canada). We examined the suitability of AIRSS as a basis for ICECON detail by ADAC in a 2015 document entitled: “AIRSS as basis for ICECON.” Briefly, application of AIRSS follows a 4-step process:

**Step 1:** Define the Ice Regime based on ice conditions (in particular, ice thickness and stage of development).

**Step 2:** Define Vessel Classes and Ice Multipliers (in which a set of Vessel Classes and a set of defined class-dependent Ice Multipliers – with positive Ice Multipliers indicating the vessel class is sufficient to handle the ice condition and with negative multipliers, indicating the vessel class was insufficient).

**Step 3:** Calculate the Ice Numeral (IN), which integrates information about the Ice Regime and the Vessel Class and accounts for concentration of each type of ice in the region of interest as well as the Ice Multiplier for the range of Ice Types for a particular vessel class. A positive IN indicates that the ship transit is safe for the ship class in question and considering the ice condition.

**Step 4:** Decide whether to proceed or to take an alternative route based on the Ice Numeral (IN).
A close examination of the AIRSS system reveals that the system boils down to a determination of whether the ship in question is rated for the ice present or not. AIRSS fails to take into account ocean/lake surface temperature (which would affect ice hardness and strength) as well as ice pressure (whether ice is diverging or converging). In addition, AIRSS does not explicitly include heat transfer calculations, which would be useful in an ice-condition forecasting system.

Fortunately, NOAA’s Great Lakes Environmental Research Lab (GLERL) currently forecasts lake surface temperature. The Finnish Meteorological Institute (a collaborator) currently forecasts ice pressure based on meteorological forecasts. ICECON investigators and associated collaborators seek an acceptable transfer of Finnish Meteorological Institute ice pressure forecast protocols to GLERL. Finally, high resolution meteorological and limnology forecasts for the Great Lakes provide the basis for heat transfer calculations. Hence, for the Great Lakes, data for building a more sophisticated decision support system for “ship transit in ice” is available.

Both USNIC and the USCG District 9 have put forward ICECON proposals that merit consideration. Transport Canada is reportedly working on an update to the AIRSS system. At the start of this project, USCG District 9 was evaluating the set of ice condition algorithms put forward by USNIC, who identified five environmental parameters that contributed to the overall condition of the lake ice. These include ice thickness, ice concentration, ice type, wind condition (causing ice convergence or divergence), and surface temperature. Based on the value of each of these environmental parameters, researchers assigned points and summed the total number of points used to indicate the ice condition index (0 through 5). Figure 30, for example, shows the points associated with varying levels of ice concentration. Figure 31 shows the relationship between total points (from the five environmental parameters), ice condition index, and vessel classification.

![Figure 30. Points contributed due to different ranges of ice concentration.](image)

*Arctic Domain Awareness Center Year 3 Annual Report 1 July 2016-30 June 2017*
Relevance to DHS: The US Coast Guard provides guidance to Great Lakes mariners on the condition of the ice, and whether specific ships and ship-classes can transit safely (for a set of given ice conditions). In response to the ice conditions and the need for maritime transit, the USCG District 9 manages a fleet of icebreakers on the Great Lakes. The ice condition index under development will provide USCG the tools they need to manage vessel traffic in the Great Lakes and their fleet of icebreakers, when ice is present.

Purpose of the Research: The main objective of the proposed research is to develop an ice condition index (ICECON) and a corresponding vessel classification system that will provide the USCG decision support for the management of winter maritime transit in the Great Lakes. The decision support system will also serve as a maritime transportation management system as it will account for the effect of icebreaker activity on the ice conditions and serve as a tool for managing the deployment of the USCG Great Lake icebreakers.

Methodology: ADAC’s ICECON project is a two-year project, started in Program Year 3. The ADAC Program Year 3 portion consisted of three tasks, which focus on the development of the ICECON and vessel classification system. The follow-on year efforts include additional tasks. Through a sequential task driven method, the research integrates detailed marine vessel information to advance a corresponding vessel classification system. This classification system integrates with current Great Lakes meteorological data (including lake temperatures), and Ice hardness model algorithms to develop a Great Lakes region ICECON. The following describes the approved project year three tasks:

Task 1. Develop algorithm/decision tree for determining the ICECON as a function of ice type, ice thickness, temperature, pressure and ice concentration. At least two ICECON-like proposals exist— one developed by USCNIC and one by USCG District 9. In addition, Transport Canada reportedly is working...
on a next generation AIRSS system. In this task, the ADAC team evaluated current ICECON and ICECON-like systems. The team’s analysis consisted in evaluation of the existing systems, and considering alternative approaches in ICECON. Research recommendations address (a) USCG needs for decision support and management to the extent possible, (b) takes maximum advantage of the data that is currently available or will soon be available and (c) is well-informed by the sciences of thermodynamics and heat transfer.

The ICECON concept originating from District 9 of the US Coast Guard is displayed in Figure 32 (from the District 9 White Paper 2015) and illustrates, for example, that 2 feet of brash ice presents a range of possible ice conditions depending on the surface temperature and pressure.

![ICECON Decision Tree](image)

*Figure 32. Image of decision tree concept from Oct 2015 District 9 White Paper on Ice Condition Index.*

The ICECON concept developed by District 9 does include data on surface temperature and pressure. Thus, it does include more environmental data than the AIRSS approach. As researchers review this approach, they emphasize a physical understanding of the relevant mechanical and thermodynamic properties of lake ice. For example, researchers use the surface temperature to estimate the compressive strength of ice of a given thickness, which in turn feeds into the calculation of the “ice pressure index” term. Wind conditions – causing either ice convergence or divergence - also contributes to the pressure term.

The research team needs to investigate the use of other parameters not included in Figure 32, such as ice concentration and snow depth. Ice concentration affects the ability of the ice pack to exert pressure on a vessel, while the presence of snow on the ice surface can significantly increase the coefficient of friction between ice and hull.

Given the limits of current abilities to observe and model the necessary processes, ADAC investigators do not expect to derive absolute physical values for ice pressure. Instead, the Center would further
investigate how to derive an index based upon theory and empirical data that can be validated using existing ice encounter data, as described in Task 2.

An alternative approach to developing an ICECON system for the Great Lakes would be to try to build on the Arctic Ice Regime Shipping System (AIRSS) developed by Transport Canada (Transport Canada 2003), according to Darlene Langlois (Chief of the Meteorological Service of Canada, Darlene.Langlois@Canada.ca).

Canada produced a chart for the Great Lakes based on AIRSS system, and could add known and validated weather factors. A significant amount of effort went into the AIRSS, as such, ADAC recommends USCG seriously consider using AIRSS as a starting point. A preliminary assessment of AIRSS and its suitability as a basis of ICECON has been prepared (ADAC 2016).

USNIC suggested a third approach to developing an ICECON (USNIC 2015). USNIC personnel employ a point system to account for the contribution of different factors (ice thickness, ice concentration, temperature, etc.) to the severity of the ice conditions. The USNIC-based ICECON approach is currently being validated in the Great Lakes.

USCG District 9 provided a spreadsheet to the cutters to collect ice and environmental data and then compute the corresponding ICECON, in order to collect ship performance data relative to the ICECON level. The effort to develop an ICECON based on the USNIC approach is better suited as a short-term effort. The Center believes that an ADAC-lead effort on ICECON is better suited as a more enduring solution.

In addressing Task 1, ADAC provides a detailed review of the existing three alternatives and investigates other approaches. ADAC will make recommendations to the council of experts in order to decide which approach would be most suitable to pursue. Evaluation of the approaches will account for the data discussed in the tasks described below (e.g., Great Lakes ship-ice encounter data, ice and environmental data available through the Great Lakes Environmental Research Lab and other sources, and AIS data).

**Task 2. Identify, adopt, or define a system of vessel types similar to that used in the Arctic Ice Regime Shipping System (AIRSS).** USCG District 9 has stated that Great Lakes vessels (the “Laker fleet”) do not have an ice classification system that defines their ice capability. Instead, the USCG District 9 uses several “rules of thumb” to determine ice capability of vessels. For example, one rule of thumb is that vessels need to have a horsepower to length ratio of 6 to 1 in order to transit in ice that is 12 inches thick or more. Accordingly, ADAC plans to develop a system of vessel types, based in part on the existing rules of thumb, and use this vessel-typing system in the validation stages of the project to (Task 3) as a way of grouping vessels into largely comparable performance classes. The council of experts created to review Task 1, evaluates the developed system. Preliminary work, described in the “Year 3 Accomplishments” section of the ICECON year 3 project has identified three ship classes. Additionally, researchers have identified example ships from each class.

**Task 3. Use available ice-encounter data from Great Lakes vessels from previous year or two and other data to help develop and validate ICECON. Define the vessel types (classes) in terms of their ability to transit through different types of ice as characterized by ICECON.** USCG District 9 has begun to collect data to validate the USNIC-based on ICECON and to assess ship performance in ice relative to ICECON. In this Task, ADAC examined the data collected through the District 9 lead’s initiative as well as other
available data including AIS information and data obtained through USCG as well as from Government of Canada sources. It is noteworthy that the Finnish Meteorological Institute (FMI) has collected 9 years of AIS ship data from the Baltic Sea that they plan use to validate their ice forecasts and ice charts based on transit times of vessels through different classes of ice. Through collaboration with FMI, we anticipate that their data and findings could help develop and validate ICECON. Task 3 will deliver a validated ice condition index with a demonstrated relationship between ICECON levels and vessel performance. The council of experts provide advice regarding the method used to assess ship performance and the way in which this is used to validate the ICECON level.

In the final ICECON research year, research team will conduct additional tasks that focus on making the ICECON system operational.

**Project Results**

**Key Accomplishments:** In summary, the research team accomplished the following over the past project year:

- Worked with USCG to streamline the collection of ship-based data on the ice condition index;
- Assessed the ICECON algorithm provided by USNIC;
- Employed a Monte Carlo approach to derive an improved set of ICECON algorithms;
- Assessed the accuracy of forecasts of ICECON-related parameters relative to forecasts of those parameters;
- Examined AIS data on winter ship passage in the Great Lakes relative to ICECON-related environmental parameters.

Research team describes each of these accomplishments in more detail below:

*Streamlining the collection of ship-based data on ICECON.* In order to collect data on the ice condition index and its relationship to the 5 environmental parameters identified by USNIC, USCG ship captains operating on the Great Lakes in ice made observations of the ice condition as well as the 5 environmental parameters. ADAC streamlined the data collection process by helping create spreadsheets for data collection.

*Assessment of the ICECON algorithm provided by USNIC.* ADAC used the ship-based “ice condition index observation” and environmental parameter data to assess the NIC ICECON algorithms. We found that the USNIC algorithms accurately calculated the ice condition index 62.5% of the time (45 accurate calculations in 72 instances).

*Derivation of improved algorithms using a Monte Carlo approach.* ADAC employed a Monte Carlo approach to develop improved algorithms, which led to increased concurrence between the calculated ice condition index and the observed index. The new algorithms result in accurate results 72.2% of the time, a 16% improvement.

*Assessment of the accuracy of forecasts of ICECON-related parameters relative to forecasts of those parameters.* Considering 10 locations, 2 in each of the 5 Great Lakes, 60% of ice concentration forecasts
(4 days in advance) were “accurate” in January 2014. By accurate, we mean that the forecasted ice concentration differed from the now-cast ice concentration by 10% or less. Similarly, 90% of temperature forecasts were accurate (within 4°C).

**Examination of AIS data on winter ship passage in the Great Lakes relative to ICECON-related environmental parameters.** Analysis of AIS (Automatic Identification System) shipping data for the Great Lakes for three recent ice seasons (2013-14, 2014-15, and 2015-16) provided two major findings. First, we found that there was a correspondence between ship ice-capability and typical (or modal) vessel speed. USCG D9 provided us with examples of three simple classes of vessels operating in the Great Lakes:

- Least Capable: *Anglian Lady, Everlast*
- Capable: *John B Aird, Algoma Transport*
- Most Capable: *Paula R Tregurtha, James R Barker*

AIS data demonstrated a distinct relationship between ice capability of ships and the modal or typical velocity (Figure 33). This suggested that modal ship speed is useful as a “first order” vessel classification system for ice capability.

![Figure 33. Frequency distribution of vessel speed for six different vessels in three different classes of ice capability.](image)

The team was able to analyze the relationship between vessel speed and ice concentration for individual ships using daily gridded ice concentration data from USNIC in conjunction with the AIS data. Figure 34 displays the probability density function of the speed of the Algoma Transport for different ice concentration ranges. In addition, the figure displays the mean and modal vessel speed as a function of...
ice concentration and highlights a decrease in both mean and modal speed with increasing ice concentration.

![Graph showing ice concentration and vessel speed](image)

**Figure 34.** Probability density function of the speed of the Algoma Transport for different ice concentration ranges.

**Key Stakeholder Engagement in Year 3:** The project team participated in the planned ADAC “Customer’s and Partner’s” Roundtable, in order to inform and receive feedback on project progress. A critical component of the project is one in-person meeting and follow-up video conference meetings with US Coast Guard officials, Great Lakes Mariners, and ice experts. The project champion for this project is the US Coast Guard Office of Waterways Management (CG-WWM).

The research team will disseminate research developed in this project through various venues including the Alaska Marine Science Symposium.

**Key Publications (Peer Reviewed):** None published in Year 3 but the following is in process:

Mahoney, A.R., S Campbell, T.M. Ravens, J.M. Jones, An ice condition index to aid navigation and icebreaking asset allocation in the Great Lakes, in preparation for submission to peer-reviewed journal such as the Journal of Cold Regions Engineering by end of 2017.

**Changes from initially approved work plan:** None.
Project Progress against each milestone:

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
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<tbody>
<tr>
<td>Assessment of two to three contending ice condition index approaches, formulation of a recommended ICECON approach, formulation of a vessel classification approach, and presentation to a council of experts [Oct. 30, 2016].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Revisions to the ICECON approach and the vessel classification approach in the aftermath of meeting with the council of experts, and continued dialog with the council via phone calls and teleconferences [Jan. 30, 2017].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Determine accuracy of ice forecasts by comparing them with post-forecast ice charts and continued calibration/ validation of the ICECON system and the vessel classification system using ice encounter data collected during the 2016/2017 winter [April 30, 2017].</td>
<td>Completed.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Assessment of the proposed ICECON/vessel classification system and reporting [June 30, 2017].</td>
<td>Partially Completed.</td>
<td></td>
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Project Progress against each metric:

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<th>Measure</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
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<tr>
<td>Accuracy of forecasted ice conditions – thickness, concentration, and type - determined by comparison with post-forecast ice charts.</td>
<td>Researchers anticipate 80% of the surface area of the Great Lakes will have reasonably accurate ice thickness and ice concentration calculations (thickness and concentration projections within 1 thickness/ concentration class of the ice chart thickness/ concentration class). It is expected that 70% of the forecasted ice type data be in agreement with the ice chart/ice type data.</td>
<td>Digging deeper, the team found that ice type was not forecasted, so it is not possible to assess its forecast. With respect to ice concentration forecasts 4 days in advance, 60% were accurate. With respect to temperature, 90% were accurate (within 4 C)</td>
</tr>
</tbody>
</table>
Consistency of ICECON assessment and ship performance: The goal is to demonstrate higher ICECON levels correspond to decreased ship performance (e.g. increased transit times) in at least 80% of cases. The team demonstrated that vessel speed decreases with increasing ice concentration (a component of ICECON).

Outcomes/output and TRL’s:

Project is at TRL-3

The first goal of the project is to develop ICECON algorithms and a vessel classification system that is sufficiently predictive to be of service to the USCG District 9 in their work to provide guidance to the Great Lakes maritime community and to manage their icebreaker fleet. For example, the original USNIC Ice Condition Index algorithms (which researchers have helped improve) rely on ice type, (not currently forecasted). Hence, some adjustment of the algorithms is necessary so that it relies only on current forecast parameters. USCG District 9 and the USCG R&D Center have clearly communicated the need for additional field validation of the ICECON algorithm. Field validation will require a winter with significant quantities of ice.

The second major goal is to develop a beta version an ICECON forecasting system for the Great Lakes. ICECON Researchers will pursue the beta version early in ADAC Program Year 4. The team expects that the NIC will operate the ICECON forecasting model when it is complete. At the time of this report, the project has a technical readiness level of “3”, according to the NASA definitions, "analytical/experimental results validating predictions of key parameters.”

In Program Year 3, project team reviewed and evaluated a pre-existing set of ICECON algorithms provided by the U.S. National Ice Center (USNIC). The algorithms were evaluated using ice encounter data collected by crews of USCGC Alder and CGC Griffon. The data provided ship-based estimates of ice parameters and in-situ assessments of the ICECON index. Using the NIC algorithms, we found that the ICECON could be accurately calculated 62.5% of the time (in 45 out of 72 instances).

In addition, project team used a Monte Carlo optimization procedure, finding that we could make minor adjustments to USNIC algorithm to increase number of concurrences by 16% (72.2% concurrence rate). We noted that the USNIC algorithm made use of ice type, which was available to the ship-based observers, but is not currently available as a forecasted data product. Hence, researchers used the Monte Carlo approach to devise predictive ICECON algorithms, which did not depend on ice type.

Research team explored historic AIS data and hindcasted ice-related environmental for the 2014-2015 winter (a season that had considerable lake ice), focusing on 6 ships that were identified by USCG District 9 as being representative of 3 different level of ice capability. We found that modal ship velocity (typical ship speed) was predictive of ice capability (and correlated to presence of increased levels of lake ice. Corresponding to the increased levels of lake ice in the winter of 2014-2015, the research team tracked details of reduced ship speed with increasing ice concentration.
At the time of this report, the project has a technical readiness level of “3”...achieving "analytical/experimental results validating predictions of key parameters."

**Unanticipated Problems and Plans for Addressing Them:** The USCG is concerned the lack of sufficiently cold winters in the Great Lakes region may delay final validation of the ice condition index algorithms. In Program Year 4, Long-range lake forecasters have predicted winter of 2017-2018 (a La Nina weather pattern season) to have lower temperatures and correspondingly increased lake ice, providing current data to model ICECON. In the event the ice does not materialize, we will concentrate on developing the ICECON index accessing additional seasons of historical data as accomplished in Program Year 3.

**Transition Plans**

**Transition Plans and Progress Made:** ADAC plans the ICECON forecasting tool to transition to operators at USNIC. In the coming year, ADAC will develop and test an ice condition index forecasting system. The research team will provide USCG access to the system once it is complete so USCG may provide feedback on the system. Once finalized, ADAC will provide the system to USNIC who will operate the system. ADAC believes there is utility for additional polar region ICECON research, based on a successful Great Lakes model.

**Theme 2 – Maritime Technology Research**

**PROJECT: Arctic Information Fusion Capability (AIFC)**

**Project PI:** Dr. Kenrick Mock  
**Project Manager:** Mr. John DeLaurentis

**Lead Institutions:** University of Alaska Anchorage

**Supporting Team and Collaborators:** “AIFC Network”
- Arctic Slope Regional Corporation Federal Mission Solutions: Mr. Eric Velte and Mr. Mark Rowan;  
- Axiom Data Sciences: Mr. Rob Bochenek, in association with Alaska Ocean Observation System (AOOS);  
- Alaska Marine Exchange: Mr. Ed Page;  
- NOVA Corporation: Mr. Brian Conroy;  
- NOAA: Mr. Robb Wright and Dr. Amy Merten;  
- Kestrel Technology Group: Mr. Leo Naboyschikov;  
- University of New Mexico: Dr. Rebecca Koskela;  
- University of Texas El Paso: Dr. Craig Tweedie;  
- National Maritime Intel Integration Office (NMIO): Mr. Todd Boone;  
- Pragmatics, Inc.: Dr. Ben Nguyen and Mr. Jared Spigner.
Program Year 3 Project Champions: Mr. H. Blaney, HQ USCG CG-255.

Student Involvement: Two undergraduate students, James Wall (UAF) and Lonnie Young (UAA) developed an annotated bibliography of relevant environmental security and compiled a dataset of planned instrument deployment and vessel transects for Arctic research.

Project Description

Abstract: Arctic Information Fusion Capability (AIFC) seeks to support operational decision makers in the maritime domain ranging from operational commanders to tactical operators to community-based observers. AIFC seeks to gain two-dimensional geographic orientation of precision mapping data, near-real-time and high-resolution satellite imagery incorporated with available modeling, sensors, web-based communications and appropriate social networking feeds to gain domain awareness in support of operational decision making and interface with humans and responders in the field.

Further, AIFC will provide elements of domain awareness from a 3-dimensional column view to gain insights vertically from seabed to surface and surface skyward. AIFC seeks to achieve a near-real-time and forecast decision support that can transition to intelligent decision support in a follow-on phase. AIFC near-real-time products are planned for rapid delivery as possible following capture and processing of the observation. In general, near real-time is a qualitative descriptor. In the AIFC context, it refers to products delivered between a few seconds up to 30 minutes following capture.

In Phase 1, AIFC leveraged and fused existing sources, capabilities, and models to provide operational decision support. This includes visualization and mapping of sensor output, marine systems modeling, communications, appropriate social networking feeds, and other information required for Arctic maritime situational awareness. This also includes a deployable/field capability to support USCG emergency on-scene coordinators and community-based observations. In Phase 2, AIFC will transition to provide intelligent decision support and prototype the automatic control of sensors and robotic systems.

Baseline: In ADAC Program Year 1 the center initiated research for an “Integrated Intelligent System of Systems (IISOS).” IISOS initiated research to develop a prototype interface between ADAC systems and the end user. The prototype ingested and visualized data from community-based observers, a high-resolution coastal storm surge model, AIS vessel tracking, a H2O and CO2/CH4 isotope detector, and a variety of environmental feeds (Extra-Tropical Storm Surge model, Global Hybrid Coordinate Ocean Model, NCEP Global Forecast System, NWS NDFD and NAM-12 for Alaska, WaveWatch III, and the AOOS real-time catalog, among others). We developed demonstration scenarios in support of SAR operations, an interactive “oil spill response” simulation, and coastal surge forecasting and response for the Yukon-Kuskokwim Delta using Delft3D. These demonstrations in sum, presented a partial index of existing modeling and data, providing a limited view of potential fusion future opportunities.

In Program Year 2, the team restructured the project as the Arctic Information Fusion Capability, a partnered approach to support maritime situational awareness in support of Arctic operators. ADAC assembled a new team referenced at the beginning of this team. The University of Alaska Fairbank's
Geographic Information Network of Alaska (GINA) handled project management on the Program Year 3 research. Early in project year 3 work, ASRC Federal Mission Solutions assumed project management and technical development from GINA. AIFC pursued a new approach to utilize NOAA’s Arctic Environmental Response Management Application (ERMA) tool, as the core of a suite of decision support protocols to meet USCG Arctic Information Fusion needs. AIFC restructuring accomplished late in ADAC Program Year 2, enabled needed developing, gaining agreement, and planning for ADAC Program Year 3.

**Relevance to DHS:** Leveraging available data, connecting with sensors, platforms and models to provide operator decision support needed for the Arctic region and is potentially useful to other mission areas. HQ USCG in their Arctic Strategy Implementation Plan (released in December 2015) specifically called out the requirement for an Arctic Fusion Center as an operational requirement and one of 13 articulated initiatives. Accordingly, a major purpose of this project is to deliver capabilities and demonstrations commensurate with available resources and past work that is required for Arctic Data Fusion.

**Purpose of the Research:** The strategic research question addressed by AIFC is to determine if fusing multiple sensors, models, observations, and data streams can improve decision support in the maritime domain. Additional research questions:

1. What is the best way for an operator to visualize and interact with specific sets of data or specific models and simulations?
2. What architecture best integrates multiple existing information systems?
3. What ontologies and metadata best facilitate information retrieval?
4. What machine intelligence can be utilized to support human decision-making and demonstrated within an “Observe, Orient, Decide and Act” (OODA) loop?

In Program Year 3 AIFC focused on the first three questions above and investigated the strategic research question number 4. Arctic ERMA and the use case prototypes begin to answer the first question but requires further iteration with USCG D17 to determine the effectiveness of the proposed solutions. AIFC project team investigated the Tactical Cloud Reference Implementation, (TCRI) as a potentially suitable approach to establish an Arctic Information Fusion Framework. TCRI is a software platform, which will provide a common framework to manage operational data while also performing analysis on this data with automated, mathematical algorithms and analytics. Essentially, the concept is similar to how people utilize clouds to synchronize different data on their numerous smart devices such as tablets and smartphones. The difference is TCRI will largely function automatically, with little user input, and will only provide information that the user designates as relevant.

TCRI architecture depicted in Figure 38 is a proposed solution to questions 2 and 3. It utilizes open standards and systems to represent information in a way to facilitate information storage and retrieval while connecting and interfacing systems at different levels. As prototypes for Arctic Fusion, these systems do not yet answer the research questions but provide the groundwork for further investigation. Research team plans investigation of question 4 for a follow-on phase of AIFC, although a prototype for machine intelligence exists using neural network technology. Goals for the latter phases of AIFC include a remotely controlled architecture for unmanned systems.
**Methodology:** The AIFC Team utilized a user-centered approach with the USCG to elicit needs and requirements in the form of user stories and presented prototypes through an agile development methodology. Team performed testing with a combination of live, historical, and synthetic data. The development at the end of Program Year 3 focused on the delivery of software features. Future iterations of the project would focus more on usability, development of decision support analytics, and fine-tuning of visualizations, although efforts were made to present information in modalities desired by the customer (e.g., email alerts when vessels cross geofences as opposed to a website notification).

**Project Results**

**Key Accomplishments in Program Year 3:** In Program Year 3, the team implemented the plan to develop and demonstrate multiple aspects of Arctic Information Fusion for operators in the field (fusion forward) or in the command center (fusion central). This included developing an operator determined “use case”/scenario data and geo-referenced decision visualizations and Fusion Engine prototypes. These prototypes were demonstrated to HQ USCG AIFC Project Champion, and USCG D17 subject matter experts in June 2017. Details follow:

*Catalogued data sources and feeds useful for Arctic operators.* The team documented the existing catalog of data sources in the Arctic to identify gaps, needs, and opportunities. From approximately 250,000 data feeds available through Data ONE, Axiom Data Sciences, and other sources, the team created a list of over 1,800 data feeds relevant to the Arctic.

*Developed “use cases” oriented to Arctic operator mission needs.* The team developed five use cases in conjunction with stakeholders. Additionally, researchers packaged use cases into a series of storyboards to paint a picture of the end-goals of AIFC. Developed use cases and detail scenario card depicted below:

- Marine Environmental Protection Response. See Figure 35 (AIFC Use Case 4).
  - There was consensus among USCG stakeholders to make this the initial focus of AIFC.
- Mass Marine Rescue Operation (MMRO).
- Ship in Distress; Ship Lost at Sea (SLAS).
- Search and Rescue (SAR).
- Ice Operations – Multi-ship research expedition in the High Arctic.
### Use Case 4: Marine Environmental Protection Response

<table>
<thead>
<tr>
<th>Marine Environmental Response – Oil spill from a grounded vessel, North Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domain awareness info environment</strong></td>
</tr>
<tr>
<td>• Traffic monitoring data shows a near-real-time plot of positions for vessels</td>
</tr>
<tr>
<td>transiting Alaskan Arctic waters&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>• Command center data shows real-time &amp; forecast air temperature, visibility,</td>
</tr>
<tr>
<td>precipitation, wave height/direction, water temperature, sea ice coverage,</td>
</tr>
<tr>
<td>currents</td>
</tr>
<tr>
<td>• Command center data base permits rapid access to information about any</td>
</tr>
<tr>
<td>registered vessel</td>
</tr>
<tr>
<td>• Command center data shows detailed coastal bathymetry</td>
</tr>
<tr>
<td><strong>Response case opened</strong></td>
</tr>
<tr>
<td>• Oil spill confirmed</td>
</tr>
<tr>
<td>• Incident command system activated, begins spill response mobilization</td>
</tr>
<tr>
<td>• Command center monitors all response assets, coordinates with incident</td>
</tr>
<tr>
<td>commander, provides direction and appropriate data (including spill</td>
</tr>
<tr>
<td>trajectory) to all involved parties</td>
</tr>
<tr>
<td>• Command center documents case, provides input for lessons learned &amp; final</td>
</tr>
<tr>
<td>report</td>
</tr>
<tr>
<td><strong>Response information environment</strong></td>
</tr>
<tr>
<td>• A transiting vessel reports loss of power; direction of drift in 5/10s ice</td>
</tr>
<tr>
<td>coverage indicates imminent grounding</td>
</tr>
<tr>
<td>• Command center obtains detailed info (# persons, nature of propulsion</td>
</tr>
<tr>
<td>casualty, amount of fuel or other hazardous material onboard, last</td>
</tr>
<tr>
<td>known position, etc.)</td>
</tr>
<tr>
<td>• Comms schedule with distressed vessel instituted</td>
</tr>
<tr>
<td>• Safety broadcasts made for any other vessel able to assist</td>
</tr>
<tr>
<td>• Diversion of vessel traffic (if any) considered, based on proximity &amp;</td>
</tr>
<tr>
<td>capability</td>
</tr>
<tr>
<td>• Area oil spill response organization mobilized</td>
</tr>
<tr>
<td>• Fixed-wing (C-130) launched with droppable repair parts, pumps or other</td>
</tr>
<tr>
<td>emergency equipment</td>
</tr>
<tr>
<td>• USCG cutter diverted to area to act as forward command post (C2), staging</td>
</tr>
<tr>
<td>platform, assist with vessel refloating &amp; repair, etc.</td>
</tr>
<tr>
<td>• Helps dispatched to FOL or cutter for spill monitoring, movement of</td>
</tr>
<tr>
<td>personnel &amp; equipment, etc.</td>
</tr>
<tr>
<td>• Spill response teams, equipment &amp; support moved to area; deployed for</td>
</tr>
<tr>
<td>spill containment &amp; clean-up</td>
</tr>
</tbody>
</table>

### Variables

<table>
<thead>
<tr>
<th>Domain awareness info environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Locations of vessels (i.e. NAIS) supplemented by Canadian Arctic</td>
</tr>
<tr>
<td>Reporting System. Validated by cutter and aircraft sensor reports (i.e.</td>
</tr>
<tr>
<td>COP)</td>
</tr>
<tr>
<td>• Locations of commercial activity (i.e. oil and gas, construction)</td>
</tr>
<tr>
<td>• Environmental conditions (sea ice, tide, current, temp &amp; wx changes)</td>
</tr>
<tr>
<td>• Ice and WX forecast data</td>
</tr>
<tr>
<td><strong>Response information environment</strong></td>
</tr>
<tr>
<td>• Environmental conditions (sea ice, tide, current, temp &amp; wx changes)</td>
</tr>
<tr>
<td>• Targeted forecast information for the area of response</td>
</tr>
</tbody>
</table>

### Desired process and outcome

- Command center has adequate information to evaluate urgency of situation and |
  alert/allocate response resources as quickly as possible
- If possible, vessel can be assisted early enough to prevent grounding (repair |
  parts provided, towing, ice management to allow anchoring, etc.)
- Once a spill is imminent, rapid movement of response personnel and equipment |
  is crucial to minimize the spill and prevent environmental impact

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*Figure 35. AIFC Use Case 4: Marine Environmental Protection Response.*
AIFC-CBONS-SA coordination to gain “Fusion Forward.” In conjunction with the CBONS-FIST team, the AIFC team deployed the Field Information Support Tool (FIST) in a successful field test with the Fusion Portal to provide forward fusion. (See Figure 36). The system provides:

- Communication to/from operators in the field that works anywhere (cellular/Wi-Fi/SATCOM) via open standards.
- A custom smartphone interface that affords easy input by observers in austere environments to make reports such as details of beach landings, marine observations, medical information, available facilities, etc.
- Local fusion portal with data connection to central fusion (e.g. Arctic ERMA) that performs data analysis and visualization.
- Audio, video, images, and text supported to enhance rapid field operational awareness.

![Figure 36. FIST and Fusion Forward.](image)

Enhancements to Arctic ERMA in support of USCG Arctic operators. The team made available several new data feeds and enhancements through Arctic ERMA in order to support USCG D17 watch standers in accordance with their requested needs. Specifically:

- CBONS HFO reports entered through the FIST tool. This tool demonstrates needed data successfully connected to map observations from the field into ERMA.
- High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) for modeling and predicting sea ice and currents in the Arctic Ocean. (See Figure 37). This tool provides access to ice thickness and current projections that were previously unavailable.
- Series of bookmarks for data layers frequently used by USCG D17.
- Utqiaġvik (formerly Barrow) Sea Ice Radar.
- Reference in Arctic ERMA to Storm Surge and Oil Spill Simulation (implemented offsite at Axiom Data Sciences)
Note: Arctic ERMA also now supports polar projections and the move to OpenLayers 3 will support enhanced mobile visualization techniques such as hexagonal binning, a useful upgrade for USCG operations.

Figure 37. HIOMAS output visualized in Arctic ERMA.

**AIFC Prototype Framework.** The ASRC Federal Mission Solutions team built a working prototype of Arctic Information Fusion based on a refined use case scenario requested by USCG D17. This use case required the ability to establish a geofence and receive alerts (e.g. email) when vessels meeting established criteria cross the geofence boundary. (See Figures 38 and 39).

Implementation of this use case demonstrated the ability to fuse live AIS data from the Alaska Marine Exchange with map data and geofences input by the user while also performing analytics such as vessel history and path prediction. The data is exportable into common formats. The system is built (TCRI) as previously described. Utility of TCRI as an AIFC foundation is due to leveraging open source tools to provide an architecture to implement future “data fusion” products and decision support tools such as determination of safest routes for vessels based on vessel characteristics and environmental conditions.

Figures 38-40 first describe the framework architecture and information flow, followed by screen captures of actual application from the June 2017 prototype demonstration to HQ USCG AIFC Project Champion and USCG D17 project advocates. Note, additional technical details on the architecture and information flow is available for technical review from AIFC project team.
Figure 38. TCRI Architecture illustrating data flow for the Geofence Use Case (ASRC Federal Mission Solutions).

Figure 39. AIFC Application screen capture for the Geofence Use Case (ASRC Federal Mission Solutions).

Arctic Domain Awareness Center Year 3 Annual Report 1 July 2016-30 June 2017
**Arctic Information Fusion Engine Prototype Investigation.** Late in ADAC Program Year 3, Center leadership and AIFC project team initiated an AIFC project excursion leveraging UAA research funding to partner with National Maritime Intelligence integration Office (NMIO) and their research team from Pragmatics Corporation. Subsequent efforts led by NMIO and Pragmatics developed an Arctic fusion prototype based on the Holistic Artificial Life Outcomes (HALO) compute platform. (See Figure 40). The information prototype integrated live vessel data from the Marine Exchange or Alaska with real-time buoy observations from the National Buoy Center. The environmental data includes visibility, wave height and period, pressure, and wind speed. From this data, an artificial neural network learned how to compute a risk score, individualized to the characteristics of a vessel based on the environmental data.

![Figure 40. AIFC Screen capture of vessel risk prototype (NMIO/Pragmatics).](image)

**Key Stakeholders Engagement in Program Year 3:** ADAC consulted an array of stakeholders and partners in project year 3, including:

- Headquarters USCG;
- USCG Pacific Area;
- USCG District 17;
- USCG RDC;
- Rutgers University;
- DHS Data Analytics Engine;
- NOAA/NWS;
- NOAA Office of Response and Restoration;
HQ USCG, USCG D17, and USCG RDC, (as critical customers to the project) highlighted the December 2015 USCG Arctic Strategy Implementation Plan as the key “requirements” aspect for AIFC. Per the USCG Arctic Strategy Implementation Plan, “Create an Arctic Fusion Center” (Page 9 of the Implementation Plan) highlighted the need for AIFC, that would in essence serve to be the decision management capability to serve at the USCG’s Arctic Fusion Center. These discussions pointed AIFC to work closely with Arctic ERMA as an existing decision support tool.

**Key Publications (Peer Reviewed):** None

**Key Reports/Presentations:** Building on AIFC planning initiated late in program year 2, the investigation team presented AIFC progress at the ADAC Annual Meeting in Washington, DC on 8 November 2016. The team provided a comprehensive set of materials for the ADAC Biennial Review on 9 December 2016, then provided two separate prototype demonstrations on 17 June and 23 June 2017 to HQ USCG Project Champion and USCG D17 Subject matter experts. These demonstrations received favorable reviews from USCG participants.

**Changes from initially approved Work plan:** The original Co-Principal Investigators for AIFC were Dr. Kenrick Mock of UAA College of Engineering and Mr. Tom Heinrichs, University of Alaska Fairbanks Geophysical Institutes’ Geographical Information Network of Alaska (GINA). In August 2016, GINA withdrew from the project, leaving Dr. Kenrick Mock of UAA as the PI. ADAC added ASRC Federal Mission Solutions to assist with project management.

**Project Progress against each milestone:**

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a two-dimensional web map presentation of geospatial data, near</td>
<td>Most metrics met by providing these products through Arctic ERMA and</td>
<td>Metrics of coastal inundation model and “oil spill simulation” model available in Arctic ERMA partially achieved. ADAC research in storm surge and coastal flooding as well as oil spill models, are linked to ERMA, and hosted at Axiom Data Sciences. Near real-time satellite imagery not achieved but path forward identified with NASA collaboration. Other</td>
</tr>
<tr>
<td>real-time and high-resolution satellite imagery; incorporate available</td>
<td>the FIST Fusion Portal.</td>
<td></td>
</tr>
<tr>
<td>modeling, sensors, web-based communications and appropriate social</td>
<td></td>
<td></td>
</tr>
<tr>
<td>networking feeds; enable domain awareness in support of operational</td>
<td></td>
<td></td>
</tr>
<tr>
<td>decision making and interface with humans and responders in the field.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[March 30, 2017]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Description</td>
<td>Measure</td>
</tr>
<tr>
<td>----</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>P.1</td>
<td>AIFC products in Arctic ERMA designed to meet Coast Guard needs.</td>
<td>Memorandum from USCG indicating that AIFC products in Arctic ERMA</td>
</tr>
</tbody>
</table>

**Project Progress against each metric:**

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Measure</th>
<th>Status at end of Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.1</td>
<td>AIFC products in Arctic ERMA designed to meet Coast Guard needs.</td>
<td>Memorandum from USCG indicating that AIFC products in Arctic ERMA</td>
<td>Stated approval by USCG D17 project supporter of AIFC</td>
</tr>
<tr>
<td>P.2</td>
<td>List of domain awareness elements from seabed to surface and surface skyward captured in consultation with Coast Guard.</td>
<td>Memorandum from UCSG indicating that AIFC products in Arctic ERMA appropriate to meet their requirements.</td>
<td>Completed with catalog of data feeds.</td>
</tr>
<tr>
<td>P.3</td>
<td>AIFC populated with supplemental data feeds relevant to Arctic Domain Awareness</td>
<td>USCG user satisfaction through teleconferences and prototype demonstrations.</td>
<td>Several AIFC products available via Arctic ERMA.</td>
</tr>
<tr>
<td>P.3.a</td>
<td>Interface developed for community-based observers, (to access data and submit observations).</td>
<td>Presence in interface.</td>
<td>Presence in Arctic ERMA.</td>
</tr>
<tr>
<td>P.3.b</td>
<td>Coastal inundation model data feed available via Arctic ERMA.</td>
<td>Presence in interface.</td>
<td>Link from Arctic ERMA to Axiom website (which houses ADAC’s Storm surge and inundation model work).</td>
</tr>
<tr>
<td>P.3.c</td>
<td>Oil spill simulation model available via Arctic ERMA.</td>
<td>Presence in interface.</td>
<td>Link from Arctic ERMA to Axiom website which houses current ADAC’s Arctic Oil Spill model research.</td>
</tr>
<tr>
<td>P.3.d</td>
<td>Near real-time weather satellite imagery available in Arctic ERMA.</td>
<td>Presence in interface.</td>
<td>Not completed; solution identified with NASA.</td>
</tr>
<tr>
<td>P.4</td>
<td>AIFC demonstration performed that fuses multiple data sources.</td>
<td>One drill or tabletop exercise identified during Year 3 and AIFC used and feedback gathered during exercise.</td>
<td>Two AIFC fusion demonstrations made to the USCG Project Champion and USCG D17.</td>
</tr>
<tr>
<td>P.5</td>
<td>Evaluation of COTS options performed.</td>
<td>Whitepaper written evaluating options and making recommendations.</td>
<td>Decision to deliver via Arctic ERMA.</td>
</tr>
<tr>
<td>P.6</td>
<td>Documentation written.</td>
<td>The state of all elements of Year 3 AIFC development captured in annual report and initial version of user manual.</td>
<td>During project year, AIFC produced numerous electronic documents and provided to USCG user community. User manual not produced due to prototype status, however if tasked, ADAC will proceed to provide.</td>
</tr>
</tbody>
</table>

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4 Near real-time products are delivered as rapidly as possible following capture and processing of the observation. Near-real-time is a qualitative descriptor, but generally refers to products delivered between a few seconds up to 30 minutes following capture.
Outcomes, Outputs and TRLs:

Project is at TRL-3.

The overall Y3 outcome was a proof-of-concept system capable of fusing multiple data sources (CBONS, outputs from environmental models, etc.) and providing visualizations to end users in the field or in a center. Fusing multiple data sources provide USCG operational watch standers the ability to gain efficiency in decision making, as machine fusion is considerable more precise and faster than watch standers mechanically fusing information (or calculating a mean from the data available as is the case from evaluating multiple weather models). The output was a successful demonstration. Feedback from USCG D17 AIFC project advocates on the Geofencing Use Case demonstration was overwhelmingly positive (remarks stated “two thumbs up”, “when can we have this system?”) which meets AIFC “customer satisfaction” benchmark for research in ADAC Program Year 3.

AIFC had a planned target TRL of 3 at the end of Y3, which is to have a prototype constructed and proof of concept delivered over a limited range of operating conditions. This target was met by the successful prototype demonstrations. Note: that some components of AIFC are at a higher TRL; for example, public consumption of the HIOMAS model through Arctic ERMA is available now. Similarly, the geofencing “use case prototype” is suitable and feasible for near-term use.

Program Year 3 Results:

After restructing late in Program Year 2, AIFC delivered several new data products through Arctic ERMA in Program Year 3. These include the Utqiagvik (Barrow) Sea Ice Radar, dedicated HIOMAS endpoints, a series of bookmarks, and references to coastal inundation and oil spill models. The AIFC team also demonstrated fusion prototypes for both fusion forward in the field and fusion central in the command center. The CBONS-FIST tool and the Fusion Portal support communications and data fusion to and from responders in the field. The geofencing prototype and neural network prototype to calculate vessel risk demonstrate fusion of AIS, mapping, and environmental data. All of these prototypes lay the technology foundation for more advanced fusion and decision support tools. For example, the neural network technology has the capability to learn new objective functions. The architecture for geofencing prototype supports the integration of other information, such as ice and weather data, to determine safe or dangerous vessel routes, etc.

Unanticipated problems and plans for addressing them: ADAC received feedback from the DHS S&T OUP Biennial Letter Review that the AIFC project would be discontinued and would not receive further funding.

Transition Plans

Transition Plans and Progress Made: The AIFC Team demonstrated forward fusion using the FIST tool with the FIST Fusion Portal and command-center fusion using both the TRCI architecture and Arctic ERMA. These platforms are capable to host additional data streams, data fusion algorithms, analytics, and decision support tools that integrate with the USCG workflow. ADAC’s AIFC architecture is a feasible framework for onward development. The software and data engineering architecture already designed, is capable to integrate specified use case scenarios. Further investigation of the existing framework with a well-specified set of requirements (where the necessary data sets are available...such
as Arctic ERMA), sets the stage to meet the vision of the project to meet the information fusion needs of the USCG Arctic operator. As due diligence, the AIFC research team did initial inquiry into U.S. Federal security standards with associated with prototype systems, necessary for USCG acquisition.

**PROJECT: Low Cost Wireless Remote Sensors for Arctic Monitoring and Lifecycle Assessment**

*Project PI:* Dr. Martin Cenek

*Lead Institution:* University of Alaska Anchorage, with support project addition provided by industry partner, ASRC Federal Solutions.

*Supporting Team:*

  University of Alaska Anchorage: Dr. Aaron Dotson

  Arctic Slope Regional Corporation Federal Mission Solutions: Mr. Eric Velte, Kevin Wainwright (Co-PIs), Mark Rowan (ASRC FS), Christopher Bartley (ASRC FS)

*Collaborators:* ASRC Federal Solutions.

*Program Year 3 Project Champions:* LCDR Margaret Kennedy (Primary); Mr. Hank Blaney (Alternate).

*Student Involvement:* Matthew Ahlrichs, UAA Graduate research assistant Civil Engineering, continued development of the sensor lifecycle cost framework for its application to the US-Canadian border protection scenario.

*Project Description:*

*Abstract:* The project goal is to develop low-cost wireless sensors for use in remote monitoring, asset management, surveillance, and security, particularly in Arctic and marine environments. The team categorizes a sensor’s functionality into three areas: detection of an input event, computation of the detected event, and communication of the data. The team will develop an inexpensive, self-organizing network of devices that can reliably compute and communicate detected events. The computing device for each sensor node is the MoteineoR4 RFM69W and an integrated RFM69 transceiver enables wireless ISM band communications. The team constructed a software simulator and hardware proof-of-concept consisting of a 7x7 array of nodes. The initial target application is to utilize acoustic and electromagnetic signal detectors to classify human vs. animal traffic in a remote area.

The concurrent phase of the project includes the evaluation of the lifecycle cost (LOC) for the deployed sensor array. The team will apply the LOC framework to the monitoring of the US-Canada border for intrusions deployment scenario. The team will assess common techniques in life cycle assessment with focus on geospatial array structure associated with terrain and climate as well as overall power requirements, proximity to urban areas and the end-of-life considerations.

ASRC Federal Solutions (ARSC FS) will identify, from the mission perspective, the systems involved in the Command and Control and Situational Awareness missions for multiple DHS projects, including USCG and Customs and Border Patrol, and develop an integration strategy that will field these sensors into
those mission components.

The team initially used its open system architecture (OSA) - based C4 system for prototype component development and initial sensor integration and fusion. This system’s capabilities are compatible with the USCG’s C2 Segment 2 system currently fielded on the National Security Cutter (NSC) platforms in-service with the USCG today. Mission Solutions is the NSC C2/S2 software development subcontractor and is intimately familiar with both the software architecture and the effort required to add new applications and capability to the architecture.

After initial integration of sensor data from both simulated and fielded sensors, the ASRC FS team will fuse the data into a tactical track picture and situational awareness display in order to prove the usefulness of the low-cost remote sensor approach for C2 and SA. The team will also seek to develop a non-trivial set of decision aids to support events detected by the sensor network, including new contacts, lost contacts, indeterminate contact information requiring human-in-the-loop interpretation, as well as network readiness information.

**Baseline:** Low power MoteineoR4 computational module with RFM69W radio antennae and/or Wi-Fi transceiver. The module’s detector is Electret Microphone Amplifier - MAX9814 with Auto Gain Control, TTL Serial JPEG Camera, or the readout from the embedded radio antennae. The hardware test bed is arranged on 7x7 regular grid with a custom topology of components' interconnectivity. The deployment and testing will use 3x40 module grid. The readout nodes position on each edge of the array (4 readout nodes minimum).

The team prepared integration of the low cost wireless sensor data into secondary or tertiary system such as command and control framework. The data integration layer supports the mission operations community for situational awareness and decision-making purposes. The sensor data are fusion ready for integration with other components of the system, including:

- Command and Control data - track / contact data, mission planning system, non-real-time networked C2 information
- Situational awareness data: operator decision aids, tactical overlays, cartographic data, and geo-referenced imagery

The architectural solution proposed in this project aims to redefine the sensor network technologies using simple, locally connected, decentralized, asynchronous nodes that will emergently (without a centralized processor) detect an event as activation of several nodes. The goals include detection and processing of signals on each device and conversion of multiple spatial-temporally adjacent signals into an actionable event that propagates to the readout nodes. The network's decentralized, distributed, asynchronous, locally connected design makes the architecture expendable, robust and redundant. The major advantages of the neuromorphic sensor network design include: rapid deployment from an airplane, snowmobile or other mobile platform, robust and redundant network sensing with -healing and self-reconfigurable node connectivity, minimal information loss in case of node failure. All major advantages address environmental and human activity monitoring needs in harsh sub-Arctic regions and US-Canadian border protection in remote regions without power grid and communication networks.

In Program Year 3, prior work plans sought to ruggedize sensors, integrate Zensor technology, and
create infrastructure based wireless networks. Prior plans did not adequately account for remote regions of Arctic that do not have reliable communication and power infrastructure and could not provide situational awareness data and fusion with operator decision aids. Restructure of the project midway in ADAC Program Year 2 set a new trajectory and condition to address sensors research oriented to Arctic conditions. The subsequent project direction focused on developing rapidly deployable, scalable, power-aware sensor network architecture to address sensing for environmental and human based events in remote, inaccessible sub-Arctic regions without reliable source of power and communication networks. In Program Year 3, team added a “sensor network lifecycle assessment” research topic to the project to address the potential environmental cost of information collection by deployed sensor nodes without re-claiming collection.

**Relevance to DHS:** This project provides capability for border intrusion monitoring, ice breakup monitoring and prediction, and supports event driven intelligence from remote in accessible regions. Sensor data integrates to create a fused display of monitored information aligned to specific areas of interest such as an Arctic port, or Arctic maritime area of concern. Sensor capability fits readily within open systems architecture based applications. Sensor integration for enhanced SAR and USCG statutory missions, such as fisheries protection and environmental monitoring.

The network’s decentralized, distributed, asynchronous, locally connected design makes the architecture expendable, robust and redundant. The applied research from this project can potentially support USCG maritime response in Arctic conditions, port security, or DHS border protection missions.

**Purpose of the Research:** The research objective is to develop a non-aggregative sensor network architecture for robust detection of environmental or security breach events in the Arctic or sub-Arctic regions without reliable source of communication and power infrastructure. The research purpose is to provide Humanitarian Assistance and Disaster Response for the Arctic or sub-Arctic regions. The applications might include border protection and monitoring, port-security or ice break-up. The goals include detection and processing of signals on each device and conversion of multiple spatial-temporally robust detection of environmental or adjacent signals into an actionable event that propagated to the readout nodes.

The potential Disaster Detection and Response in the Arctic region lack reliable communications and power infrastructure to support traditional sensors. Through integrating a set of ad hoc sensors that can self-configure as part of a larger network, DHS could potentially benefit improved situational awareness tactical capability edge that promotes information gathering and eliminates expensive operations and maintenance costs associated with manned sensors of similar capability.

**Methodology:** Project team investigates sensor network “neighbor discovery” protocol design and implementation via in-simulator and hardware testbed signal-to-even in-place computation and conversion. Each sensor is activated from microphone input by comparing the real-time signal with the databased of acoustic signatures. Generating the acoustic signature is via discrete Fast Fourier Transforms, power density spectrum and mean selection of the pre-recorded samples of acoustic signals. Processing real-time microphone input is via the same signal-processing stream. A subsequent sensor event triggers and sends as a signal to its neighbors, if the cosine similarity between the acoustic signatures are stored in the database, and the real-time microphone signal exceed imperatively established threshold.
The decentralized spatial computation architecture of sensor activation into reportable event is implemented using Hebbian rule inspired Spike-Timing-Dependent Plasticity. The reportable event is propagated to the readout nodes using altered Dijkstra's shortest path algorithm. The neuro-physiology approach converts received peer-to-peer sensor activations into reportable event for the temporally misalignment sensor activation signals and for the accumulation of local sensor activations.

The sensor network “neighbor discovery” protocol design and implementation via in-simulator and hardware testbed signal-to-even in-place computation and conversion. This applied research includes device and detector system integration (to include operating system software layer).

The LCA study encompasses two components:

- Creation of a GIS model to calculate the ideal spacing of each subarray sensor based off of ecosystem type and topological conditions;
- Creation of an LCA decision protocol, which contains a life cycle inventory (LCI) in conjunction with the LCA evaluation, which uses an extensive database of materials and methods to quantify the costs associated with each sub-array.

The LCA implements using ISO 14040 and 14044 with 4 components: (1) goal and scope, (2) inventory, (3) impact assessment, and (4) improvement assessment.

**Project Results**

**Key Accomplishments in Program Year 3:**

**Successful Architecture integration.** The team completed architecture integration with the “software network topology” simulator, hardware testbed and the data collection unit. Specifics:

- The hardware testbed implemented neuromorphic computation and the conversion of signal-to-event node activations.
- The data collection unit contains a special purpose sensor that collects data-events from the readout nodes when the network is in normal operation. Sensor also collects raw data-activations that are sensor activations pre-conversion to event when the network is in promiscuous mode. The database logic layer includes verification if desired activations resulted in an event conversion.
- Figure 41 shows the architecture design and testing framework completed for the project. To test the influence of the sensor network topology on the architecture’s computational ability to convert sensor node activations into an actionable event, the network simulator first generates random sensor node layouts. The control parameters used to generate the network layout include the minimal number of nearest neighbors, spatial variation from optimal grid placement, or the sensor node fan-out. The topology is exported and loaded onto generic hardware testbed for testing and evaluation of signal-to-event conversions and triangulations. The signal activations present as dark concentric circles, where the number of concentric circles indicated the age of signal activations: more circles represents the older signals, fewer circles recent signal activations. The activations trigger manually but pin input, or by a special packet received by RF antennae. The hardware testbed reports the number of hops it took an event from a sensor.
node where signal converts to event to reach the readout nodes (number of links from white circle to red circle). The data collection unit is a database server with a special sensor node attached to the server. The database collects both the raw sensor activations (network promiscuous mode) and the events with associated hop counts from the readout nodes.

- Figure 41 also shows the completed architecture. A. network simulator generates random sensor node layouts with number of nearest neighbors, spatial variation from optimal grid placement, and node “fan-out” control parameters. B. The topology exports and loads onto generic hardware testbed for testing and evaluation of signal-to-event conversions and triangulations. The hardware testbed reports the number of hops it took an event from a sensor node where signal converts to event to reach the readout nodes. Red nodes are the readout circles, white is an event converted from signal, and black concentric circles are node raw activation with temporal stamp – more circles, older the signal. The yellow circles indicate triangulation of the event source from the hops reported to the readout-nodes. C. The data collection unit is a database server with a special sensor node attached to the server. The database collects both the raw sensor activations and the events with associated hop counts from the readout nodes.

Figure 41. Completed architecture design and testing framework.
Validated architecture. Researchers validated the architecture's ability to convert signal to event in the hardware testbed using the above describe architecture. Specifics:

- Researchers automated the test harness for heuristic testing of the network's ability to convert signal-to-event. The data collection unit implemented a dedicated sensor that broadcasted a special purpose packet to normally distributed, linearly adjacent sensors to simulate the node activation. The packets send with temporal signature of an event where two adjacent nodes activates no later than 1-second intervals.

- Researchers found much greater success than the planned target of 80% “signal-to-event” detection and propagation in the sensor array. In fact, “signal-to-event” detection was on average 130% “more successful” as the activation of any three linearly adjacent nodes triggered event conversion in all spatially adjacent nodes. The linearly adjacent nodes share more than one node (on average, 6 nodes are shared among 3 linearly adjacent nodes, but the temporal signal aging per node degrades the signal-to-event conversion to approximately 1.3 nodes (see Figure 42).

- Figure 43 shows the event propagation from sensor nodes to the fringe readout nodes was 100% successful.

- The results were achieved on a simulator-generated topology, then transitioned onto the hardware testbed and used a special controller/global collector node to simulate signal event triggers. The test harness tested 100 randomly generated network topologies that were loaded into the generic hardware testbed; each network topology tested using 100 tests for signal-to-event conversion with activation of nodes using network packets broadcasted from the data collection node's dedicated sensor over RF. The time between node activation did not exceed 1 second and three nodes were adjacent to each other on a line in Cartesian space. The starting node of the three-node sequence selected at random. Note that even though the nodes were spatially adjacent and in a line, does not assume the network topology connected these nodes. The network topology loaded onto the hardware testbed was random without assuming mutual connection among the nodes. The network did assume node interconnectivity. All experiments used one hop distance propagation of signal the node where signal originated.
Figure 42. Triangulation 4 Conversion Success.

- Figure 42 shows results of signal to event conversion averaged on 100 randomly generated topologies with simulation of 100 spatial-temporal activation of three linearly adjacent sensor nodes executed on each network topology. The “x” and “y” coordinates represent sensor location; “z” values are the conversion rate. Note that a minimum of three nodes were needed for signal to even conversion was always exceeded and resulted in 100% conversion success.
Figure 43 shows the success of communication transmission from the event node to readout nodes. Unsuccessful transmissions have number of hops equal to zero. The empirical results use the same statistical test harness configuration as results in Figure 43.

Tested network triangulation. Researchers tested the sensor network's triangulation accuracy for the experimental setup described previously. Details of the testing:

- Figure 44 shows triangulation error was a maximum of 3.2% of the network's average link length. The achieved triangulation error was below target 5% link length.

- The error increased toward the network's corners without readout nodes. The network corners did not successfully triangulate for events originated in these nodes from all four readout nodes, which also contributed to error increase. If desired, the error at the fringe of the network minimizes by seeding the periphery (or corners) by additional readout nodes.

- The minimum error of 1.6% of the network's average link length was achieved in the center of the network where the triangulation intersect included the event node from all four readout nodes and the intersect area was minimal.
Designed and completed power and communication profile. Researchers completed the power and communication profile of the sensor node to inform LCA and prepare for the deployment scenario. Details follow:

- Researchers gained significant power savings by adjusting the clock frequency. The device allows for 32 power level settings for transmit but we only tested the minimum and maximum settings. Figure 45 shows the best compromise between power and performance depends on the amount of transmissions the network will perform.

- At lower transmission rates, the best performance seems to be around the 2MHz clock cycle (this is where receiver performance begins to flatten out). At higher transmit cycles a slower clock rate provides the most efficient power consumption. Operators need to consider processor performance when selecting a power profile. If intense processor computation were required, perhaps a higher clock rate would be beneficial.
IV.

Researchers found that the communication reliability in water or humid environment in infeasible due to high attenuation as a function of submersion. These findings informed us to select a “winter-field” deployment scenario. Figure 46 shows signal loss (maximum distance) as a function of submersion: at a range of about 10 feet, complete signal loss was achieved if the device was submerged to 1 foot. This required depth quickly dropped off as distance increased. At a distance of 20 feet 8 inches was required for signal loss. At 30 feet about 6 inches was required for signal loss. At 40 feet, 4 inches was required for signal loss. After 50 feet, a 2-inch submersion would result in complete signal loss.

<table>
<thead>
<tr>
<th>Range</th>
<th>Depth of signal loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>10'</td>
<td>12&quot;</td>
</tr>
<tr>
<td>20'</td>
<td>8&quot;</td>
</tr>
<tr>
<td>30'</td>
<td>6&quot;</td>
</tr>
<tr>
<td>40'</td>
<td>4&quot;</td>
</tr>
<tr>
<td>50'</td>
<td>2&quot;</td>
</tr>
<tr>
<td>150'</td>
<td>0&quot;</td>
</tr>
</tbody>
</table>

Figure 46. Complete loss of signal as a function of Moteino submersion (or deployment in an environment with high humidity).
Key Stakeholder Engagement in Program Year 3: The project team participated in the ADAC “Customers and Partners” Roundtable, in order to inform and receive feedback on project progress. ADAC Executive Counselors, CDR Ruth Lane, Director of U.S. National Ice Center, and Mr. Mike Faust, former Vice President of Exploration at Conoco-Phillips Corporation. Both expressed interest in the technology to supplement the existing mote technology developed by Conoco-Phillips for environmental monitoring. Further discussion between research team and CDR Lane focused on applicability of sensor research in support U.S. Navy Ice Exercise (ICEX) to monitor ice breakup around ICEX Ice Camp as an early warning system that would alerting the personnel of unstable ice conditions indicating possible ice breakup.

Discussion between the research team and Borders, Trade and Immigration (BTI) CoE (University of Houston) researchers included potential deployment scenarios for the southern border intrusion detection. BTI expressed interest in network architecture as a communication framework, not as a technology for emergent event detection.

Research team solicited several stakeholders for the project deployment scenarios and technology utilization that included Jennifer M. Konon, LCDR USCG D17 Intelligence Branch Chief, Bert Macesker, USCG, Jonathan Mcentee, DHS Borders and Maritime Security Division, Alan Arsenault CIV, USCG Research & Development Center C4ISR, James Fletcher, USCG Research & Development Center.

Key Publications (Peer Reviewed): None.

Key developments/presentations:

- Researchers presented progress report on the sensor network project at the ADAC Annual Meeting in Washington DC on 8 November 2016.

Changes from initially approved Work plan: Due to feedback received at the 8 November 2016 ADAC Annual meeting, project team needed to reinvestigate fundamental design assumptions in order to account for DHS and USCG mission needs. This resulted in refocus on fundamental research of the network, and not proceeding with the winter field test or integration of sensor data to command and control system ingesting. The DHS S&T OUP Biennial Letters Review determined project would conclude at end of ADAC Program Year 3. Accordingly, ASRC Federal Mission Solutions planned work for integration of sensor data to command and control system ingesting was transitioned to advance work within Arctic Information Fusion Capability, in accordance with DHS S&T OUP Cooperative Grant expanded authority.

Project Progress against each milestone:

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify interfaces for low-cost sensor hardware and software;</td>
<td>Completed. For COTS, details see baseline and the software systems are described below.</td>
<td>N/A</td>
</tr>
<tr>
<td>Build input model for sensor data;</td>
<td>Completed. A database</td>
<td>N/A</td>
</tr>
</tbody>
</table>
reporting system collecting both event information as well as node's raw promiscuous mode completed for the hardware testbed.

<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop operator-approved visual displays for sensor data and information;</td>
<td>An interface to the event aggregation database is available for data export and fusion for a secondary system.</td>
<td>Due to feedback at ADAC annual meeting, and subsequent DHS S&amp;T OUP Biennial Review, team delayed then concluded plan to research transition or geo-visualization as unsuitable.</td>
</tr>
<tr>
<td>Develop doctrine-based automation for sensor data qualification and operator alerting;</td>
<td>Completed. Implemented in the database reporting logic layer as a cross-event packet validation</td>
<td>N/A</td>
</tr>
<tr>
<td>Identify sensor and C2 system response for data detection and analysis;</td>
<td>N/A</td>
<td>Due to feedback at ADAC annual meeting, and subsequent DHS S&amp;T OUP Biennial Review, team delayed then concluded plan to research transition or geo-visualization as unsuitable.</td>
</tr>
<tr>
<td>Field deployment test of the sensor array architecture;</td>
<td>N/A</td>
<td>Winter field test not conducted based on feedback from November 2016 ADAC Annual meeting. Project team needed to reinvestigate fundamental design assumptions in order to account for DHS and USCG mission needs.</td>
</tr>
<tr>
<td>Initial network triangulation testing</td>
<td>Completed in the hardware testbed.</td>
<td>N/A</td>
</tr>
<tr>
<td>Event validation using remote</td>
<td>Completed. Independently of the sensor network</td>
<td>N/A</td>
</tr>
<tr>
<td>ID</td>
<td>Description</td>
<td>Measure</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>P.1</td>
<td>Geo-referencing within 10-meter margin of error in Cartesian coordinate system, or &lt;= 5% deviation in range/bearing coordinate system.</td>
<td>Completed, independent of the deployment. The geo-referencing error in range of 1.6% to 3.2% of the network's average link length for 1 hop distance signal propagation and the network</td>
</tr>
</tbody>
</table>

**Project Progress against each metric:**

<table>
<thead>
<tr>
<th>Database design, event and location logging;</th>
<th>Completed and validated on the “hardware testbed” architecture deployment.</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal-to-even acoustic and antennae signature generation and validation;</td>
<td>Completed. Independently of the sensor network architecture. Proof-of-concept completed on a sensor equipped with Electret Microphone Amplifier - MAX4466 with Adjustable Gain.</td>
<td>N/A</td>
</tr>
<tr>
<td>Device and detector integration;</td>
<td>Completed. Independently of the sensor network architecture. Integration of the baseline MoteineoR4 COTS with Electret Microphone Amplifier - MAX4466.</td>
<td>N/A</td>
</tr>
<tr>
<td>Application and evaluation of the lifecycle assessment cost framework on the US-Canada border intrusion detection deployment scenario.</td>
<td>Partially completed. GIS model, hardware component list and network topology completed. Work in progress and on schedule. ADAC Student Fellow continuing research as part of established thesis project. Project estimated to complete Spring 2018.</td>
<td></td>
</tr>
<tr>
<td>Page</td>
<td>Description</td>
<td>Details</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>P.2</td>
<td>Data processing times within operational timeline for singularity events such as new contact detection.</td>
<td>The events propagation, logging and triangulation did not exceed 5 second for a spatial-temporal event with time-stamp signature 1 second.</td>
</tr>
<tr>
<td>P.3</td>
<td>110% signal detection in the deployed sensor array.</td>
<td>A parameterized threshold of comparing acoustic signatures database with a signal collected on a sensor node allows for a dynamic activation threshold in range 0-100%.</td>
</tr>
<tr>
<td>P.4</td>
<td>Interface developed for “community-based observers” to access data and submit observations.</td>
<td>Data collection unit's event logging database implementation includes interface or remote query by a secondary system such as AIFC.</td>
</tr>
<tr>
<td>P.5</td>
<td>80% signal-to-event detection and propagation in the sensor array;</td>
<td>Signal-to-event detection was 130% successful as activation of any 3 linearly adjacent nodes triggered event conversion in all spatially adjacent nodes.</td>
</tr>
<tr>
<td>P.6</td>
<td>Signal, event and validation communication and logging into a database;</td>
<td>Implementation of event based and promiscuous network logging.</td>
</tr>
<tr>
<td>P.7</td>
<td>Cosine similarity between the database of recorded acoustic signatures and the real-time acoustic input of 80%+;</td>
<td>Completed, independent of the deployment. See metric P3. Measurements.</td>
</tr>
<tr>
<td>P.8</td>
<td>90%+ event triangulation accuracy from the readout nodes in the deployed sensor array;</td>
<td>Completed, independent of the deployment. See metric P1. Measurements.</td>
</tr>
</tbody>
</table>
Outcomes, Outputs and TRLs:

Project is at TRL-3

The overall outcomes for Program Year 3 include architecture integration of network simulator, hardware testbed and data collection unit with test harness automation. The network architecture concludes a proof-of-concept for the emergent signal-to-event detection with geo-referenced triangulation. The feedback from multiple stakeholders and potential technology customers was overly positive, optimistic, but it did not result in a tangible commitment of supporting the project towards technology transition. The technology readiness level achieved for ADAC Program Year 3 is TRL3, by implementing the geo-referenced event information database with events locations ready for integration into a secondary system such as AFIC or sub-arctic operators.

The project's accomplished Program Year 3 outcomes and outputs Products 1-7 with exception of Product 3 and Product 7 as described below:

- **Product 3: Concept of operations for geo-referenced integration and fusion in support of operational capability for USCG systems** planned in partnership between UAA researcher and ASRC Federal Mission Solutions. Due to feedback at ADAC annual meeting, and subsequent DHS S&T OUP Biennial Review, team delayed then concluded plan to research transition or geo-visualization as unsuitable based on no Year 4 project pathway.

- **Product 7: Develop, apply and evaluate** the device lifecycle assessment cost is still in progress as approved Civil Engineering Thesis research continuing by ADAC graduate student. The LCA assessment will complete in May 2018.

Program Year 3 Results:

After resetting the project scope and direction late in Program Year 2, the sensor network project delivered proof-of-concept of novel network architecture with emergent signal-to-event spatial computation. The deliverables include several software products and a hardware integration logic. The software products include the sensor node communication and spatial computation operating code, the event and signal collecting database, test harness automation operating code, and the acoustic signature opcode. The architecture also demonstrates the use of machine learning's approach to high precision event triangulation in asynchronous, clock-less, spatially non-explicit sensor networks. The software deliverables demonstrate the architectural POC and the feasibility of the technology's integration with the downstream fusion technologies and integration into the operator's decision support tools.

Unanticipated problems and plans for addressing them: As discussed, due to feedback received at the 8 November 2016 ADAC Annual meeting, project team needed to reinvestigate fundamental design assumptions in order to account for DHS and USCG mission needs. This resulted in refocus on fundamental research of the network, and not proceeding with the winter field test or integration of sensor data to command and control system ingesting. The feedback received from DHS S&T OUP and HQ USCG included major concerns for the proposed architecture's environmental impact at the time of deployment. The sensor network's LCA research component is actively studying this aspect of the
Transition Plans

Transition Plans and Progress Made: As a TRL 3 project there are no technology transition plans in place. The project deliverables include

1) Testing the robustness of the spatial computation;
2) Signal's acoustic or antennae signal signature generation and signature classification and;
3) Application and evaluation of the lifecycle assessment cost framework on the “border intrusion detection” deployment scenario.

The technology transition plans for the products 1) & 2) – are available as a source-code for a device operating system and the hardware test-bed’s automated test harness, respectively. The GIS model associated with 3) – will be publicly available for download as a supplementary material attached to with the MS thesis publication.

While ADAC concluded research for this project at end of Program Year 3, the Center seeks to investigate alternative sponsorship, with the most promising aspect as technology to support U.S. Navy ICEX to monitor ice conditions and subsequent unexpected ice breakup. While environmental impact of sensors is an ongoing concern for research to provide suitable remedies, the potential ability to monitor ICEX’s ice-camp could help preserve and protect lives and expensive equipment.

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

Project Team and Champions

Project PI: Dr. Jim Bellingham (WHOI), Brett Hobson (MBARI)
Project Manager: Ms. Amy Kukulya (Co-PI)

Lead Institutions: Woods Hole Oceanographic Institution

Supporting Team: Dr. Chris Reddy

Collaborators: Dr. Robyn Conmy, EPA USEPA/NRMRL/RTEB, USCG Research and Development Center

Program Year 3 Project Champions: LT Rebecca Brooks, CG-MER, HQ USCG, Mr. Jerry Popiel, CG-MER, USCG D-9, Mr. H. Blaney, HQ USCG CG-255

New Project Champions Established by DHS S&T OUP and HQUSCG at end of Program Year 3:
Champion: Ms. Kirsten Trego, HQ CG-MER; Support: Mr. Jeff Wheeler, CG-731 and CAPT Tom Meyer, CG-761.
Student Involvement: None

Project Description

Abstract: The increasing level of commercial marine activity in high latitudes creates an ever-growing risk of oil spills. Even in logistically accessible, ice-clear oceans, characterizing the extent and nature of a spill can be difficult as highlighted by the 2010 Macondo Canyon/Deepwater Horizon accident in the Gulf of Mexico. The research team proposes to develop an AUV-based approach leveraging a small, long-range system developed by the PI, called the Tethys Long-Range AUV (LRAUV). The LRAUV is helicopter-portable, allowing rapid response to incidents to provide situational awareness for first responders.

Outcomes of this project will be construction of a small long-range AUV (LRAUV) equipped with oil sensors and navigation systems, demonstration of the LRAUV survey capability, and creation of a simulator for gaming AUV deployments for oil spills. The resulting capability to survey oil spills at high latitudes and under ice answers an unmet need for DHS and the USCG.

Baseline: PI Jim Bellingham’s prior laboratories at MBARI originally created the Tethys vehicles specifically to carry biological and chemical payloads for long distances and times. The vehicles are small, about 30 cm (12 inches) in diameter, and require no special handling equipment. Prior deployments range from a few days to over three weeks, and are unattended by adjoining escort surface vessels. The longest-range mission to date was over 1800 km at a speed of 1 meter/second (m/s). In that deployment from and to Moss Landing, California, the vehicle operated as far as 500 km from shore independent of any escort. Achieving ranges two to three times greater is possible by operating at a speed of 0.5 m/s with minimal sensors. Maximizing endurance is achievable by using the buoyancy engine, through shifting internal weight, trimming to neutral buoyancy and drift at zero propeller speed, and again, by using minimal sensors.

The vehicle is typically shore-launched and recovered, using a small boat to tow the vehicle between the harbor entrance and a boat launch ramp. Importantly, Tethys is helicopter transportable to remote areas. Tethys occupies the design space intermediate between gliders and the current generation of propeller-driven AUVs.

While existing gliders such as the Teledyne Webb Slocum, the Scripps Spray, and the Kongsberg Seaglider have sufficient operational range to achieve the desired range goals needed by USCG, they do not have the payload capacity or power to carry the chemical and biological sensors, nor can these existing gliders operate at higher speeds without redesign. Typical gliders operate at speeds of about 0.3 m/s and with minimal power consumption: a 1W average payload is characteristic.

By contrast, existing propeller-driven AUVs such as those manufactured by Hydroid, Bluefin, OceanServer, and Teledyne Gavia consume more power and correspondingly, achieve shorter endurance. These commercial propeller-driven systems operate 24 hours or less at 1.5 m/s, providing ranges of less than 130 km. Consequently, Tethys is uniquely capable in its combination of payload capacity, range, and endurance for remote under-ice oil detection.
Mission-level control of Tethys is achieved using an architecture called ‘state-configured layered-control’. This is an improved variant of the layered control architecture developed by Bellingham (1991) and implemented on vehicles ranging from Webb gliders to the Dorado AUVs. State-configured layered control supports autonomous adaptive operations for long periods. Its building blocks are ‘behaviors,’ which are control laws that can be combined to accomplish tasks, which in turn can be conditionally connected to achieve missions that are more complex or respond to contingencies. The vehicle software is able to detect faults in critical components and respond appropriately, improving reliability. In some cases, through configuration changes, Tethys may continue a mission even though a component has failed. For example, vertical plane control is redundant: if the elevator actuator fails, the vehicle can continue the mission controlling depth by shifting internal weight.

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, at operator-determined intervals.

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 (http://aosn.mbari.org/TethysDash/data/daphne/realtimedlogs/2012/20121211/20121127T053258/). 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 send via email or mobile phones on certain conditions.

Prior research established design, created operating and navigation software, investigated the range of capabilities associated with critical components, created a systems integration plan, and conducted successful field-tests to validate research. Further research has created an advanced LRAUV design package with first article fabrication to allow subsequent full platform fabrication. The completed research to date provides a design for platform fabricators to construct LRAUV platform that meets stated parameters in navigation, mission performance, and operator ease of use.

Relevance to DHS: When an oil spill occurs in U.S. coastal waters, the U.S. Coast Guard leads the response. The ability to manage the response hinges on early information of the nature and magnitude of the spill. Unfortunately, methods for characterizing spills in ice-covered oceans are lacking. The relevance of this project is that it develops and demonstrates logistically manageable methods for under ice oil-spill characterization.

Currently AUV operations in ice are possible. Responders to oil spills in ice conditions, however, need oil spill sensing, navigation and mapping to leverage AUV capabilities to a needed mission outcome. Due to remoteness and lack of infrastructure, Arctic AUVs require ease of launch and recovery capabilities. In order to operate in complex ice environments in turn requires supporting simulator capability (to help operators achieve preparedness and accomplish response strategies) along with advanced navigation knowledge and experience. The LRAUV project provides USCG and other DHS maritime mission operators the ability to create a baseline of data relevant to Arctic marine environments.

In sum, LRAUV vehicle is a proven AUV platform that can solve many of the challenges outlined above for the USCG.
**Purpose of Research:** The ADAC’s objective is to develop an Autonomous Underwater Vehicle (AUV) based capability to observe and sample dynamic processes in the Arctic Ocean in order to characterize oil spills and other environmental hazards under ice.

**Methodology:**

In Project Year 3, LRAUV research advanced using a task-oriented team of expert marine mechanical and electrical engineers to create a readily deployable, easily handled, variable speed, long range AUV capable of detecting and mapping oil spills under ice. The team leveraged prior investments in AUV research and oil sensor technology, and overall leveraged mechanical and electrical engineering to adapt the *Tethys* vehicle with sensors, navigation, and chemical mapping to operate under ice.

The LRAUV re-design of *Tethys* seeks to observe and sample dynamic processes in the Arctic marine environments in order to characterize oil spills and other environmental hazards under ice. The sensor focus is to detect and acquire mapping of dissolved hydrocarbons and oil drops. The developed technology is useable in other regions (such as the Canada-U.S. Great Lakes). The LRAUV research team will investigate sensing and mapping information relay needs to get data quickly from the platform to on-scene operators. Research team integrated prior ADAC sponsored research in systems software, AUV simulator, chemical detection sensors, navigation, and mapping to design changes of the *Tethys* platform.

The approach is to leverage an existing Long-Range AUV developed at MBARI (the Tethys LRAUV), and to modify that system to operate under ice. Critical 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.

Since the starting point is a vehicle designed for biological oceanography at temperate latitudes, the LRAUV research activities include: a) selecting an appropriate oil detection sensor, b) simulating survey operations for oil spills in potentially shallow, high-current environment, c) developing a system for high-latitude operations, and d) testing the resulting system. As the project has evolved, we added an activity in year 3 (the just completed year) to test oil spill response using an off-the-shelf AUV (REMUS 100) and a fluorescent dye patch.

The following outlines risks associated with under-ice and high-latitude operations, along with strategies for mitigating those risks.

- Magnetic compasses are a preferred heading reference because of their low power consumption and reasonable cost, however they perform poorly in proximity to the North magnetic pole. Careful attention to minimizing vehicle-induced magnetic influences on the compass and the use of compass calibration methods should ensure adequate compass performance. Our prior experience with high latitude navigation provides an excellent foundation for this work [McEwen 2004].

- Arctic surface waters tend towards less salinity, creating a requirement that a vehicle manage a wider range of buoyancy. *Tethys* is uniquely suited to deal with this as it has a variable buoyancy system. Depending on the additional displacement of the cytometer package, the existing buoyancy system can be doubled in size to ensure adequate reserve buoyancy.
• Low temperatures can alter the property of certain materials (fluids too viscous, plastics below glassy transition, battery performance degraded, etc.). We will revisit the material choices for the vehicle to ensure the vehicles can be transported at low temperatures.

• A range of task-level control capabilities specific to under-ice operations will be required. For example, sampling near the ice may require reducing vehicle speed to zero, and using the buoyancy system to bring the vehicle up to the ice canopy. Vehicle behaviors for fault-detection and recovery will have to be less conservative. Usually vehicles will ‘bail’ to the surface at the first hint of failure, where they will either communicate home by satellite or be recovered. Under-ice, this is not acceptable, consequently the vehicle must be capable of operating even in the event of failures. The mission-level control architecture used for the LRAUVs is well suited for such demands [Godin, 2010].

• In shallow Arctic water, the ice canopy can ground on the bottom, creating a fully three-dimensional environment in which the vehicle must navigate. We will restrict AUV operations to regions where the water depth is much greater than the ice thickness. An upward-looking altimeter will provide the vehicle the ability to sense the overhead ice and navigate to avoid it in the same manner as AUVs navigate near the seafloor. The acoustic Doppler system will be useful in allowing the vehicle to measure local currents and time activity.

A principal objective of the project is to develop the onboard ‘intelligence’ that will allow the AUV to operate under ice. Mission-level control of Tethys is achieved using an architecture called ‘state-configured layered-control’. This is an improved variant of the layered control architecture developed by Bellingham (1990) and implemented on vehicles ranging from Webb gliders to the Dorado AUVs. State-configured layered control supports autonomous adaptive operations for long periods. Its building blocks are ‘behaviors,’ which are control laws that can be combined to accomplish tasks, which in turn can be conditionally connected to achieve missions that are more complex or respond to contingencies. Reliability is enhanced, as the vehicle software is able to detect faults in critical components and respond appropriately. In some cases, Tethys can be configured to continue a mission even though a component has failed. For example, vertical plane control is redundant: if the elevator actuator fails, the vehicle can continue the mission controlling depth by shifting internal weight.

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, 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/). 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, and includes a display of science and engineering data (http://aosn.mbari.org/TethysDash/data/daphne/realt ime/sbdlogs/2012/201211/20121127T053258/).

The research seeks to address key questions such as: In the Arctic, how do you control the source of an oil spill if you cannot find it? How and where do you place your assets without the necessary and timely
intelligence? The objective is to develop an Autonomous Underwater Vehicle (AUV) based capability to observe and sample dynamic processes in the Ocean in order to characterize oil spills and other environmental hazards under ice. Creating a baseline of data for Arctic Ocean communities can systematically be carried out with the LRAUV.

Currently, an autonomous underwater vehicle capable of under-ice oil detection that is portable and has long-range endurance and variable speed capability is not available. Our objective is to provide high-value, relevant, and timely observations of dissolved hydrocarbons and oil drops to oil-spill responders using the LRAUV. Not only is there a void in the available technology for under ice baseline surveys that require minimal resources for launch and recovery, but there is also a lack of a platform with multiple capabilities for navigational accuracy and data transfer. Accordingly, research aims to improve on this by exploring multiple modes of navigation in order to mitigate complex environmental conditions and changing scenarios.

The team will use several levels of navigation for the AUV. First, a GPS system built into the Tethys antenna will routinely obtain GPS fixes when the vehicle surfaces. Second, the vehicle will dead-reckon using a Doppler sonar to measure velocity relative to the bottom, and a compass for heading. Third, an ultrashort baseline (USBL) acoustic system will measure range and direction to a transponder and allow acoustically marking interesting sites for revisit by the vehicle. Furthermore, due to the small size of the vehicle as outlined above, the team can operate minimally in regards to personnel needed for launch and recovery (L&R) as well as being highly portable for L&R from a small boat; helicopter or LRAUV can even be launched from shore.

Tethys’ variable buoyancy system provides useful capabilities for high latitude operations. Variable buoyancy enables more efficient operations at low speed, but also permits the vehicle to surface and sink at zero speed. This allows the vehicle to surface in open water between ice floes, for example, for satellite communications and a navigation fix. Incorporation of a USBL system allows homing on a transponder, which would allow recovery of the vehicle through an ice hole.

The leaders in Tethys development, Bellingham (WHOI) and Hobson (MBARI), have extensive sea experience with AUV operations, including in the Arctic [Deffenbaugh, 1993; Bellingham, 2000; Cokelet, 2008; Bellingham, 2008]. Bellingham was involved in the response to the Deepwater Horizon incident [Zhang, 2011]. Bellingham and Hobson have also developed have developed a number of AUVs in addition to the Tethys platforms, including ALTEx [Bellingham, et.al., 2000], the MBARI Dorado AUV [Sibenac, et.al., 2002], the Odyssey II AUVs [Bellingham et.al., 1994], the Odyssey [Bellingham et.al., 1992], the Cetus hovering AUV [Curcio et.al., 1998], and the Sea Squirt [Bellingham et.al., 1989]. WHOI has extensive facilities to support AUV development, including engineering labs, machine shop, and 10-m deep saltwater test tank.

The team’s approach to developing the AUV under-ice oil-spill survey capability involves identifying the appropriate sensors, integrating that sensor on a long-range AUV, and demonstrating the resulting survey capability. Technical challenges that must be mastered as elements of this effort include the ability to navigate under ice, and the optimization of surveys especially in high current environments.

Observation requirements for the AUV system include
- Ability to map in 3D;
- Detection and quantification of dissolved particles;
- Determine the environment (is it hypoxic?);
- Take CTD measurements.

**Project Results:**

**Key Accomplishments in Program Year 3:** The highlight of program Year 3 was a successful demonstration and training exercise of a WHOI AUV equipped with a plume mapping sensor and software capability delivered to the USCG R&D Center. In addition, the team began fabrication of the LRAUV vehicle in conjunction with MBARI and improved the software simulation package for the LRAUV:

- Integrated an oil plume mapping sensor package on a REMUS AUV for open water testing and completed an open water demonstration to ADAC leadership and members of the USCG R&D Center on 3 Nov 2016;
- Further developed software simulation for mission planning and operator training
- Wrote an IEEE conference paper, presented and published at OCEANS 2016 in Tokyo, Japan. (NOV 2016) (please see supporting documentation);
- Produced a DEMO video to show ease of operation and training of USCG and provide training to USCG members;
- Started software development of LRAUV oil sampling under ice;
- Began LRAUV TETHYS fabrication and procuring parts in May in conjunction with MBARI;
- Started development of modified nose section with WHOI technology for ice navigation/docking and launch and recovery;
- Conducted a compass (AHRS) evaluation for high latitude performance and wrote a technical document’
- Wrote an abstract, which was accepted into MTS IEEE Oceans on Demo/mapping work.

**Key Stakeholders Engagement in Program Year 3:** WHOI interacted with Project Champions/Stakeholders in YR3

- ITAC Meeting October 2016, Woods Hole (Kukulya, Bellingham, Reddy)
- LRAUV DEMO, Woods Hole, Nov 3 2016 (USCG R&D Center) (Kukulya, Reddy)
- Annual Meeting, D.C. Nov 7-10 2016 (Bellingham, Reddy)
- DC Meeting, Dec. 2016 (Bellingham with Captain Evans)
- International Oil Spill Conference, week of May 15, Long Beach, CA (meetings with ICCOPR member CAPT Joseph Loring, Kirsten Trego, ICCOPR member EPA oil expert Robyn Comny, NOAA Senior Scientist Lisa DiPinto-Office of Response and Restoration, Jay Cho-BSEE (Oil Spill Preparedness Division) and Kurt Hansen at USCG R&D Center
- Ongoing email conversations with USCG HQ CG-MER-3, ICCOPR (Kirsten Trego) and USCG R&D Center (Bert Macesker, Captain Evans, Rich Hansen, Jim Fletcher)

**Key Publications (peer reviewed or in review):** N/A

**Key Reports/developments/presentations:**
2. Developed dye-mapping DEMO video, which is now on the DHS COE website.

**Changes from initially approved Workplan:** MBARI status in the LRAUV project was changed from Outside Services to a Subaward recipient in April 2017 and therefore directly funded by ADAC. Brett Hobson, Lead Mechanical Engineer from MBARI for the LRAUV, was made a Co-PI and is directly responsible for facilitating the procuring and building of the LRAUV in conjunction with WHOI. Delays in finalizing a license agreement with MBARI and WHOI caused a slip in the ordering and fabricating of the LRAUV vehicle. By reclassifying funds earmarked for ‘Outside Services’ previously awarded to WHOI in YR3 to an MTDC free object code (equipment > $5000), the team was able to procure a higher volume of parts and instrumentation for the LRAUV build in YR3 not previously planned. This included dual ADCPs and the Capture Nose Assembly.

**Project Progress against each milestone:**

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
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<tbody>
<tr>
<td>(ML3-1): Purchase a sensor package; integrate into a REMUS AUV system and develop software capability for near real-time data transfer and adaptive mission sampling. (September 30, 2016).</td>
<td>Completed integration and successful and testing on a REMUS AUV.</td>
<td>N/A.</td>
</tr>
<tr>
<td>(ML3-2): Run an AUV Demo in local waters (Woods Hole, MA) demonstrating environmental plume mapping, real-time data transfer, visualization, and adaptive mission sampling. (October 30, 2016).</td>
<td>Completed successful Demonstration in Woods Hole on 2 Nov 2016 with ADAC Executive members and members of the USCG R&amp;D Center.</td>
<td>N/A.</td>
</tr>
<tr>
<td>(ML4-1): Begin fabrication of the LRAUV, 25-35% of vehicle estimated to be complete in Year 3. (June 30, 2017).</td>
<td>Completing agreement with MBARI on building LRAUV5 and began fabrication and procurement of parts. Had estimated 30% of vehicle to be complete. We currently have 70% of the parts on order</td>
<td>N/A.</td>
</tr>
<tr>
<td>MILESTONE</td>
<td>PROGRESS</td>
<td>WHY NOT REACHED?</td>
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<td></td>
<td>and are on target to complete in 2018.</td>
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</tbody>
</table>

**Project Progress against Metrics:**

<table>
<thead>
<tr>
<th>ID</th>
<th>DESCRIPTION</th>
<th>MEASURE</th>
<th>STATUS END YEAR 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML3-1.1</td>
<td>Identify and purchase a sensor package.</td>
<td>a) Detection levels. b) Update rate c) Power consumption d) Integrated into vehicle sensor suite.</td>
<td>a) &lt; 80ppb b) 1 Hz c) 0.8 W approx. d) Yes. All complete. Sensor identified, purchased, and integrated into REMUS for demo using fluorescein dye frequencies (see ML3-2).</td>
</tr>
<tr>
<td>ML3-1.2</td>
<td>Develop software capability for adaptive mission sampling.</td>
<td>Vertical plane sampling algorithms developed to concentrate vehicle operations in depth range of greatest oil concentration.</td>
<td>Completed integration and successful and testing on a REMUS AUV. See results of ML3-2. Autonomous horizontal-plane.</td>
</tr>
<tr>
<td>ML3-1.3</td>
<td>Develop software capability for near real-time data transfer.</td>
<td>Acoustic communication with REMUS demonstrated for operational control of AUV.</td>
<td>Completed integration and successful and testing on a REMUS AUV. See results of ML3-2.</td>
</tr>
<tr>
<td>ML3-2</td>
<td>Run an AUV Demo in local waters (Woods Hole, MA) demonstrating environmental plume mapping, real-time data transfer, visualization, and adaptive mission sampling.</td>
<td>A. Successful deployment and recovery of AUV. B. Successful detection and mapping of plume as validated for first mission by UAV, C. Successful remove interaction with AUV via acoustic link for mission modification.</td>
<td>A through C completed successful Demonstration in Woods Hole on 2 Nov 2016 with ADAC Executive members and members of the USCG R&amp;D Center.</td>
</tr>
<tr>
<td>ML4-1</td>
<td>Begin fabrication of the LRAUV, 25-35% of vehicle estimated to be complete in Year 3.</td>
<td>A. Bill of Materials. B. Order parts. C. Assemble platforms.</td>
<td>A. Complete B. 70% complete C. Target was 30% of vehicle to be assembled, but completing agreement with MBARI on building</td>
</tr>
</tbody>
</table>
Outcomes, Outputs and TRLs:

**Project is TRL-5/6**

Following the LRAUV’s testing plan (which is beyond Program Year 3) and completion of data relay devices, the overall system will be TRL 7/8. The Researchers emphasize that the platform will remain developmental, as platforms typically require thousands of hours of operational time to work through technology refinement problems.

*Demonstration Results:* WHOI conducted a LRAUV System demonstration using a REMUS AUV and surrogate dye plume for autonomous detection and mapping

*Date:* November 2-3 2016 aboard the R/V *Discovery*

*Participants included:*

- Randy "Church" Kee, Maj Gen, USAF (Ret), Executive Director, Arctic Domain Awareness Center (ADAC)
- Jim Fletcher, Environmental & Waterways Technical Branch Chief, USCG RDC
- Captain Dennis Evans, USCG. Commander, USCG RDC
- Bert Macesker, Executive Director, USCG RDC Center
- ENS Shafeian, USCG RDC
- Dr. Chris Reddy, WHOI, Amy Kukulya, WHOI, Roger Stokey, WHOI and Sean Whelan, WHOI

A video of the demo was produced and is available for viewing, please contact amy@whoi.edu

*Purpose of Exercise:* To test a WHOI developed oil detection capability using a REMUS-100 autonomous underwater vehicle (http://www.whoi.edu/osl/remus-100) outfitted with an environmental sensor package including the SeaOWL UV-A (Sea Oil-in-Water Locator) sensor. The vehicle payload also included 900 kHz side scan sonar, a CTD, optode probe, an inertial navigation system and a 1200 kHz ADCP. The detection and mapping capability is being developed for integration on the Tethys class long-range AUV from MBARI. The prototype LRAUV system is currently being built under a collaboration between WHOI and MBARI. While development is underway, the team developed vehicle software in order to test various mission plans for mapping and detected oil in seawater. Lessons learned from the Demo will improve mission planning as well as real-time data transmissions. Furthermore, improvements will be transitioned onto the Tethys platform. The team also used the Demo opportunity to show the simplicity of deploying and operating a commercially available vehicle. Members of the R&D Center, as well as, USCG deployed, operated and helped to recover the vehicle demonstrating how quick operators can learn the system. Since a release of oil in coastal waters is not feasible, we re-configured the SeaOWL for detecting uranine/fluorescein. The team built a “flow control” release
system in order to control the volume of the plume (fluorescein) and calibrated the flow output to be 4 gallons/hour.

The team created a new vehicle objective for plume mapping called 'Find Max'. The current architecture is:

- Does a “mow-the-lawn” survey until it exceeds some user-defined threshold.
- When the vehicle then drops and stays below the threshold for 30 seconds, it turns right 90 degrees.
- It stays on this transect for at least 30 seconds. If during this time the threshold is exceeded the timer is reset. Once 30 seconds has elapsed without exceeding the threshold, the vehicle turns:
  - If it never exceeded the threshold during this leg, it turns and aims for the position with the highest saved concentration and goes to step 4.
  - If it DID exceed the threshold on this leg, it turns right 90 degrees and repeats step 3.
- The vehicle will pass through the point with highest (saved) concentration. After that point is achieved, the vehicle starts its 30-second count down. If the threshold is exceeded, the vehicle resets the timer, and continues traveling in the same direction. When the 30 seconds have elapsed, the vehicle turns right 90 degrees again and goes to step 3.

At any time, the user could send the run command via modem or Iridium, and the vehicle will then return to the spot where it broke off the mission and resume the preprogrammed navigate rows objective.

While the vehicle is conducting its mission, it sends acoustic modem data packets with detection info back to the operator’s laptop for interpretation. The modem packets currently give information on when and if the vehicle followed the plume. The research team will be improving the message to report sensor info/detections that can be translated into a heat map in real-time for quick decision making by first responders. Near real-time data can be seen in Figure 47 and dye flow with vehicle mapping underwater is seen in Figure 48. Figure 49 shows drone surface footage of dye with vehicle tracks overlaid.
Top left are chlorophyll counts reported by the SeaOWL. Detection thresholds are preset by the user. Backscatter data correlates with fluorescence. Vehicle was programmed to yo-yo between 2 and 7 meters but then autonomously adjusted its depth when detections were recorded. FDOM is also measured and can be used as a detection indicator.

Figure 47. Near real-time data.
**Figure 48.** Dye flow with vehicle mapping underwater. Fluorescein flow of 4 gallons/hour and REMUS homing in on it near ship.

**Figure 49.** Arial footage of dye from Mission One (green), red tracks are preprogrammed mow-the-lawn. White tracks show vehicle path when plume was detected.

**Launch and Recovery.** The vehicle can be launched from a davit or by tossing off the side/back of a boat. Recovery of the portable vehicle does not require a knuckle crane, but was available to us for easy recovery. 2-3 people are needed for recovery. (See Figure 50).
Tethys LRAUV Vehicle Build:

The start of the build was delayed by changes to the Tethys structure and by changes to the administrative timelines associated with making MBARI a full ADAC. As of the end of the year, the Bill of Materials had been compiled, including about 1000 items, and 70% of the items on order. The new organization allows significant parts of actual vehicle construction to coordinate with a multiple vehicle

Figure 50. LRAUV Launch and Recovery.

Robost AUV can be tossed off the back of a boat, or from a helicopter with caution.

Recovery of the portable vehicle does not require a knuckle crane, but was available to us for easy recovery. 2-3 people needed for recovery.
build already occurring at MBARI. Thus, we expect efficiencies achieved will allow us to complete the vehicle close on schedule.

Software: Improving precision in measurements vs. depth: LRAUV control algorithms and sampling strategies were historically optimized for signals that vary slowly with depth, and consequentially, precise depth control has not been a system requirement, especially near the air-water interface. Likewise, the capability to react to measurements made at specific near-surface depths (or to consider several discrete depths) has not been a system requirement. As shown in Figure 51, the effect is especially pronounced in the case of “yo-yo” profiling, where the sensor making a measurement may be at a different depth than the primary depth sensor.

Due to this effect, typically when making vehicle-based adaptive sampling decisions, only the upcast or downcast data are used, effectively cutting the sampling rate in half. The Program Year 3 strategy to deal with this problem was to develop a zero-pitch “yo-yo” (using both elevators and the LRAUV’s movable center of mass) that would remove the effect of pitch variation from sensor measurements. This is shown in Figure 52, along with example data.

Figure 51. Illustration of pitch-induced yo-yo behavior and depth-related offsets in measurements when making measurements in a thin layer.
In simulations, the zero-pitch “yo-yo” was very successful at reducing the effect of pitch on measurements. It did not result, however, in the desired increase in sampling frequency at specific depths because the vehicle’s rate of ascent and descent was reduced by an order of magnitude.

When processing data on shore after a cruise, a scientist can account for the pitch and roll of the vehicle and the locations of the depth and other sensors to correct the depth of individual sensors. This capability has been added to the LRAUV on-board software. Now every sensor that is configured with an X, Y, Z coordinate in the vehicle’s frame of reference (see Figure 53) also has a real-time sensor-specific adjusted depth measurement associated with every sensor measurement. The addition of this capability has effectively doubled the rate of data available to on-board adaptive sampling algorithms. Specifically, the on-board dissolved “oil plume” tracking algorithms are now being adjusted and tested with this capability.
Unanticipated Problems and Plans for Addressing Them: Thus far, the principal challenges have revolved around adjusting work packages to make most efficient use of project participants. In year 3, we worked to bring MBARI onboard as a full ADAC participant. Although this occurred at the end of the year, and therefore created scheduling challenges with end of year funds, it ultimately made the project far more efficient as MBARI is building multiple Tethys platforms. By building on those efforts, we achieve a level of efficiency that should be much higher than is possible for a one-off platform build. Thus, while this delayed us in year 3, we anticipate a faster build in year 4 than originally planned.

Transition Plan:

Transition Plans and Progress Made: The goal of this project is to create an operational system that the USCG can use for characterizing spills in ice-covered ocean environments. The ADAC activity focuses on creating and demonstrating prototype systems. The platform used for the initial year 3 demonstration, a REMUS-100, is commercially available. The customized payload design developed for that platform and used in the demonstration is also built using commercially available sensors. As with all of the IP created under this effort, the designs are available for government systems on a royalty free basis. Consequently, the year 3 demonstration vehicle can be readily replicated for the USCG. The platform built in year 4 will be a modification of a proven vehicle whose design was led by the PI when at MBARI. That vehicle has performance far beyond commercially available systems, and thus transition of that capability to the USCG requires some planning.

Depending on DHS and USCG acquisition desires, the project team emphasize that WHOI and MBARI have around-the-clock technical expertise available if any such need arises. This technical support covers hardware, software, design, fabrication, and specialty application, plus operations expertise.

Woods Hole Oceanographic Institution (WHOI) has a long history transitioning technology to operational use, especially with the US Navy. Over the years, a variety of transition methods have been employed tailored to the nature of the challenges associated with the transition. Factors influencing the nature of transition include technological maturity, complexity of operations, availability of investment for ‘hardening’ of systems, market prospects, and more. Transition methods include the following:

Facilities: WHOI operates facilities for certain high complexity platforms such as the ALVIN Human Occupied Vehicle, the JASON Remotely Operated Vehicle, and the Sentry Autonomous Underwater Vehicle. These systems are operated as part of the National Deep Submergence Facility (NDSF) under the sponsorship of the National Science Foundation, the Department of the Navy, and the National Ocean and Atmospheric Administration. The facility is typically chosen for systems that are going to be operated in small numbers, yet which require a highly specialized team. The facility allows costs to be spread across the user base, and frees users from the need to carry operators on staff.

Service for-Hire: Some platforms, such as the REMUS vehicles, are operated on a for-hire basis. Examples of for-hire operations include the location of the El Faro data recorder by a Deep Submergence Laboratory WHOI team funded by DoT, and the location of Air France Flight 447 by the WHOI Ocean Systems Laboratory. Like the facility model, the for-hire model frees the user from the need of creating and maintaining a staff of expert operators. Unlike the facility model, where
scheduling is driven by the sponsors, for-hire operations may be precluded if vehicles have prior commitments.

**Hardware Builds:** When an organization wants to replicate a WHOI system, WHOI has in the past built small numbers of devices for a customer. For example, many of the early REMUS 100 platforms were built for scientists and other users by the WHOI inventors. Since the user takes delivery of and owns their own platform, scheduling is completely under the user’s control. The user, however, does need to build their own operational team, and that team will need training and support from key WHOI staff. For example, Amy Kukulya, the Project Manager for this effort, trains Navy sailors in the operation of REMUS platforms.

**Commercialization:** When there is sufficient demand for a system, commercial production is the logical solution. A healthy commercial enterprise will make investments to improve manufacturing and reliability, and provide operator support. Commercialization may occur by licensing of the technology to a commercial entity, or by a spin-off company. Examples of the former include recent WHOI developments of REMUS 600 technology by WHOI for the US Navy that are now produced as Kongsberg Hydroid products. Examples of the later include the original spin-out of Hydroid from WHOI and Bluefin Robotics from MIT (J. Bellingham was a co-founder of the later).

The research team suggests that the transition plan for the capabilities being developed under this program might transition in two stages: first by building one or more systems for the USCG, and then by commercializing the resulting platform. Stage one would initiate after a successful demonstration, as envisioned in ADAC. The team would build one or more vehicles for the USCG. As part of the project funding for that build, funds would be allocated for WHOI training of USCG operators, and for WHOI support of USCG operations. Given the nature of Tethys LRAUV operations via a satellite link, WHOI operators could participate directly in USCG operations remotely if that were desirable.

Lesson learned in transitioning a system to USCG operation would be invaluable in preparing the system for commercialization. WHOI would work with one of its many partners to commercialize the resulting system. Selecting the company is premature at this point, as marine robotics space is evolving rapidly and there are likely to be more options a year from now.

In parallel with ADAC funded efforts building the proven Tethys design, the WHOI Center for Marine Robotics plans to devote resources to creating a long-range vehicle more efficient to manufacture. As a scientific platform, the Tethys design was not designed with efficiency of manufacturing as a consideration. We plan to revisit the long-range AUV design with efficiency of manufacturing as a central goal. This effort would leverage the nearly $1M investment made by the state of Massachusetts in the Center for Marine Robotics Dunk Works maker space. Dunk Works opened officially on July 20 of this year, equipped with the latest in design tools, 3D printers, circuit board printers, and the like, the space is ideally set up for the initiative. Further, the prospect of low-cost, high-reliability, long-range AUVs is attracting other sponsors, creating the prospect of a well-funded effort.
Theme 3 – Production Transition Strategy

**ADAC Research Transition Process.** Throughout ADAC Program Year 3, ADAC further developed and refined Center process for research transition. ADAC leadership benefitted from the 15-16 August 2016 DHS S&T OUP Research and Technology Transition (RTT) Workshop hosted at University of Minnesota, Minneapolis, Minnesota. Throughout the research year, ADAC discussed transition with both industry, HQ USCG CG-7 (Assistant Commandant for Capabilities) and HQ USCG CG-9 (Assistant Commandant for Acquisitions) and USCG RDC. During Program Year 3, ADAC and USCG RDC agreed the Center’s LRAUV platform would be suitable for operational testing at RDC facilities.

**Research transition as an anticipated activity.** During Program Year 3, Center leadership evaluated project transition planning during quarterly reviews via the ADAC Review Group, and solicited input the center’s Executive Counselors (during the January 2017 Review. The ADAC quarterly review was one way to discern the pathway of transition planning needed to support end user mission needs and that an acquisition opportunity is feasible, acceptable, and supportable. Throughout year 3, ADAC’s USCG Project Champions were integral to research transition planning. USCG Project Champions were consulted by individual project leads on a frequent basis and by ADAC leadership during periodic Customer’s and Partner’s Roundtables as well as ADAC’s Annual Meeting.

**ADAC’s “Research-to-Capability Process” (RTCP).** ADAC’s RTCP is the Center’s approach for finalizing transition of research to end users. In Program Year 3, ADAC initiated plans to add an industry-provided transition advisor to work with the ADAC Executive Director and Project Management Director to transition concluding research to DHS and USCG acquisition professionals. To accomplish this, ADAC initiated discussions with the University of Alaska Business Enterprise Institute and UAA Office of Sponsored Programs to support transition activities, to include handling of transfer for appropriate documentation and patent initiation. ADAC refined existing RCTP aspects from the approved Year 3 Workplan to clarify, ADAC’s Principal Investigator, Research Director and Executive Director will determine the task organization needed to migrate research to receiving development and acquisition professionals.

Theme 4 – Integrated Education Outreach (and Workforce Development)

**Program overview.** An important goal of the Arctic Domain Awareness Center is to foster the next generation of scientists and engineers devoted to the discovery, development and improvement of technologies and applications for Arctic Maritime Domain Awareness, Response, and Resilience. By attracting talented undergraduate and graduate students to join the ADAC Fellows program, the Center is contributing towards the next generation of Science, Technology, Engineering, and Mathematics (STEM) professionals offering their Arctic expertise for the benefit of the Homeland Security Enterprise (HSE).
In accordance with DHS S&T OUP Program Year 3, approvals, ADAC Education program adjusted to reflect the following categories of student fellows associated with ADAC research.

- Career Development Grant (CDG), a student scholarship activity funded via DHS supplemental;
- Workforce Development Program (WFD), student developmental activities funded in the overall ADAC program year award;
- Minority Serving Institution (MSI) Summer Internship Program, a student summer internship for students from underrepresented classifications funded in the overall ADAC program year award.

Combined, these three different program strands make up the ADAC Education and Workforce Development program, also referred to as the ADAC Fellows program, which brings together undergraduate and graduate students from the University of Alaska system and beyond. During Year 3, the Center supported 14 student fellows (ten undergraduate and four graduate) from three different institutions. University of Alaska Anchorage (UAA) was the home institution for ten fellows (six undergraduate and four graduate) while University of Alaska Fairbanks (UAF) and University of Idaho (UIdaho) both had two undergraduate students supported by the Center (Table 1.). In addition, the ADAC supported one MSI student from Tougaloo College in Mississippi for a 10 – week summer internship.

ADAC received approval for its expanded Workforce Development program in late November 2016. With the recruitment of additional fellows to join the existing five CDG Fellows already enrolled in the Center’s Fellows program principally happening in December and January, the following activities largely took place during the 2017 spring semester. In summary, the Education Program activities Year 3 included the following activities for all fellows:

- Bi-monthly mentoring meetings that were attended by fellows either in-person or remotely via telephone/Skype for Business. Starting in April 2017, ADAC shifted mentoring meetings to a monthly basis.
- Participation in ADAC’s quarterly Customer and Partners teleconference meetings.
- ADAC’s annual student research symposium hosted at UAA on April 25, 2017.
- ADAC fellows research poster session at UAF on May 10, 2017 as part of the Week of the Arctic activities in Fairbanks, Alaska.
- Participating in the Arctic 2030 workshop hosted by ADAC and U.S. Coast Guard Headquarters Office of Emerging Policy at UAF on May 11-12, 2017.
- Continued support for fellows on their monthly reports and ADAC research project related activities during Year 3.
- Assisting fellows on their summer internship search and placement for an internship.

Fellow attendance in the monthly meetings was good throughout Year 3 and greatly assisted in developing essential connections between the previously enrolled CDG fellows and new WFD fellows joining the program from different disciplines and institutions. Attending quarterly Customer and Partners teleconference meetings offered ADAC Fellows insights into the tangible questions from USCG personnel and research project Principal Investigators were dealing with as they carried on their research for Year 3.
ADAC’s first annual student research symposium on April 25, 2017 at UAA served as an excellent opportunity for the fellows to practice conference poster design and submission. Presenting about their ADAC related research work to their peers and invited guests in a large conference room offered a public speaking opportunity experience, welcomed by the fellows. Following the research symposium, fellows continued to work with ADAC’s Administrative and Communications officer Kukkonen on improving their posters and verbal presentations for the ADAC fellows’ research poster session held at the University of Alaska Fairbanks on May 10, 2017. Each fellow presented their completed, large poster at the ADAC Fellows research poster session during an evening event that was part of the official agenda of the Week of the Arctic. An estimated 50-60 people attended the evening event while the overall Week of the Arctic participation in the different events reached approximately 1,000 people from different parts of the world.

ADAC Fellows activities for spring 2017 concluded with a final monthly meeting held in ADAC’s new office suite in May. During the last meeting, fellows describe their experience in the Year 3 program. Without an exception, each fellow had a positive development to share with everyone. For some undergraduate fellows, the positive example was growing as a student and developing their presentation skills. For others the highlight was the support and encouragement offered by peer fellows to carry on with their studies and continue working hard towards graduation. ADAC fellows benefited from opportunities to present in a professional setting and interacting with researchers, industry representatives, and agency staff. These are important steps mentoring them towards transition into the workforce. Carrying on the good work with the continuing fellows in fall 2017 is very important and ADAC leadership is looking forward to providing new educational and mentoring opportunities to our existing and future fellows by utilizing the Center’s continuously developing network of Arctic operator, industry, and research partners.

As a part of ADAC’s efforts in education, Maine Maritime Academy (MMA) concluded research and development in creating courseware for Arctic mariners to certify compliance with the International Maritime Organization (IMO) Polar Code. At the end of ADAC Program Year 3, MMA achieved completion of courseware and simulator program scenarios (complete with software code) for advanced Ice Navigation and other IMO Polar Code requirements for Ship Captains and First Mates. Following MMA final internal academic reviews, Project investigators will submit courseware to HQ USCG Office of Navigation for certification. As discussed in the Arctic Education Implementing the Arctic Strategy in Training, ADAC and MMA seek promulgation of completed courseware within USCG, mariner academies, and U.S. mariner pilots and masters unions.

The following provides details of ADAC education program.
PROJECT: Arctic Education Implementing the Arctic Strategy in Training

Project Team and Champions:

Project PI: Susan Hazlett, Administrative PI, Captain Ralph Pundt, Technical PI

Lead Institution: Maine Maritime Academy, Castine, ME

Supporting team: N/A

Collaborators: Merchant Mariner Captain Patrick Toomey. Captain Toomey is a retired icebreaker captain and currently an ice navigator on ships in the Northwest Passage

Program Year 3 Project Champions: HQ USCG-751 (Primary), USCG RDC (Secondary).

Student Involvement in Program Year 3: Twenty-two MMA students at Maine Maritime Academy enrolled and completed the basic ice navigation course during the spring semester of 2017. A number of MMA students will serve as mariner interns with companies operating in Alaska, including the Bering Sea region. Additionally, capable and interested students assisted with the development and piloting of the ice simulations for the advanced class.

Project Description:

Abstract: Program Year three efforts for the Maine Maritime Academy project entitled "Arctic Education: Implementing the Arctic Strategy in Training" expanded from the original scope of work to include an advanced ice navigation course. This course is required for masters and first mates who will be sailing in Polar waters. This is a requirement under the International Maritime Organization (IMO) Polar Code.

This project includes courses developed and submitted over three years. HQ USCG Office of Navigation approved the basic ice navigation course for Standards of Training, Certification and Watchkeeping (STCW) certification. MMA’s Year 3 task was the completion of the advanced ice navigation course. The courseware and associated bridge simulator scenario software development was completed. The new courseware and software was currently with the MMA Continuing Education department for a final review of the submission documents before transmitting to HQ USCG Office of Navigation for certification.

Baseline: MMA created a basic course to train and certify mariner watchkeepers for ice navigation and other standards established in the IMO Polar Code. The basic course is established courseware at MMA. The advanced class is a continuation of the basic class, and builds on the knowledge gained in that course. However, since the responsibility, level is much higher for the officers taking the advanced class and since some time may elapse between taking the two classes due to the requirement for sea time in polar waters, some additional review is necessary. Overall, however, the depth into which this class goes and the knowledge required is at a much higher level, and completion of the advanced course
allows ships masters and first mates certified compliant with the IMO Polar Code (once HQ USCG SCTW certification is awarded). In sum, MMA Program Year 3 goals are complete with the submission of the advanced ice navigation class for certification.

**Relevance to DHS:** USCG has the responsibility of ensuring US port and state compliance with the directives of the International Marine Organization (IMO). This includes ensuring that mariners operating in polar waters have the proper training and certifications. The basic and advanced ice navigation courses satisfy these requirements for US mariners. Upon completion of these courses, American ship’s officers will have met or exceeded all Standards for Training, Certification, and Watchkeeping (STCW) required by international maritime law.

**Purpose of Research:** Develop and complete the advanced ice navigation course required by the IMO Polar Code for masters and first mates operating vessels in polar waters. This course is completed and has two components, an online component where students learn advanced principles of ice navigation, icebreaker operations, search and rescue in polar waters, operating equipment in polar conditions, and health and safety of the crew in polar conditions. This course will become the official USCG course required to achieve a certificate that will put mariners in compliance with the requirements of the new Polar Code (see below).

<table>
<thead>
<tr>
<th>Ice conditions</th>
<th>Tankers</th>
<th>Passenger ships</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Free</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Open waters</td>
<td>Basic training for master, chief mate and officers in charge of a navigational watch</td>
<td>Basic training for master, chief mate and officers in charge of a navigational watch</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Ice Free</td>
<td>Tankers</td>
<td>Passenger ships</td>
<td>Other</td>
</tr>
<tr>
<td>Ice Free</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Other waters</td>
<td>Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch</td>
<td>Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch</td>
<td>Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch</td>
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</tbody>
</table>

*Figure 54. Polar Code requirements as of January 1, 2017.*

**Methodology:** The basic and advanced course use similar methods. Courseware design conducted by an expert polar mariner, with significant understanding of the IMO Polar Code, serving as an instructor at an accredited and acclaimed mariner academy. Courseware development collaboration conducted via technical exchange meetings and teleconferences with industry and other mariner training.
institutions. The advanced course adding bridge simulator scenarios, suited to train mariner masters and first mates in IMO polar code in difficult ice navigation situations. Completed courseware provides 40-hour classroom-based course and a blended course in which students take part of the class online and then travel to a certified USCG exam center to complete the simulation section and take the final exam.

**Project Results**

**Key Accomplishments in Program Year 3.** MMA designed and developed an advanced Ice Navigation academic course and associated bridge simulator training to educate mariner masters and first mates in ice navigation and associated IMO Polar Code mariner standards. In spring semester 2017, 22 students at Maine Maritime Academy enrolled and completed the basic ice navigation course for academic credit. All students passed the class and received certification for the basic ice navigation class from USCG, making these students the first in the country to hold a basic IMO Polar Code ice navigation certificate.

**Key Stakeholder Engagement in Program Year 3:** Development and submission of advanced ice navigation course has involved cooperation with USCG. ADAC and MMA remain engaged with USCG for potential training courseware for future USCG icebreaker watchkeepers, and vessel captains. ADAC and MMA have initiated private sector engagement to transition both the basic and advanced ice navigation courseware and associated software.

**Key publications (peer reviewed)** N/A

**Key presentations:** Captain Ralph Pundt delivered a presentation on Arctic exploration in Portland, Maine and a presentation on history and new directions in the Arctic in Bath, Maine. Susan Hazlett delivered a presentation on ice navigation at a symposium held in conjunction with the Arctic Council meeting in Portland, ME.

**Changes from initially approved Workplan.** N/A

**Project Progress against each milestone:**
**MILESTONE**

Completion, submission and acceptance of advanced ice navigation course and associated software for bridge simulator by USCG (Spring, 2017).

**PROGRESS**

The advanced ice navigation course and associated courseware completed on 30 June 2017. Currently courseware is undergoing MMA final academic review (in accordance with accreditation standards). Following, MMA will transmit courseware is transmitted USCG for certification.

**WHY NOT REACHED?**

ADAC and MMA did not receive approval for funding for this project until January 2017, which did not allow enough time for completion of courseware software and HQ USCG Office of Navigation for SCTW certification. The USCG process normally takes around three months to complete. ADAC and MMA expect to receive USCG certification in Fall, 2017.

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**Project Progress against each metric:**

<table>
<thead>
<tr>
<th>Metric</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
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</thead>
<tbody>
<tr>
<td>Completion of advanced Ice Navigation Courseware and associated bridge simulator software.</td>
<td>The advanced ice navigation courseware and associated bridge simulator software is completed. Currently courseware is undergoing MMA final academic review (in accordance with accreditation standards). Following, MMA will transmit courseware is transmitted USCG for certification.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>

**Outcomes/output and TRLs:**

**Project is TRL 8/9** (ready for transition).

**Unanticipated problems and plans for addressing them:** N/A

**Transition Plans**

**Transition Plans and Progress Made:** Following MMA final internal academic reviews, Project investigators will submit courseware to HQ USCG Office of Navigation for certification. ADAC is currently awaiting feedback from USCG on interest to proceed with incorporating basic and advanced navigation courseware (and associated bridge scenario software) to support training requirements of USCG icebreaker operators. ADAC and MMA are currently in work to establish promulgation of
courseware in the private sector, specifically across west and east coast state sponsored mariner academies, and U.S. mariner pilots and masters unions.

**PROJECT: Minority Serving Institution (MSI) and Significant Minority Enrollment (SME)**

**Project PI:** ADAC interim Education and Administration Manager, Ms. Malla Kukkonen

**Lead Institution:** University of Alaska Anchorage

**Supporting Team:** N/A

**Collaborators:**

**MSI Institutions:**
- University of New Mexico (Hispanic)
- University of Texas El Paso (Hispanic)

**SME Institutions:**
- Texas A&M (Hispanic)
- University of Alaska Anchorage (Native American Indian)
- University of Alaska Fairbanks (Native American Indian)
- University of New Mexico (Native American Indian)

**Industry Partners:**
- ASRC Federal (Tribally owned)
- NOVA Corporation (Tribally owned)

**Program Year 3 Project Champions:** N/A. However, project is subject to joint approval of DHS S&T OUP ADAC Program Manager, Mr. Theo Gemelas and DHS S&T OUP Education POC, Ms. Stephanie Willet.

**New Project Champions Established by DHS S&T OUP and HQ USCG at end of Program Year 3:** N/A

**Student Involvement.** Program is 100% focused on students from under-represented classifications. A maximum of five students from under-represented classifications attending a 10-week interdisciplinary internship.

**Project Description:**

**Abstract:** The focus of this project is to establish a Summer Internship geared at recruiting for under-represented classifications. The specifications in expectations for the project are included in the DHS - ADAC Terms and Conditions for Workforce Development Plan. ADAC seeks to recruit student summer interns from under-represented classifications through collaborative partnerships with designated MSI and SME institutions. Further, ADAC seeks to leverage partnerships with established industry partners in order to place classifications of under-represented students on meaningful work to advance ADAC research. ADAC will develop and recruit these categories of students to place into 10-week summer internships.
Additionally, in order to provide more opportunity, ADAC Center leadership will seek to connect these students, once recruited, into the ADAC Fellow Program to advance mentoring and professional development as previously described, to include gaining these students into DHS Career Development Grant Scholarships (as described under CDG Scholarship project).

**Baseline:** ADAC MSI program provides undergraduate student summer internship opportunity to travel to either the University of Alaska System or an ADAC Industry collaborators for a ten-week long summer internship. These internships will focus on providing students workforce development opportunities in operational capacities to benefit the Department of Homeland Security and its components. ADAC seeks to recruit five student summer interns from under-represented classifications.

**Relevance to DHS:** Professionally developing students from under-represented classifications conforms to DHS diversity goals.

**Purpose of the Research:** Recruiting students from under-represented classifications into ADAC Fellows program and in particular, place into meaningful summer research internships.

**Methodology:** Students from under-represented classifications and the overall ADAC Fellows program are a planned particular focus for ADAC leadership. Accordingly, students from under-represented classifications who focus in science, technology, engineering and mathematics (STEM) fields are most likely the candidates who have interest in connecting with many of the projects the Center is pursuing. ADAC seeks to recruit and connect with students from under-represented classifications. Consequently, recruitment efforts at Minority Serving Institutions such as University of Texas El Paso and University of New Mexico provide ADAC an opportunity to gain these students into important science research and development projects at the Center. University of Alaska’s Alaska Native Science and Engineering (ANSEP) program provides another venue to recruit students who may have particular interest in advancing work ADAC is conducting for the Arctic operator. ADAC Students from under-represented classifications will comply with DHS Approved Safety Plan as coordinated with the University of Alaska Anchorage procedures. DHS approved safety procedures apply to all ADAC sponsored academic, government and industry institutions and be applied in both field and laboratory conditions.

Coach and mentoring of students from under-represented classifications and other ADAC Fellows as described in Education and Workforce Development will be purposely conducted to orient these students to careers in government service across the DHS enterprise as well as science and technology industry.

**Project Results**

**Key accomplishments in Program Year 3:** ADAC’s 2017 MSI summer internship successfully accomplished an interdisciplinary curriculum, hosted at UAA with one under-represented classified student from a Historically Black College/University. ADAC’s MSI Summer intern accomplished ADAC program overview, researched and drafted an assessment report about the development of an Arctic deep-water port on the west coast of Alaska. With one-on-one assistance and orientation support from ADAC MSI Project Lead, Ms. Dixon was able to dive into the details of the existing literature on the subject. ADAC CDG graduate fellow Leif Hammes also continuously worked with Ms. Dixon on the draft report, for example by sharing his knowledge of port design and development. In addition to working on
the research assignment, ADAC staff and volunteer UAA students introduced Ms. Dixon to the larger Anchorage area for example by taking her to visit local landscape and historical as well as cultural sites.

**Key Stakeholder Engagement Plan:** Recruitment across ADAC collaborative institutions (academic and industry with access to students from under-represented classifications to gain a maximum of five students to participate in a 10-week summer internship program.

**Key publications (peer reviewed or in review):** N/A

**Key publications/developments/presentations:** MSI authored report: “An assessment for the development of an Arctic deep-water port on the west coast of Alaska” (in draft)

**Changes from initially approved Workplan.** ADAC planned MSI for five students, but gained only one student for the summer internship. During fall and winter, ADAC’s Education and Workforce Development Director Clarice Conley worked ADAC’s partner MSI institutions setting the groundwork for the program recruitment. The unanticipated March 2017 change in ADAC’s Education and Workforce Development staff caused additional delay in the student recruitment for the program and by the end of May 2017; ADAC had received four applications for the program. Out of these four applications, one was not qualified for the program and two had found alternative summer internships when ADAC’s Administrative and Communications Officer Kukkonen (acting as Center Education manager until formalized on 1 July 2017) reached out to them in mid-May. Following assessment, ADAC accepted the remaining MSI applicant, Ms. Karien Dixon, from Tougaloo College in Mississippi.

**Project Progress against each milestone:**

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADAC will recruit, assign mentors and student research work and outline expectations and opportunities for students from under-represented classifications.</td>
<td>Completed as planned for one MSI student.</td>
<td>N/A</td>
</tr>
<tr>
<td>Recruited students will be provided opportunity bi-monthly ADAC Fellows coaching and mentoring sessions via webinar, co-hosted by ADAC Executive Director and Education Outreach and Workforce Development Director.</td>
<td>Partially completed. Project PI and ADAC ED conducted advance mentoring of student in advance of arrival. However, student was recruited later in the program year than planned (following the completion of the academic year), after the close of the Year 3 ADAC Student Fellow bi-monthly mentoring sessions.</td>
<td>Due to late recruitment, only a limited amount of prior mentoring accomplished at start of internship</td>
</tr>
<tr>
<td>Recruited students will be provided opportunity to participate as available in bi-monthly ADAC Customers and Partners meetings as a way to</td>
<td>Not completed</td>
<td>Due to late recruitment, student was unable to join Customer’s and Partner’s meetings.</td>
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</tbody>
</table>
gain further insights to professional networks.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Progress</th>
<th>Why Not Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students from under-represented classifications will be expected to participate in a ten-week summer internship with in academic or industry hosted research.</td>
<td>Accomplished. MSI student accomplished 10-week summer internship with ADAC in residence at University of Alaska Anchorage, and home institution (Tougaloo College, Mississippi).</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Project Progress against each metric:**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Progress</th>
<th>Why Not Reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruitment at Fall Outreach to Students from under-represented classifications at ADAC Student Research Symposium.</td>
<td>Not accomplished. ADAC Student Research Symposium accomplished in Spring 2017.</td>
<td>DHS S&amp;T OUP did not approve ADAC’s education program until mid-way through Fall Semester 2016. MSI recruitment initiated in Spring semester.</td>
</tr>
<tr>
<td>Assessed Performance of students from under-represented classifications students in summer research programs.</td>
<td>Accomplished in recruiting ADAC’s MSI student for Center summer internship program.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Students from under-represented categories who subsequently compete and earn CDG Scholarships.</td>
<td>Not accomplished and not applicable.</td>
<td>ADAC notified DHS S&amp;T OUP Supplemental funding opportunities for CDG discontinued. However, ADAC is working with MSI student to connect with other DHS student program opportunities.</td>
</tr>
<tr>
<td>Successful entry of students in this category into DHS enterprise careers and/or meaningful science and technology industry careers</td>
<td>In progress.</td>
<td>Student is still in undergraduate status. ADAC will continue to monitor student progress.</td>
</tr>
</tbody>
</table>

**Unanticipated problems and plans for addressing them:** ADAC was unable to recruit five qualified MSI summer interns for the inaugural project. Earlier recruiting in Program Year 4, plus adding a field portion at Utqiaġvik (formally Barrow), Alaska is anticipated to improve recruiting efforts.

**Outcomes/output & Transition Plans:** Coached, mentored and professionally developed students from under-represented classifications enter DHS enterprise workforce. Transition plans will continue past lifecycle of grant for tracking and job initiatives.
PROJECT: DHS Career Development Grant (CDG) program

Project PI: ADAC interim Education and Administration Manager, Ms. Malla Kukkonen

Lead Institution: University of Alaska Anchorage administers resources and project; open student competition provided they meet DHS criteria.

Supporting Team: ADAC Industry Partners

Proposed Collaborator: DHS Marine Security Center of Excellence, Stevens Institute of Technology

Program Year 3 Project Champions: N/A.

New Project Champions Established by DHS S&T OUP and HQ USCG at end of Program Year 3: N/A

Student Involvement. Program is 100% focused on students.

Project Description:

Abstract: An important goal of the Center is to foster the next generation of scientists and engineers devoted to the discovery, development and improvement of technologies and applications for Arctic Maritime Domain Awareness, Response, and Resilience. The Center proposed to award four scholarships annually for full time support for both undergraduate and graduate students who will contribute to an essential role for the center’s mission.

The Center intends to mentor and develop CDG students to be capable of competing for future opportunities in DHS and/or DHS enterprise careers. Center leadership will put a particular focus in connecting CDG students in applied areas of science and technology. Center leadership will also seek to provide CDG students opportunities to connect with research sponsored by DHS and/or USCG.

Baseline: ADAC seeks to attract the highest caliber undergraduate and graduate students that are contributing towards ADAC sponsored science and engineering programs. ADAC seeks CDG scholars to be the vanguard of the ADAC Fellows program, which will also include ADAC student researchers/interns in addition to CDG Scholars. Consequently, Center leadership will seek to award CDG scholarships to qualified students who are seeking degrees from across academic disciplines related to: Advanced Data Analysis and Visualization, Communications and Interoperability, Community, Commerce, and Infrastructure Resilience, Emergency Preparedness and Response, Maritime and Port Security, Natural Disasters and Related Geophysical Studies, and Decision Sciences.

As described in Education Outreach and Workforce Development, ADAC will mentor CDG Scholars as part of the overall ADAC Fellows program over the course of the planned program year for student enrichment. In particular, events such as the planned Annual ADAC Student Research Symposium, summer interns and research needed in association with Incidents of National Significance Workshops, provide useful opportunities to incentivize CDG productiveness.
**Purpose of the research.** DHS Career Development Grant scholars program is planned to provide fiscal resources, substantial mentoring and professional development for openly recruited, qualified students in science, technology, engineering and mathematics disciplines in order to gain useful preparation for careers of substance across the DHS enterprise.

**Relevance to DHS:** As previously presented, CDG scholarships provide resources for education and mentorship (via the ADAC Fellows Program) for undergraduate and graduate students which enables to their successful and timely completion of academic degree useful in DHS S&T areas of concentration. Student research conducted by CDG scholars can meaningfully advance projects within the ADAC portfolio to the benefit of DHS, USCG and other DHS maritime missions.

**Methodology:** CDG Scholars and the overall ADAC Fellows program are a planned particular focus for ADAC leadership. Accordingly, students who focus in science, technology, engineering and mathematics (STEM) fields are most likely the candidates who have interest in connecting with many of the projects the Center is pursuing. ADAC plans CDG Scholars involvement in as many projects as practically possible as well as other center tasks such as Arctic related Incidents of National Significance workshops and White Paper development calls/cycles. ADAC Education and Administration Manager, assesses CDG Scholars research interests and strengths to match with a suitable research professor and center research.

Accordingly, the ADAC Fellows program seeks to invest CDG Scholars as well as ADAC research interns to advance and present their ADAC related/supported research at the planned ADAC Student Research Symposium, Annual ADAC Partners meeting, and research needed in association with Incidents of National Significance Workshops. CDG Scholars participate in summer research in support of ADAC projects.

ADAC CDG Scholars will comply with DHS Approved Safety as coordinated with the University of Alaska Anchorage procedures. DHS approved safety procedures apply to all ADAC sponsored academic, government and industry institutions and be applied in both field and laboratory conditions.

Coach and mentoring of ADAC CDG Scholars and other ADAC Fellows as described in Education and Workforce Development will be intentionally conducted to orient these students to careers in government service across the DHS enterprise as well as science and technology industry.

Part of the professional coach and mentoring will include leadership and management as complimentary aspects apart from STEM courses of study. ADAC conducts an Annual performance review of CDG Scholars and mentors and mentoring program at the conclusion of the program year. ADAC will appropriately host an awards event at the close of the academic year. ADAC tracks CDG Scholars until successfully connected to placement into a DHS careers following graduation.

**Project Results**

**Key Accomplishments in Program Year 3:** Five CDG scholars started Program Year 3 in student internships, which included one CDG scholar participating at Maritime Security Center Summer Internship at Stevens Institute. Students participated in project research or in directed study programs in both fall semester 2016 and spring semester 2017.
ADAC’s inaugural annual meeting took place at the Hilton Alexandria Old Town Hotel on November 9-10, 2016. ADAC undergraduate fellows Kyle Alvarado and James Matthews (both from UAA) travelled with the Center leadership and project Principal Investigators of ADAC led projects to Alexandria, VA and attended as well as presented at the meeting. ADAC’s Education and Workforce Development Director Clarice Conley guided the fellows through the collaborative presentation on the second day of the meeting. Annual meeting participants complemented ADAC Fellows’ presentation. Both fellows later described the experience of attending and presenting at the meeting “as very important for their professional development.”

ADAC Program Year 3 CDG Fellow participation included:

- Bi-monthly mentoring meetings that were attended by fellows either in-person or remotely via telephone/Skype for Business. Starting in April 2017, the mentoring meetings were held monthly.
- Participation in ADAC’s quarterly Customer and Partners teleconference meetings.
- ADAC’s annual student research symposium hosted at UAA on April 25, 2017.
- ADAC fellows research poster session at UAF on May 10, 2017 as part of the Week of the Arctic activities in Fairbanks, Alaska.
- Participating in the Arctic 2030 workshop hosted by ADAC and U.S. Coast Guard Headquarters Office of Emerging Policy at UAF on May 11-12, 2017.
- Continued support for fellows on their monthly reports and ADAC research project related activities during Year 3.
- Assisting fellows on their summer internship search and placement for an internship.

CDG Fellow attendance in the monthly meetings was good throughout Year 3 and greatly assisted in developing essential connections between the previously enrolled CDG fellows and new Workforce Development fellows joining the program from different disciplines and institutions. Attending quarterly Customer and Partners teleconference meetings offered fellows insights into the tangible questions that the U.S. Coast Guard personnel and research project Principal Investigators were dealing with as they carried on their research for Year 3.

ADAC’s first annual student research symposium on April 25, 2017 at UAA served as an excellent opportunity for the fellows to practice conference poster design and submission. Students benefitted in receiving and responding to questions from both peer and attending UAA professors.

Following the research symposium, ADAC Fellows continued to work with ADAC’s Administrative and Communications Officer (serving as the interim Education and Administration Manager) Malla Kukkonen...
on improving their posters and verbal presentations for the ADAC fellows’ research poster session held at the University of Alaska Fairbanks on May 10, 2017. Each fellow presented their completed, large poster at the ADAC Fellows research poster session during an evening event that was part of the official agenda of the Arctic Interchange. An estimated 50-60 people attended the evening event while the overall Week of the Arctic participation in the different events reached approximately 1,000 people from different parts of the world.

An important culmination point of Year 3 Education and Workforce development activities was the Arctic 2030+ workshop on May 11-12 that followed the ADAC Fellows research poster session at UAF. ADAC hosted the workshop, with sponsorship from Headquarters U.S. Coast Guard’s DCO-X Future Concepts Division. Facilitators included the U.S. Coast Guard Academy’s Center for Arctic Study and Policy, and the RAND Corporation’s Homeland Security Operations Analysis Center. This invitation only workshop brought together approximately 85 Arctic researchers, operators, and industry leaders from various organizations participated in the Arctic 2030+ workshop. The purpose of the event was to examine possible future Arctic conditions, identify needed capabilities, and uncover gaps and shortfalls in the realms of science, technology, and policy for the Department of Homeland Security (DHS) and a variety of Arctic maritime operators, in particular the United States Coast Guard (USCG).

ADAC undergraduate CDG fellows James Matthews, Kyle Alvarado and Christina Hoy supported workshop organizers by compiling a comprehensive literature review of existing research available on the long-term needs of future Arctic operations prior to the workshop. During the workshop, ADAC fellows supported workshop organizers with organizational tasks and participated in breakout group discussions as note takers and active observers. After the workshop, each fellow submitted a summary of his/her workshop notes to ADAC leadership. These notes supported the final report for the Arctic 2030+ workshop. After the workshop, ADAC CDG Fellows Leif Hammes assisted Center leadership with the drafting of the workshop report. For ADAC fellows, the workshop offered a unique opportunity to participate in discussions about future operator needs in the Arctic. The fellows also had the opportunity to be part of development of applicable new research questions that the Arctic operator would like to have addressed in the near to long-term.

ADAC CDG Scholars joined final monthly meeting held in ADAC’s new office suite in May 2017, which served as end of year recognition for the students.

**Key Stakeholder Engagement:** CDG Scholars as well as ADAC Fellows participated in the planned ADAC “Customers and Partners” Roundtable, Annual meeting, Center Quarterly Reviews, and the Arctic 2030 workshop at the University of Alaska Fairbanks.

**Changes from initially approved Workplan.** DHS S&T OUP decision to offer additional CDG supplemental awards changed ADAC plans to award additional CDG scholarships. Once the current CDG supplemental award is exhausted, student funding will proceed via Education and Workforce Development management and funded via the main ADAC award from DHS S&T OUP.
Project Progress against each milestone:

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADAC will recruit, assign mentors and student research work and outline expectations and opportunities for CDG Scholars.</td>
<td>Completed. ADAC added a new CDG Fellow in Program Year 3, and was provided requirements and student workplan.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Scholars will conduct tailored research work during the academic year with schedules as mutually determined by CDG Scholar and Project PI, with appropriate Center leadership overview (normally conducted by the Education Outreach and Workforce Development Director).</td>
<td>Completed. Each ADAC Fellow was provided workplan and conducted student research tailored to the individual student. Student CDG Fellows were either assigned to an established ADAC funded project or were assigned individual research aligned to Arctic maritime science research.</td>
<td>N/A.</td>
</tr>
<tr>
<td>As previously approved by DHS S&amp;T OUP, CDG Scholars will be expected to participate in a ten-week summer internship with in academic or industry hosted research.</td>
<td>Completed. All CDG Fellows participated in a ten week summer internship. 2 CDG Fellows participated in MSC’s Summer Intern program, at Stevens’ Institute at Hoboken New Jersey, while the remaining participated in Alaska based internships</td>
<td>N/A.</td>
</tr>
<tr>
<td>CDG Scholars will join planned bi-monthly ADAC Customers and Partners Roundtable in order to gain insights to operator driven research requirements.</td>
<td>Completed. Late in Program Year 3, meetings switched to monthly to accommodate student schedules.</td>
<td>N/A.</td>
</tr>
<tr>
<td>CDG Scholars will be provided bi-monthly coaching and mentoring sessions via webinar, co-hosted by ADAC Executive Director and Education Outreach and Workforce Development Director.</td>
<td>Completed. Late in Program Year 3, meetings switched to monthly to accommodate student schedules.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Anchorage-based based CDG Scholars will be expected to present at the annual fall ADAC Student Research Symposium</td>
<td>2 Student symposiums conducted in Spring Semester 2017.</td>
<td>Adjusted to coincide with approved ADAC education program.</td>
</tr>
</tbody>
</table>
(hosted at University of Alaska Anchorage). ADAC will seek to enable non-Anchorage-based CDG Scholars to present at the symposium and enable their participation via 2-way video conferencing such as Skype.

<table>
<thead>
<tr>
<th>METRICS</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding of CDG Scholar fill rates vs unfilled with quality qualified students awarded the scholarship.</td>
<td>Completed. ADAC has qualified CDG student fellows</td>
<td>N/A</td>
</tr>
<tr>
<td>Review of CDG Scholars assigned vs available for assignment to Project PIs for student research during the academic year.</td>
<td>Completed. All CDG Fellows were provided workplans and project PIs.</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of CDG Scholars assigned vs available for student summer research.</td>
<td>Completed. All CDG Fellows participated in 10-week summer internship.</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of CDG Scholars assigned vs available for ADAC Student Research Symposium.</td>
<td>Completed. All CDG Fellows participated in both the April UAA and May UAF Symposiums.</td>
<td>N/A</td>
</tr>
<tr>
<td>Compilation of assessments for CDG Scholar performance via annual review.</td>
<td>Completed (by ADAC Education and Administration Manager)</td>
<td>N/A</td>
</tr>
<tr>
<td>Aggregation of CDG Scholars graduates accredited to DHS enterprise careers vs graduates</td>
<td>In progress. ADAC CDG Fellows have yet to graduate from their program of study.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

CDG Scholars will conclude the academic year with performance review conducted by assigned mentor, with review conducted by ADAC Education Outreach and Workforce Development Director and join year-end ADAC awards event via Videoconference/webinar.

Completed. ADAC’s Education and Administration Manager conducted the performance review, and Center leadership conducted the end of Academic Year ADAC Fellows Forum at ADAC UAA Facilities on 25 May 2017. This meeting was also carried via Skype.

Project Progress against each metric:
Unanticipated problems and plans for addressing them: None.

Outcomes/output & Transition Plans: In program Year 3, CDG Fellows continued their course of study and executed their assigned workplans. The first ADAC CDG graduates will graduate in December 2017 and seek admission into the DHS enterprise workforce.

PROJECT: Arctic-related Incidents of National Significance (IoNS) and Arctic Medium and Long Term Environment (MaLTE) Workshops

Project PI: ADAC Executive Director Randy Kee

Lead Institution: University of Alaska Anchorage

Supporting Team: Arranged based on USCG designated research topic.

Project Champions: Arctic IoNS: HQ USCG-5PW (Primary). HQ USCG-CPE and USCG District 17 (Secondary) Arctic MaLTE: HQ USCG DCO-X

New Project Champions Established by DHS S&T OUP and HQ USCG at end of Program Year 3: Arctic IoNS: N/A. Arctic MaLTE: HQ USCG DCO-X.

Partnered team: USCG District 17 Staff officers for Arctic IoNS and HQ USCG DCO-X staff officers for Arctic MaLTE workshop. Note:

Student Involvement. ADAC Fellows provide preparation and administrative support.

Project Description:

Abstract: ADAC planned to conduct an Arctic IoNS workshop in close coordination with USCG District 17. Based on identified operator concerns, Arctic IoNS assembles expert academic and industry research professionals to work with select Canada and U.S. Coast Guard Arctic operators, along with U.S. and Canada government security officials in a structured workshop to understand gaps and shortfalls in science and technology and to provide corresponding research questions to address. An outcome of the workshop will be a Rapporteurs report informing research questions for a solicitation.

ADAC plans and conducted an Arctic focused Medium and Long Term Environment (MaLTE) workshops to understand and address the medium and long-term research needs specific to the Arctic environment. ADAC planned and Arctic MaLTE in close coordination with HQ USCG Future Concepts Division (HQ USCG DCO-X, “Evergreen”). Arctic MaLTE is a structured workshop involving select academics, industry researchers, and government officials, who explore longer, range challenges.
comprehensively, from policy, governance, and science & technology. Arctic MaLTE employees Delphi research techniques to support workshop participation and associated topic investigation.

**Baseline:** During a national incident, the public (including academia) offers technology solutions to the incident commanders to assist in the response. ADAC believes such an approach, while ultimately may assist in a successful outcome, often generates ad hoc solutions that prove to be sub optimal to capabilities developed by well-planned and researched processes.

The planned Arctic IoNS workshop identify research and development gaps and research questions aimed at closing the gaps with relevant research to support the USCG mission before an actual Arctic IoNS occurs. Arctic IoNS 2016 (conducted at UAA in June 2016) addressed a disabled cruise ship in Arctic waters.

In order to complement near term operator-driven research, the Arctic MaLTE workshops look towards the 10-20-year time horizon to investigate potential mission needs based on projected technology gaps driven by the anticipated Arctic operational environment. This future look coincides well with HQ USCG DCO-X, Future Concepts Division, chartered to investigate future strategic and long-term operational challenges facing the USCG. In Program Year 3, ADAC established a collaborative partnership with HQ USCG DCO-X, and provided planning and support to the development of an Arctic futures workshop. Accordingly in Program Year 3, ADAC planned and conducted “Arctic 2030+...Understanding the Needs of the North, a futures workshop held at the University of Alaska Fairbanks 11-12 May 2017. This workshop assembled a select group of participants to create initial understanding of the potential Arctic future operating environment. Sponsored by HQ USCG DCO-X, ADAC collaborated with Rand Corporation, and USCG Academy’s Center of Arctic Study and Policy (CASP), in jointly creating the Arctic 2030 workshop.

**Relevance to DHS:** Arctic-related IoNS and Arctic-focused MaLTE workshops provides USCG and other DHS maritime missions unique forums using similar methodologies. The end-result for both IoNS and MaLTE is ultimately gaining needed capability to address gaps and shortfalls in relevant science and technology to support the Arctic operator.

**Purpose of the research:** Both Arctic IoNS and Arctic MaLTE workshops seek to identify relevant research questions to support USCG mission needs based on given scenarios. ADAC plans Arctic IoNS workshops with dedicated research funding following the workshop, while noting Arctic MaLTE workshops do not have dedicated funding. Each workshop format creates opportunities to identify knowledge gaps to benefit USCG mission needs in the Arctic.

**Methodology:** These two Arctic-focused workshops exercise a similar development methodology. Each workshop seeks to identify research gaps and define research questions.

Arctic IoNS method is expert research, operator and government official structured seminar oriented to provide follow-on research to address discovered shortfalls. Arctic IoNS development begins with the Arctic operators providing specified areas of concern to investigate. ADAC conducts a comprehensive literature review through Center Fellows to establish a baseline of published experts. ADAC solicits and assembles an appropriate panel of select researchers from the baseline to present to invited operators and government officials in Canada and the U.S. their research findings a comprehensive plenary
session. After the plenary, ADAC divides participants across facilitated breakout workshops to discover real.

Through this structured plenary and breakout workshop, participants gain understanding of knowledge gaps and shortfalls in science and technology. Equipped with this understanding, participants will develop research questions to address shortfalls. ADAC will create a Rapporteur’s report, with prioritized research questions and prepare an open RFP to address research approaches. Workplan Annex B describes the planned ADAC open call process. The output of each workshop will be workshop proceedings, relevant research questions, and request for proposals (RFPs) solicitation addressing specific research relevant to USCG mission needs leading to solutions related to gaps and shortfalls.

Arctic MaLTE workshops seek to investigate future scenarios, based on literature review and developing scenarios based understandings by futurist researchers in terms of economic, security and physical environment of the future Arctic.

Guided by the Literature Review, expert opinion of selected and polled researchers, and the strategy documents, an invited team of researchers, operators and government officials assemble to analyze the preparatory materials to investigate alternative scenarios to determine needed policy, governance, and science & technology to realize DHS and USCG strategic goals and objectives. ADAC will then publish the findings of the research in a comprehensive report and advantage relevant research questions for calls for research within the Arctic community of research.

Project Results

Key Accomplishments in Program Year 3:

**Arctic IoNS**  In Program Year 3, ADAC prepared the June 2016 Arctic IoNS Rapporteur’s Report, corresponding research solicitation, and conducted a wide-ranging solicitation. Following close of the solicitation, the Center provided DHS S&T OUP a proposal evaluation plan and collaborated with two selected proposals to create workplans for the following research year. In Program Year 3, ADAC also conducted planning and coordination with USCG D17 to coordinate an Arctic oil-spill workshop to be executed early in Program Year 4. In Program Year 3, ADAC conducted initial planning discussions with University of New Hampshire’s Center for Coastal Resilience Research Center, the NOAA Senior Arctic Advisor, HQ USCG interagency oil spill coordinators, USCG R&D Center, plus an array of academic and industry oil spill researchers to provide background and scope for the planned October 2017 Arctic IoNS workshop. The Theme for the Oil Spill Workshop is “Coping with the Unthinkable...an Arctic Maritime Oil Spill.”

**Arctic MaLTE**  HQ USCG DCO-X contracted with ADAC via a DHS Basic Ordering Agreement to plan and host the Arctic 2030+ workshop on 11-12 May 2017 at the University of Alaska Fairbanks. The Arctic 2030+ Workshop as part of the Arctic Interchange events at the University of Alaska Fairbanks. USCG Headquarters Office of Emerging Policy (HQ USCG DCO-X) sponsored the workshop. ADAC, RAND Corporation’s Homeland Security Operational Analysis Center (HSoAC) and USCG’s Center for Arctic Study & Policy (CASP) facilitated the workshop. ADAC provided planning support by compiling an advance Literature Review, conducting a plenary session presentation, and assisting with logistics coordination, workshop facilitation, breakout group recording. After the workshop, ADAC also produced
Key Stakeholder Engagement: Through a series of prior research and coordinating meetings, ADAC networked with a number of Canada and U.S. operators, researchers and government officials to support the development and execution of the Arctic 2030+ workshop.

Key publications (peer reviewed or in-review). N/A.

Key publications/developments/presentations: For Arctic MalTE, ADAC developed the Arctic 2030+ Literature Review, conducting a plenary session presentation and produced a comprehensive workshop Rapporteur’s report to HQ USCG DCO-X including a series of research questions for HQ USCG consideration.

Changes from initially approved Workplan. ADAC conducted planning for an Arctic IoNS workshop in Program Year 3, but shifted execution for the workshop to Program Year 4 as requested by USCG D17 planners to not conduct a workshop in the spring and summer personnel transition season at the District. Accordingly, the next planned Arctic IoNS workshop is set for October 2017.

Project progress against each milestone: (Arctic IoNS)

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work closely with DHS, USCG and Canadian counterparts on the workshop scenario.</td>
<td>In-progress. USCG D17 Commander approved oil spill focused Arctic IoNS workshop addressing a leak from oil tanker in Chukchi or Beaufort Sea</td>
<td>Workshop execution planned for October 2017 (in Program Year 4)</td>
</tr>
<tr>
<td>Conduct research to identify the universe of SMEs (international, domestic, in/out government, etc.); conduct research to determine what research is underway to address the likely challenges posed by the scenario and those challenges most relevant to USCG.</td>
<td>In-progress. ADAC established planning team with USCG D17 emergency management, NOAA, University of New Hampshire’s Coastal Resilience Research Center (CRRC) and HQ USCG leadership of Interagency Coordinating Committee on Oil Pollution Research (ICCOPR).</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Organize workshop (securing facility, inviting participants, developing agenda etc.) • Completed workshop participants’ selection; • Completed workshop participants’ invitations;</td>
<td>In-progress. Workshop planned 23-25 October 2017 at University of Alaska Anchorage, co-facilitated by ADAC Executive Director and University of New Hampshire CRRC director, Dr. Nancy Kinner.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Task</td>
<td>Progress</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Completed logistics arrangements;</td>
<td>In-progress.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Completed workshop announcement;</td>
<td>In-progress.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Completed workshop program.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Make a determination to identify appropriate SME speakers to discuss relevant research activities across disciplines that likely address USCG challenges relevant to the scenario.</td>
<td>In-progress. Workshop planned 23-25 October 2017 at University of Alaska Anchorage, co-facilitated by ADAC Executive Director and University of New Hampshire CRRC director, Dr. Nancy Kinne. Planning an array of oil spill responders as well as a logistics shortfall aspect (per request of USCG) from U.S. Federal, State of Alaska, International academics and U.S. industry.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Complete panel selection and invitations.</td>
<td>In-progress. In-progress. ADAC established an initial planning team with USCG D17 emergency management, USCG R&amp;D Center, NOAA, University of New Hampshire’s Coastal Resilience Research Center (CRRC) and HQ USCG leadership of Interagency Coordinating Committee on Oil Pollution Research (ICCOPR).</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017.</td>
</tr>
<tr>
<td>Execute workshop – Research Questions developed and provided to USCG.</td>
<td>In-progress, workshop planning underway at the end of Program Year 3.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017. ADAC anticipates workshop will execute as planned.</td>
</tr>
<tr>
<td>Complete report/proceedings and slides deck representing the workshop discussions and submitted to USCG for review.</td>
<td>In-progress, workshop planning underway at the end of Program Year 3.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017. ADAC anticipates workshop will execute as planned.</td>
</tr>
<tr>
<td>Publish rapporteurs report/proceedings, including list of participants, and slides deck will be publically posted (website) with the ADAC RFP.</td>
<td>In-progress, workshop planning underway at the end of Program Year 3.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017. ADAC anticipates workshop will execute as planned.</td>
</tr>
</tbody>
</table>
### Project progress against each milestone: (Arctic MaLTE)

<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROGRESS</th>
<th>WHY NOT REACHED?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepare RFP.</td>
<td>In-progress, workshop planning underway at the end of Program Year 3.</td>
<td>Planning conducted in Year 3 to support a workshop in October 2017. ADAC anticipates workshop will execute as planned.</td>
</tr>
<tr>
<td>Work closely with DHS, USCG and Canadian counterparts on the workshop scenario.</td>
<td>Completed as planned. USCG DCO-X approved Arctic 2030+ workshop scenario, which included Canadian and other international participants.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Conduct research to identify the universe of SMEs (international, domestic, in/out government, etc.); conduct research to determine what research is underway to address the likely challenges posed by the scenario and those challenges most relevant to USCG.</td>
<td>Completed as planned. ADAC constructed comprehensive Literature Review for Arctic 2030+ Workshop and collaborated with U.S. Coast Guard Academy’s Center for Arctic Study &amp; Policy and RAND Corporation’s Homeland Security Operational Analysis Center for scenario development and workshop facilitation.</td>
<td>N/A.</td>
</tr>
<tr>
<td>Organize workshop (securing facility, inviting participants, developing agenda etc.)</td>
<td>Completed as planned. ADAC utilized University of Alaska Fairbank’s “Arctic Interchange” to construct a workshop that coincided with a large international gathering already planned for the transition of Chairmanship of the Arctic Council to from the United States to the Government of Finland. A total of 95 people from U.S. Government, U.S and other national universities, International government, State of Alaska, Native Alaskans and industry registered and participated in the workshop on 11-12 May 2017.</td>
<td>N/A.</td>
</tr>
</tbody>
</table>
Outcomes/output:

Arctic IoNS: In Program Year 3, ADAC initiated planning with USCG D17 to determine the overall research topic and timing of the next Arctic IoNS workshop. Through a series of teleconferences in Program Year 3 with D17 Arctic planner, ADAC received guidance the District wished to have Arctic IoNS focus on a vessel-borne oil spill disaster scenario, in Chukchi or Beaufort Sea, occurring in late fall just as sea ice was advancing. As a courtesy to D-17 summer personnel transition, D-17 Arctic planner requested an October 2017 workshop date. ADAC initiated initial planning with USCG D17, NOAA, University of New Hampshire’s Coastal Resilience Research Center (CRRC) to outline an October 2017 workshop with the majority of planning and coordination aligned to ADAC Program Year 4. ADAC received USCG D-17 commander concurrence of plan on 30 June 2017.
Arctic MaLTE: In Program Year 3, ADAC collaborated with HQ USCG DCO-X “Evergreen” team, RAND’s Homeland Security Operational Analysis Center (HSOAC), and U.S. Coast Guard Academy’s Center for Arctic Study and Policy (CASP), to create a highly cost effective Arctic Futures workshop. ADAC proposed and HQ USCG DCO-X accepted a workshop plan that leveraged the University of Alaska Fairbanks Arctic Interchange Conference, coinciding with the transition of chair of the Arctic Council from the Government of the United States to the Government of Finland. ADAC created a comprehensive Literature Review, drafted and presented the initial overall plan and presented scenarios which where adapted and further developed by HSOAC. ADAC conducted overall workshop logistics, determined and invited participants, designed and arranged plenary sessions and supported Breakout groups with recorders and co-facilitators. ADAC then provided breakout group data and interim report to HQ USCG DCO-X, which included an array of potential future research questions and then provided Finalized Rapporteur’s report to HQ USCG DCO-X on 5 Sep 2017.

At the close of Program Year 3, ADAC and HQ USCG DCO-X agreed to investigate a focused future workshop that solicits Alaskan Native Arctic residents and subject matter experts at the 2018 Western Alaska Interdisciplinary Science Conference scheduled for late winter 2018 in Nome, Alaska.
### Appendix A: Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACNFS</td>
<td>Arctic Cap Nowcast/Forecast System</td>
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<tr>
<td>ADAC</td>
<td>Arctic Domain Awareness Center</td>
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<tr>
<td>ADCIRC51</td>
<td>Advanced Circulation Model</td>
</tr>
<tr>
<td>AESC</td>
<td>Arctic Executive Steering Committee</td>
</tr>
<tr>
<td>AFP</td>
<td>ADAC Fellows Program</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>AIA</td>
<td>Aleut International Association</td>
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<tr>
<td>AIFC</td>
<td>Arctic Information Fusion Capability</td>
</tr>
<tr>
<td>AIS</td>
<td>Automatic Identification System</td>
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<tr>
<td>AOOS</td>
<td>Alaska Ocean and Observation System</td>
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<tr>
<td>AOSC</td>
<td>Artic Oil Spill Calculator</td>
</tr>
<tr>
<td>ARN</td>
<td>ADAC Research Network</td>
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<tr>
<td>ASRC FS</td>
<td>Arctic Slope Regional Corporation Federal Systems</td>
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<tr>
<td>BOEM</td>
<td>Bureau of Ocean Energy Management</td>
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<tr>
<td>BSSN</td>
<td>Bering Sea Sub-Network</td>
</tr>
<tr>
<td>CAFF</td>
<td>Conservation of Arctic Flora and Fauna</td>
</tr>
<tr>
<td>CDG</td>
<td>Career Development Grant</td>
</tr>
<tr>
<td>CBP</td>
<td>Customs and Border Protection</td>
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<tr>
<td>CBO</td>
<td>Community Based Observers</td>
</tr>
<tr>
<td>CBONS-SA</td>
<td>Community Based Observing Networks for Situational Awareness</td>
</tr>
<tr>
<td>C&amp;ES AD</td>
<td>Communications and Educational Support Associate Director</td>
</tr>
<tr>
<td>CIMES</td>
<td>Center for Island Maritime and Extreme Environment</td>
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<tr>
<td>CIS</td>
<td>Critical Indicators System</td>
</tr>
<tr>
<td>CFS</td>
<td>Climate Forecast System</td>
</tr>
<tr>
<td>CMR</td>
<td>Center for Maritime Research</td>
</tr>
<tr>
<td>COE</td>
<td>Centers of Excellence</td>
</tr>
<tr>
<td>CONAS</td>
<td>Community Observing Network for Adaptation and Security</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off-the-Shelf</td>
</tr>
<tr>
<td>CFS</td>
<td>Climate Forecast System</td>
</tr>
<tr>
<td>DA-E</td>
<td>DHS Data Analytics Engine</td>
</tr>
<tr>
<td>DGPS</td>
<td>Differential Global Positioning System</td>
</tr>
<tr>
<td>DHS</td>
<td>Department of Homeland Security</td>
</tr>
<tr>
<td>DHSEM</td>
<td>Division of Homeland Security and Emergency Management (State of Alaska) Department of Homeland Security Science &amp; Technology’s Office of University Programs</td>
</tr>
<tr>
<td>DHS S&amp;T OUP</td>
<td>Data Information Protection Plan</td>
</tr>
<tr>
<td>DIPP</td>
<td>Disaster Response</td>
</tr>
<tr>
<td>DR</td>
<td>End to End</td>
</tr>
<tr>
<td>E2E</td>
<td>Executive Director</td>
</tr>
<tr>
<td>EO&amp;WFDD</td>
<td>Education Outreach and Workforce Development Director</td>
</tr>
<tr>
<td>ERAU</td>
<td>Embry Riddle Aeronautical University (ERAU)</td>
</tr>
<tr>
<td>EO&amp;WFDD</td>
<td>Education Outreach and Workforce Development Director</td>
</tr>
<tr>
<td>ERMA</td>
<td>Environmental Response Management Application</td>
</tr>
<tr>
<td>ET-Storm Surge</td>
<td>Extra Tropical Storm Surge</td>
</tr>
<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>FMI</td>
<td>Finnish Meteorological Institute</td>
</tr>
<tr>
<td>FIST</td>
<td>Field Information Support Tool</td>
</tr>
<tr>
<td>FTD</td>
<td>Federal Tribal Designation</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>FTIR</td>
<td>Fourier Transform Infrared Spectroscopy</td>
</tr>
<tr>
<td>GoMRI</td>
<td>Gulf of Mexico Research Initiative</td>
</tr>
<tr>
<td>GNOME</td>
<td>General NOAA Operational Modeling Environment</td>
</tr>
<tr>
<td>HA</td>
<td>Humanitarian Assistance</td>
</tr>
<tr>
<td>HFO</td>
<td>High Fidelity Observer</td>
</tr>
<tr>
<td>HIOMAS</td>
<td>High-resolution Ice-Ocean Modeling and Assimilation System</td>
</tr>
<tr>
<td>HIPPA</td>
<td>Health Insurance Portability and Accountability Act</td>
</tr>
<tr>
<td>HSARPA</td>
<td>Homeland Security Advanced Research Projects Agency</td>
</tr>
<tr>
<td>HYCOM</td>
<td>Hybrid Coordinate Ocean Model</td>
</tr>
<tr>
<td>IANA</td>
<td>Indian and Northern Affairs</td>
</tr>
<tr>
<td>IARPC</td>
<td>Interagency Arctic Research Policy Committee</td>
</tr>
<tr>
<td>ICECON</td>
<td>Ice Conditions Index</td>
</tr>
<tr>
<td>IICWG</td>
<td>International Ice Charting Working Group</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>InSAR</td>
<td>Interferometric Synthetic Aperture Radar</td>
</tr>
<tr>
<td>IONS</td>
<td>Incidents of National Significance</td>
</tr>
<tr>
<td>JTFN</td>
<td>Joint Task Force North (Canada)</td>
</tr>
<tr>
<td>KTG</td>
<td>Kestrel Technology Group</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>LPBK</td>
<td>Local Place Based Knowledge</td>
</tr>
<tr>
<td>LRAUUV</td>
<td>Long Range Autonomous Underwater Vehicle</td>
</tr>
<tr>
<td>LWIR</td>
<td>Longwave Infrared</td>
</tr>
<tr>
<td>MBARI</td>
<td>Monterey Bay Aquarium Research Institute</td>
</tr>
<tr>
<td>MIZMAS</td>
<td>Marginal Ice Zone Modeling and Assimilation System</td>
</tr>
<tr>
<td>MMA</td>
<td>Maine Maritime Academy</td>
</tr>
<tr>
<td>MDA</td>
<td>Maritime Domain Awareness</td>
</tr>
<tr>
<td>MN</td>
<td>Member Node</td>
</tr>
<tr>
<td>MOTR</td>
<td>Maritime Operational Threat Response</td>
</tr>
<tr>
<td>MSI</td>
<td>Minority Serving Institutions</td>
</tr>
<tr>
<td>MXAK</td>
<td>Marine Exchange of Alaska</td>
</tr>
<tr>
<td>NAIS</td>
<td>North American Ice Service</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NCAR</td>
<td>National Center for Atmospheric Research</td>
</tr>
<tr>
<td>NCEI</td>
<td>National Centers for Environmental Information</td>
</tr>
<tr>
<td>NCEP</td>
<td>National Center for Environmental Prediction</td>
</tr>
<tr>
<td>ND</td>
<td>Nova Dine</td>
</tr>
<tr>
<td>NIC</td>
<td>National Ice Center</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NSC</td>
<td>National Security Cutter</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NWS</td>
<td>National Weather Service</td>
</tr>
<tr>
<td>OODA</td>
<td>Observe, Orient, Decide and Act</td>
</tr>
<tr>
<td>OGCWS</td>
<td>Open Geospatial Consortium Web Service</td>
</tr>
<tr>
<td>OSA</td>
<td>Open Systems Architecture</td>
</tr>
<tr>
<td>OUP</td>
<td>Office of University Programs</td>
</tr>
<tr>
<td>ORR</td>
<td>Office of Response and Restoration</td>
</tr>
<tr>
<td>ONR</td>
<td>Office of Naval Research</td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigator</td>
</tr>
<tr>
<td>PII</td>
<td>Personally Identifiable Information</td>
</tr>
<tr>
<td>PIOMAS</td>
<td>Pan-arctic Ice–Ocean Modeling and Assimilation System</td>
</tr>
<tr>
<td>PM</td>
<td>Program Manager</td>
</tr>
<tr>
<td>PMD</td>
<td>Project Management Director</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>POA</td>
<td>Port of Anchorage</td>
</tr>
<tr>
<td>PoISAR</td>
<td>Polarimetric Synthetic Aperture Radar</td>
</tr>
<tr>
<td>RD</td>
<td>Research Director</td>
</tr>
<tr>
<td>RPA</td>
<td>Remotely Piloted Aircraft</td>
</tr>
<tr>
<td>SAR</td>
<td>Search and Rescue</td>
</tr>
<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>SETS</td>
<td>Social-Ecological-Technological Systems</td>
</tr>
<tr>
<td>SDI</td>
<td>Spatial Data Infrastructure</td>
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<tr>
<td>SME</td>
<td>Significant Minority Enrollment</td>
</tr>
<tr>
<td>STCW</td>
<td>Standards of Training, Certification, and Watchkeeping</td>
</tr>
<tr>
<td>SWAN</td>
<td>Simulating Waves Near Shore</td>
</tr>
<tr>
<td>TAMOC</td>
<td>Texas A&amp;M Oil Spill Calculator</td>
</tr>
<tr>
<td>TAMU</td>
<td>Texas A&amp;M University</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>UAA</td>
<td>University of Alaska Anchorage</td>
</tr>
<tr>
<td>UAF</td>
<td>University of Alaska Fairbanks</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aircraft Vehicle</td>
</tr>
<tr>
<td>UDOP</td>
<td>User-defined Operating Picture</td>
</tr>
<tr>
<td>UoI</td>
<td>University of Idaho</td>
</tr>
<tr>
<td>UNM</td>
<td>University of New Mexico</td>
</tr>
<tr>
<td>UGV</td>
<td>Unmanned Ground Vehicle</td>
</tr>
<tr>
<td>USCG</td>
<td>United States Coast Guard</td>
</tr>
<tr>
<td>USCG RDC</td>
<td>United States Coast Guard Research and Development Center</td>
</tr>
<tr>
<td>USGCRP</td>
<td>US Global Change Research Program</td>
</tr>
<tr>
<td>US MDA</td>
<td>United States Maritime Domain Awareness</td>
</tr>
<tr>
<td>USN</td>
<td>United States Navy</td>
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<tr>
<td>USNORTHCOM</td>
<td>United States Northern Command</td>
</tr>
<tr>
<td>USV</td>
<td>Unmanned Surface Vehicle</td>
</tr>
<tr>
<td>UTEP</td>
<td>University of Texas El Paso</td>
</tr>
<tr>
<td>UUV</td>
<td>Unmanned Underwater Vehicle</td>
</tr>
<tr>
<td>UW</td>
<td>University of Washington</td>
</tr>
<tr>
<td>WHOI</td>
<td>Woods Hole Oceanographic Institution</td>
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