



**ARCTIC DOMAIN
AWARENESS CENTER**
A DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE

Arctic Domain Awareness Center (ADAC)

A Department of Homeland Security Science and Technology Office of University Programs,

Center for Maritime Research

ADAC Annual Performance Report for Program Year 7

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Photo: Credit ADAC

ADAC respectfully submits the report below to the U.S. Department of Homeland Security, Science and Technology Directorate, Office of University Programs. *This ADAC Program Year 7 report complies with terms and conditions of the ADAC Cooperative Agreement to the University of Alaska Anchorage.* Additionally:

- ADAC certifies one patentable invention during the budget period: a Provisional Patent filed for under-ice capabilities of the LRAUV.
- ADAC has reviewed the 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 7 in summary: The Arctic Domain Awareness Center achieved greater maturation and technological readiness of multi-year research projects, launched new research initiatives relevant for Arctic operations, convened workshops and new events, advanced knowledge products, and expanded the Center's network of international and local partners while developing the next generation workforce to advance the homeland security in the Arctic.

As seasonal sea ice continues to diminish, the opening of the Arctic region to natural resource development, maritime trade, and tourism have transformed the security landscape of the high latitude north. New international actors now look above the Arctic Circle for opportunity, while existing Arctic nations have begun to realize its economic potential. Environmental change in the region has disrupted the traditional social and economic systems that have thrived in the Arctic for centuries. Weather has become more volatile and unpredictable while rising ocean temperatures have caused fish stocks to move into higher latitudes. In the midst of this evolving dynamic, it falls to the U.S. Department of Homeland Security (DHS) and the United States Coast Guard (USCG) to serve as the United States' visible sovereign presence within the region to safeguard American territory and national interest the Arctic.

In order to prepare for these emerging challenges, the United States Coast Guard released the USCG Arctic Strategic Outlook from 2019 describes three "complementary lines of effort" to protect national interests: 1. Enhance Capability to Operate Effectively in the Dynamic Arctic. 2. Strengthen Rules-Based Order. 3. Innovate and Adapt to Promote Resilience and Prosperity. As a DHS S&T University Program with the USCG as the primary "customer," ADAC promotes each line of effort daily through the development of ADAC research projects.

As a DHS Science and Technology Office University Programs (DHS S&T OUP) Center of Excellence in Maritime Research, the Arctic Domain Awareness Center (ADAC), hosted by the University of Alaska Anchorage, continues to provide relevant science and technology research and support for the USCG as they conduct and enhance their statutorily assigned missions in the Arctic.

As ADAC's principal customer is the USCG, ADAC investigates operational shortfalls and gaps for the USCG mission needs in the Arctic. Through this effort, ADAC supports the primary USCG missions in the Arctic of search and rescue, environmental protection, disaster response, and coastal security. As University hosted Center, ADAC promotes education through the Center's Fellows program which engages and prepares students for careers within the Homeland Security Enterprise (HSE). Through these core functions, ADAC supports the USCG, and other DHS Maritime mission needs throughout the Arctic.

With this report, ADAC reflects upon the 7th year of providing science and technology research in support of DHS and the USCG. In Program Year 7, ADAC continued to mature existing investigations and prepared technology developed through the center for the transition to real-world application. ADAC continued advanced Arctic knowledge and domain awareness through numerous ADAC and partner-led workshops, conferences, and symposia, which resulted in knowledge products that inform DHS and USCG policy and strategy in the Arctic.

This report describes Year 7 project work completed by ADAC from 1 July 2020 to 30 June 2021. In addition to updates on the ADAC supported research, the report provides an overview of the Center's activities within this period. The report reflects the results and accomplishments performed in accordance with the DHS S&T UP approved Program Year 7 Workplan of ADAC.

ADAC's approved vision, mission, and strategy remain:

Vision: The DHS Center of Excellence provides networked and mission-focused support to the USCG Operator in the High North.

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. ADAC seeks to accomplish this mission through an inclusive approach.

Strategy: ADAC will conduct a parallel effort over five lines of a major collaboration with DHS S&T UP and USCG in order to:

- Investigate, develop, resource, and initiate new research.
- Execute approved research work plans that are appropriately detailed and resourced.
- Successfully integrate university student Fellows into the Homeland Security Enterprise workforce.
- Transition sufficiently mature research to meet customer acquisition needs and commercialize as appropriate.
- Adapt Center activities, management, and communications to continue to learn and collaborate with an array of Center partners and continue to suitably expand the reach of ADAC across U.S. and Canada to include Arctic government, military, and security operators, researchers, and industry partners.

ADAC's specific research activities approved for Program Year 7

ADAC launched Program Year 7 on 1 July 2020 with DHS S&T UP approval. During Program Year 7, the Center received further project notifications of accepted proposals for the following research projects on 19 Jan 2021 and 24 Mar 2021 respectively:

- Alaska and Arctic Maritime Communications and Connectivity Analysis (AAMC&CA)
- Arctic Facilities and Infrastructure Environmental Change Risk Index.

ADAC's partner academic and research institutions.

The following universities or research institutions partnered with ADAC's Center efforts or conducted individual research projects in Program Year 7:

- Alaska Ocean Observation System (AOOS), Anchorage, Alaska.
- Bigelow Laboratory for Ocean Sciences, East Boothbay, Maine.
- Texas A&M University, College Station, Texas.
- Monterey Bay Research Aquarium Institute (MBARI), Monterey Bay, California.
- University of Alaska Anchorage, (UAA) Anchorage, Alaska.
- University of Alaska Fairbanks, (UAF) Fairbanks, Alaska.
- University of New Hampshire (UNH) Coastal Response Research Center (CRR) Center for
- Spills in the Environment (CSE), Durham, New Hampshire.
- University of Maryland, (UMD) College Park, Maryland.
- University of Texas El Paso, (UTEP) El Paso, Texas.
- University of Washington Applied Physics Laboratory, Seattle, Washington.
- Ukpeagvik Inupiat Corporation (UIC)-Science, Utqiagvik, Alaska.
- Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.
- US Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

Industry partners.

The following industry or business enterprises contributed to ADAC's Center efforts or individual research projects in Program Year 7:

- Marine Exchange of Alaska, Juneau, AK
- Alaska Marine Prevention and Response Network, Juneau, AK
- Axiom Data Science, Anchorage, AK.
- IntelliSense Marine, LLC, Seattle, WA.
- Induced Polarization Associates, LLC, Seattle, WA.
- Williamson and Associates, Seattle, WA.

Collaborative organizations.

The following organizations provided research input, collaborations, or contributed in ADAC activities (such as workshops and/or educational activities):

- Alaska Department of Public Safety, Juneau, Alaska.

- Bering Straits Native Corporation, Nome, Alaska.
- Canadian Department of National Defense and Canada National Research Council, Ottawa, Canada.
- City and Port of Anchorage, Alaska.
- City and Port of Nome, Alaska.
- DHS Centers of Excellence at George Mason University, Stevens Institute of Technology, and University of Houston.
- Kawerak Incorporated, Nome, Alaska.
- NOAA and National Weather Service, Anchorage, Alaska; Seattle, Washington; and Washington, D.C.
- North Slope Borough, Utqiagvik, Alaska.
- Pacific Northwest National Laboratories, Hanover, Washington.
- Sandia National Laboratories, Albuquerque, New Mexico.
- U.S. Arctic Research Commission, Washington, D.C.
- U.S. Coast Guard Academy and their Center for Arctic Study and Policy (CASP), New London, Connecticut.
- USCG Headquarters, USCG Pacific Area, USCG Research and Development Center, and Districts 9 and 17.
- U.S. National Ice Center, Suitland, Maryland.
- United States Naval Academy, Annapolis, Maryland.
- Aleutian and Bering Sea Islands Land Conservation Council, Anchorage, Alaska.

A Summary of ADAC Program Year 7 Activities:

The timeline below provides a list of major Center activities conducted throughout Program Year 7. The majority of these activities follow ADAC's long-range schedule, established in the Center's DHS S&T OUP approved Program Year 7 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 to prepare and conduct activities expected of DHS S&T OUP, while accomplishing planned research and developing students to serve in the Homeland Security Enterprise.

While the advent of the Coronavirus 2019 (COVID-19) pandemic forced ADAC to postpone in-person gatherings or transition to "virtual" activities starting on 17 March 2020, which continued through much of ADAC's Program Year 7, ADAC was still able to foster Arctic innovation and collaboration through effective workshops, conference presentations, stakeholder meetings, customers partners and roundtables, and the Virtual ADAC Annual Meeting. ADAC leadership respectfully extend sincere thanks our research teams, external partners and collaborators and to DHS S&T OUP and Arctic minded USCG leadership, and staff for their resourcefulness and flexibility in these challenging times. Note, no DHS provided travel funds were used for any event in ADAC Program Year 7.

ADAC's Program Year 7 was marked by significant service in advancing research and research collaboration to the Arctic, including the following activities:

8 July 2020: ADAC Leadership joined the initiation of the Arctic Policy Study Group hosted by Commonwealth North.



In recognition of the Arctic as a region of increasing importance, as well as a domain composed of rapidly changing issues and opportunities, Commonwealth North authorized a new charge through the Arctic Policy Study Group, which is a collaborative effort amongst a variety of Arctic thought leaders.

12 July 2020: DHS S&T CoE Directors Meeting.



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

14 July 2020: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting of the ICE-PPR Situational Awareness working group focused specifically on U.S. Executive and Principles only.

14-16 July 2020: IARPC Team Leader Conference



ADAC Leadership participated in the International Arctic Research and Policy Committee (IARPC) Team Leader Conference.

21 July 2020: Chatham House meeting on the Russian Arctic.



ADAC's Executive Director participated in a virtual Chatham House meeting regarding the Russian Arctic hosted by the U.S. Naval War College.

31 July 2020: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting of the ICE-PPR Situational Awareness working specifically focused on the goals and initiatives of each team through a team leaders meeting.

7 August 2020: ADAC Fellows Completed the Virtual Arctic Summer Internship Project 2020.



ADAC Fellows finished their respective courses of workforce development associated with the Arctic Summer Intern Project (ASIP). As described in detail later in the report, due to the COVID-19 pandemic, the ASIP summer 2020 was a virtual program that took place for 10 weeks throughout a variety of online mediums, including Microsoft Teams, Zoom, and Google Calendar. The program entailed weekly lectures on Arctic specific topics, as well as academic and professional development topics, as well as an esteemed series of guest presentations,

independent research projects, and group research projects. ASIP 2020 leveraged DHS S&T OUP Funds to support this event.

21 August 2010: ADAC Leadership supported the Criminal Investigations and Network Analysis Center (CINA)'s workshop on the impacts of COVID-19 on the supply chain.



Criminal Investigations and Network Analysis
A DHS CENTER OF EXCELLENCE

ADAC's Executive Director supported a panel at CINA's workshop specifically focused on rural area criminal trends (and responses to those trends) from a supply chain vantage in light of COVID-19.

9 September 2020: DHS S&T CoE Directors Meeting.



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

22-26 July 2019: ADAC Senior Research Professional (SRP) presented during Air Force Chief Scientist Group Visit to JBER Alaska.



ADAC's Associate Director and Senior Research Professional conducted a presentation on ADAC Arctic research to USAF Chief Scientist Dr. Richard J. Joseph during his visit to Alaska. The meeting was attended by Dr. Joseph, representatives from ALCOM, and congressional staffers. The presentation and follow-on discussions included overviews of ADAC projects, workshops, and partnerships.

14-17 September 2020: ARPC's 5-Year Plan Meeting



ADAC Leadership participated in writing session for IARPC's Next 5 Year Plan.

17-18 September 2020: CANADA-U.S. ACCUSARS I Workshop hosted by ADAC and NAADSN.



Building upon a June 2017 workshop on Security in the Arctic Borderlands Region, the North American Marine and Environmental Security Workshop hosted by ADAC in September 2018, and the Arctic Command Arctic

Symposium held in November 2019 in Fairbanks, NAADSN and ADAC cohosted a follow-on workshop focused on specific initiatives to improve understanding and enhance collaboration between Canada-US Arctic security professionals.

24 September 2020: ADAC's 1st Quarterly Review



ADAC Leadership, along with ADAC project teams, conducted the first Quarterly review of Program Year 7. The event was conducted virtually via Webex

30 September 2020: ADAC's 1st Quarter Customers and Partners Roundtable



ADAC Leadership, along with ADAC project teams, conducted its Customers and Partners Roundtable for ADAC's first quarter of Program Year 7. The event was virtually attended by ADAC's broad network of constituents.

5 October 2020: Wilson Polar Institute and ADAC Inaugural Arctic Security Dialogues



Wilson Center



ADAC Executive Director assisted in the development and execution of a round table discussion regarding the Air Force Arctic Strategy, to include contextual perspectives about the new Arctic, the Arctic in context of Great Power Competition, and the role and importance of the Air Force in Alaska and the Arctic.

9 October 2020: ADAC Executive Director Co-Hosted State of Alaska Civil Armed Services Team (ACAST) 3rd Quarter 2020 Meeting.



ADAC ED co-hosted a meeting to support a number of new initiatives to advance needed support to U.S. military, to include USCG concerns in Alaska. Meeting minutes and draft memo for State of Alaska Governor drafted and provided to Alaska Adjutant General.

14 October 2020: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

15-17 October 2020: The Alaska Federation of Natives Virtual Annual Meeting



ADAC's Executive Director participated in the Alaska Federation of Natives Virtual Annual Meeting. The Convention featured a combination of live presentations and pre-recorded videos of top local, state, federal, and Native leaders and elected officials, a keynote address by Alaska House Speaker Representative, Bryce Edgmon, interactive panels, and AFN President's awards. ADAC ED moderated a military panel on 16 Oct 2020 to support Alaska Command, which included major U.S. military commanders in Alaska, including USCG D17 for the military presentations.

26-30 October 2020: The 11th USCG Maritime Risk Symposium



ADAC Leadership, staff, and students participated in the 2020 Maritime Risk Symposium through various capacities. ADAC Executive Director served as the Evergreen activity senior mentor, now connected with HQ USCG DCO-X (CAPT Westfall), while ADAC's graduate fellows participated in the symposium's student poster competition.

3-5 November 2020: Virtual Maritime and Arctic Safety and Security Conference

ADAC Executive Director provided a briefing on the final day of the conference regarding Arctic safety and security from a U.S. perspective.

6 November 2020: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the ICE-PPR Situational Awareness working group only.

16 November 2020: Arctic Maritime Spill Modeling Workshop I



ADAC's AMSM Project team virtually conducted the first of its three Arctic Maritime Spill Modeling Workshops.

23 November 2020: Arctic Maritime Spill Modeling Workshop II



ADAC's AMSM Project team virtually conducted the second of its three Arctic Maritime Spill Modeling Workshops.

30 November 2020: Arctic Maritime Spill Modeling Workshop III



ADAC's AMSM Project team virtually conducted the third and final event for its Arctic Maritime Spill Modeling Workshops.

3 December 2020: ADAC Executive Director Co-Hosted State of Alaska Civil Armed Services Team (ACAST) 4th Quarter 2020 Meeting.



ADAC ED co-hosted a meeting to support a number of new initiatives to advance needed support to U.S. military, to include USCG concerns in Alaska. Meeting minutes and draft memo for State of Alaska Governor drafted and provided to Alaska Adjutant General.

4 December 2020: U.S. Army Alaska Arctic Conference

ADAC Executive Director virtually participated in the U.S. Army Alaska Arctic Conference.

7 December 2020: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the ICE-PPR Situational Awareness working group only.

8 December 2020: ADAC Executive Director provided congressional testimony.

ADAC Executive Director provided congressional testimony for the Senate Security of the Transportation, Commerce and Science Committee.

9 December 2020: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

9-10 December 2020: Alaska Coastal Mapping Summit



ADAC's Executive Director, as well as the Associate Director and Senior Research Professional, participated in the 2020 Alaska Coastal Mapping Summit hosted by the State of Alaska Geospatial Council. The Summit focused on the Alaska Coastal Mapping Strategy (ACMS), which was released in June of 2020.

11 December 2020: Wilson Polar Institute & ADAC Arctic Security Dialogues



Wilson Center



ADAC's Executive Director assisted with the development and execution of a round table discussion dually hosted by the Wilson Polar Institute. This panel specifically focused on the U.S. Army Alaska.

14 December 2020: Hudson Institute Virtual Arctic Event



ADAC Executive Director conducted an interview for Hudson Institute video event, *Rising Geopolitical Tensions in the Arctic: Responses of the U.S. Administration*. The event included ADAC's Executive Director, Richard Weitz and Bryan Clark.

8 January 2021: COVID19 Supply Chain Workshop



ADAC Executive Director served as part of the organizing committee led by Rutgers University and Kansas State University to develop a workshop focused on the impacts of the COVID-19 pandemic on the U.S. supply chain.

8 January 2021: ADAC's 2nd Quarterly Review



ADAC Leadership, along with ADAC project teams, conducted its second quarterly review for Program Year 7,

11 January 2021: Start of the University of Alaska Anchorage Spring Semester

ADAC's Executive Director, as well as ADAC's Principal Investigator, began teaching their spring 2021 semester Arctic Environmental Security, which is dually offered through the University of Alaska Anchorage (UAA), as well as the University of the Arctic.

13 January 2021: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

15 January 2021: ADAC's 2nd Quarter Customers and Partners Roundtable



ADAC Leadership, along with ADAC project teams, conducted its Customers and Partners Roundtable for ADAC's second quarter of Program Year 7. The event was virtually attended by ADAC's broad network of constituents.

25-29 January 2021: Alaska Marine Science Symposium



ADAC's Leadership, along with four of ADAC's graduate fellows, virtually attended and participated in the Alaska Marine Science Symposium. The four graduate students presented posters during the student poster competition, with one graduate student, Katherine Humpal (UNO), receiving an award for one of the top three graduate posters.

10 February 2021: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

15 February 2021: Wilson Polar Institute & ADAC Arctic Security Dialogues



Wilson Center



ADAC's Executive Director assisted with the development and execution of a round table discussion dually hosted by the Wilson Polar Institute.

22 February 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the USA ICE-PPR Situational Awareness working group only.

10-11 March 2021: Virtual Arctic Senior Leader Summit



This event was oriented to addressing senior leader strategic views on the developing range of security and defense matters affecting the Arctic region. Day 1 of ASLS 2021 was focused on Plenary and Keynote presentations. Day 2 of the ASLS



2021 included a planned tabletop exercise for crisis action discussions for only U.S. and Canadian military personnel. The event was hosted and attended by Lt General David Krumm, USAF, Commander Alaska Command, Alaska NORAD Region and 11th Air Force and a host of Defense and Security Leaders.

16-17 March 2021: Arctic C-ICE Expo



The Arctic Domain Awareness Center's (ADAC) Arctic Challenges, Innovations, and Commerce Expo (Arctic CICE) sought to explore the networks, resources, and infrastructure needed to enable the commercial entrance of Arctic-related



products and technologies into the Arctic domain. Drawing from ADAC's vast experience in federally funded operational research and design, the expo used an interdisciplinary and collaborative approach to foster conversations around Arctic-centered business pressure points, state-of-the-Arctic-focused R&D, gap analysis of investment and innovation, and the future of business in the region.

16-18 March 2021: Port of the Future Conference



ADAC Executive Director conducted a panel presentation on day 2 of the Port of the Future Conference hosted by the University of Houston in partnership with the Energy Conference Network, which focused on updates to the risks and opportunities associated with Arctic shipping.

24 March 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the USA ICE-PPR Situational Awareness working group only.

25-26 March 2021: ACCUSARS II Workshop



ADAC and the North American and Arctic Defense and Security Network (NAADSN) hosted its follow-up from the Advancing Collaboration in Canada-U.S. Arctic Regional Security (ACCUSARS) conference in September 2020. The



purpose of ACCUSARS II was to create a subset Strategic Foresight Assessment (SFA) for the North American Arctic by specifically focusing on Alaska and Western Canada.

1 April 2021: ADAC's 3rd Quarter Customers and Partners Roundtable



ADAC Leadership, along with ADAC project teams, conducted its Customers and Partners Roundtable for ADAC's third quarter of Program Year 7. The event was virtually attended by ADAC's broad network of constituents.

6-9 April 2021: One Health One Future Conference



ADAC's Principal Investigator, along with ADAC's Education & Administrative Manager, virtually attended the One Health One Future Conference, hosted by the University of Alaska Fairbank's Center for One Health Research. The conference was partnered with the U.S. Department of State, as well as the Arctic Circle Sustainable Development Working Group.

9 April 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the ICE-PPR Situational Awareness working group only. The meeting was led by Dr. Patrick Mason from the Office of Naval Research.

20-22 April 2021: Arctic Sustainable Energy Conference



ADAC's Executive Director participated in the Arctic Sustainable Energy Conference, which examined Research and community needs in the context of a global energy transition. The virtual workshop was cosponsored by the U.S. Arctic Research Commission, the Housing Research Center, the National Renewable Energy Laboratory and the Alaska Center for Energy and Power.

27 April 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting (Worldwide Meeting).



This meeting was focused on overall updates to ICE-PPR, as well as national updates regarding polar research.

29-30 April 2021: ADAC's 3rd Quarterly Review



ADAC Leadership, along with ADAC project teams, conducted its third quarterly review for Program Year 7,

4-6 May 2021: Arctic Maritime Horizons



In partnership with HQ USCG Director of Maritime Transportation Systems and the Senior Arctic Policy Advisor, the Arctic Maritime Horizons tabletop exercise was oriented to address policy, plans and initiatives to support HQ USCG and the

Coast Guard Enterprise in addressing the 2019 USCG Arctic Strategic Outlook (ArcSO) task to “Advance and Modernize the Arctic Marine Transportation System.”

12 May 2021: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

17-21 May 2021: DHS S&T OUP COE Summit



U.S. Department of Homeland Security
Centers of Excellence Summit
University Research and Workforce Development
for a Safe and Secure Homeland

The 2020 DHS Centers of Excellence Summit was co-organized and hosted by the Criminal Investigations and Network Analysis (CINA) and held virtually on May 17-21, 2021. The event served as an important opportunity for ADAC staff and leadership to collaborate and engage with fellow Centers of Excellence and the DHS enterprise. ADAC supported the DHS S&T CoE network in hosting expert presentations that involved organizing and securing participation of distinguished leaders in the Homeland Security Enterprise. ADAC’s Education & Administrative Manager also played a role in the development and execution of the event’s student Grand Challenge Tabletop Exercise, which ADAC’s Executive Director served as facilitator. ADAC student Fellows also had the opportunity to present posters at the Summit’s student poster competition.

1 June 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting.



This meeting was specifically amongst members of the ICE-PPR Situational Awareness working group only.

2-3 June 2021: ADAC’s Program Year 7 Virtual Annual Meeting



Homeland Security
Science and Technology



Despite transitioning from in-place to a conference call medium, the Program Year 7 Annual Meeting theme was “Finish and Forward...in support of the future Arctic” ...which included a summary review of the Center’s current research endeavors, as well as discussions oriented towards fostering USCG and our partner community’s thinking in better leveraging ADAC in the upcoming Program Year 8 and beyond. The packed agenda also included aspects of transition and commercialization as suitable. “Finish” was associated with the DHS S&T OUP Cooperative Agreement that will conclude on 30 June 2022 in accordance with the Notice of Funding Award and “Forward” was oriented to ADAC’s plan to transition to alternative arrangements on 1 July 2022 and onward. ADAC was honored to welcome reflections from DHS S&T, U.S. Coast Guard, DoD’s Alaskan Command, the U.S. Arctic Research Commission and Interagency Arctic Policy Research Committee VIP leadership.

9 June 2021: DHS S&T OUP CoE Directors Meeting



ADAC Leadership participated in the monthly DHS S&T OUP Directors meeting.

14 June 2021: ADAC supported ICE-PPR Situational Awareness Working Group Meeting (U.S. Only).



The purpose of this meeting was to have an internal update on the US HPWG progress. It was led by Dr. Patrick Mason from the Office of Naval Research.

17 June 2021: ADAC’s 4th Quarterly Review



ADAC Leadership, along with ADAC project teams, conducted its final program review for Program Year 7,

21 June 2021: CCICADA/ADAC/CREATE Workshop



ADAC's Executive Director supported the leadership of the Command, Control and Interoperability Center for Advanced Data Analysis (CCICADA) Center of Excellence, along with CREATE, in the development and execution of a workshop focused specifically on the Suez Canal Incident, and its Impact and Implications for the Global Maritime Supply Chain in light of COVID-19.

24 June 2021: ADAC's 4th Quarter Customers and Partners Roundtable



ADAC Leadership, along with ADAC project teams, conducted its final Customers and Partners Roundtable for ADAC's fourth quarter of Program Year 7. The event was virtually attended by ADAC's broad network of constituents.

30 June 2021: DHS S&T OUP approved ADAC's Program Year 8 Workplan and Close of ADAC Program Year 7.



DHS S&T OUP provided official approval of ADAC's Program Year 8 Workplan, to begin program execution for ADAC's Program Year 8 on 1 July 2021.

30 June 2021: Close of ADAC Program Year 7.

The remainder of this report maps ADAC's results for the period of performance from 1 July 2020 through 30 June 2021 in accordance with the Center's Program Year 7 workplan approved by DHS S&T OUP. This report addresses the following

- Center management efforts.
- Performance reports on each project, including:
 - Explanations of changes from the associated ADAC Year 7 approved Workplan.
 - Progress against milestones with explanations.
 - Unanticipated problems and obstacles and how they were overcome.

II. SUMMARY OF CENTER MANAGEMENT EFFORTS

The overall effort of the Center's leadership, staff, and research team was to achieve the deliverables and meet the metrics outlined by the Program Year 7 Workplan. The Workplan serves as an overall strategy to drive Center efforts, allowing leadership to effectively divide responsibility to accomplish multiple tasks and efforts simultaneously. The follow describes the strategic implementation of the plan and results of Center management activities.

USCG and other DHS maritime Arctic operators remain the key end users propelling research for the Center. Throughout Program Year 7, the Center continued to explore both fundamental and applied research in the Arctic.

ADAC's leadership delineated the execution of the Program Year 7 Work Plan accordingly:

- Direct and manage the research of established projects, which includes extensive research transition coordination between Project teams, USCG Project Champions, HQ USCG Acquisition and DHS S&T OUP. This entailed 60% of the ADAC management focus. Specific tasks and associated measurements include:

Table 1. Tasks and associated metrics for direction and management of established projects.

Task	Associated Metric	Met task and associated metric?
Conduct weekly teleconferences with ADAC Project leads and research teams.	Informed ADAC leadership and research team.	Yes
Participate in weekly teleconference with DHS S&T UP Program Manager.	Informed DHS S&T UP Program Manager.	Yes
Conduct monthly project invoice review.	Fiscal understanding of each project performance on monthly basis.	Yes
Conduct a Quarterly Review with ADAC Project Leads and research teams for DHS S&T UP Approved workplans that includes specific project transition planning.	Comprehensive review of project performance by ADAC leadership team, enabling oversight on a scheduled basis.	Yes
Conduct one Quarterly Review with ADAC Project Leads and research teams, with the Executive Counselors.	Comprehensive review as with regular reviews, with added recommendations from ADAC's Executive Counselors.	Yes
Prepare Center and project Work plan for any approved research activities that extend beyond Year 7 (30 June 2021).	Approved plans and activities by DHS S&T UP PM.	Yes
Subrecipient monitoring via ADAC leadership in-person visits at each subrecipient of the DHS S&T OUP Cooperative Grant location (university or business).	Successfully concluded subrecipient monitoring. ADAC leadership plans to conduct a minimum of one subrecipient monitoring visit at each location at least once per two-year program period.	Yes

Prepare Annual Report reporting on Center activities and Project Research	Approved report by DHS S&T UP PM.	Yes
Participate in detailed effort for project transition, including collaboration with HQ USCG CG-9 ADAC point of contact and USCG Project Champions.	Established transition pathway for ADAC research to meet USCG acquisition needs.	Yes
Investigate commercial opportunities for research transition, including patent and licensing.	Approved patents and/or licensing from submitted proposals.	In/work. Note, 1 Project Provisional Patent has been filed (for Propeller-driven Long Rang Autonomous Underwater Vehicle).

- Continue research development Initiative started in Program Year 4 and extended through Years 5, 6, and 7. This entails 10% of ADAC leadership focus. This effort entails collaborating with DHS S&T OUP and USCG for workshops that generate research questions, conducting and processing calls for research. Specific tasks and associated measurements include:

Table 2. Tasks and associated metrics for continuation of Year 4, 5, and 6 research initiatives.

Task	Associated Metric	Met task and associated metric?
Plan and conduct Arctic IoNS workshop, with topic determined by USCG (in particular, USCG D17 Commander).	Successfully concluded workshop that provides workshop Rapporteur's report and USCG approved research questions. Research questions may result in ADAC funded solicitation, simply intended for mission agencies to consider sponsoring research, which addresses priority shortfalls identified at the workshop.	No , workshop delayed to Program Year 7 due to COVID19. Now planned for March 2022 per request of USCG D17.
Coordinate and conduct Arctic Medium and Long-Term Environment (Arctic MaLTE) workshop focused on HQ USCG security and safety concerns	Conducted workshop addressing HQ USCG security and safety concerns.	Yes

- Conduct outreach, engagement and communications with customers, partners and collaborators, including potential new partners, to inform of center initiatives and research project details, while advancing ADAC's research networks. This encompassed 10% of ADAC leadership focus. Specific tasks and associated measurements include:

Table 3. Tasks and associated metrics for conducting outreach, engagement, and communications.

Task	Associated Metric	Met task and associated metric?
Prepare and conduct Annual meetings in Washington D.C. (preferably at HQ USCG).	Successfully presented meeting, informing DHS, USCG and invited participants of ADAC research and transition planning.	Yes (Conducted Virtually due to COVID-19 Travel Restrictions)
Conduct approximately quarterly Customers and Partners Roundtables via teleconference/webinar.	Successful completion of roundtables, and publishing of associated minutes.	Yes
Conduct semi-annual USCG focused ADAC “Principal Customer’s” research project teleconference.	Successful completion of teleconference.	Yes
Participate in Alaska Marine Science Symposium (January 2021).	ADAC completing a planned presentation.	Yes, however, conducted via student presentations.
Develop center and project motion graphics presentations in support of outreach.	Completed and posted motion graphics that describe ADAC efforts.	Yes
Prepare and release quarterly newsletters.	Published newsletters to established ADAC mailing list and posted to Center website.	Yes
Prepare brief noteworthy activities and project vignettes for DHS S&T UP communications staff.	Providing DHS S&T UP, communications needed information of ADAC activities and project research.	Yes
Update ADAC website, Facebook and Twitter of Center activities and noteworthy events.	Informing public of ADAC activities and research.	Yes
Publish specific ADAC events and activities to Interagency Arctic Research Policy Committee (IARPC).	Informing community of Arctic researchers about ADAC activities.	Yes

- Continue conducting education, outreach, and workforce development efforts consisting of a variety of activities that include both ADAC Fellows and minority students. ADAC anticipated this effort requires 10% of Center leadership focus.

Table 4. Tasks and associated metrics for conducting education, outreach, and workforce development efforts.

Task	Associated Metric	Met task and associated metric?
Recruit student interns (ADAC Fellows) for available research.	Achieve 100% fill for ADAC Fellow available slots.	Yes
Assign projects and develop workplans to ADAC Fellows.	Students fully assigned to projects with associated workplans.	Yes
Conduct monthly ADAC Fellows meetings.	Accomplish planned meeting schedule.	Yes

Conduct an ADAC Student research Symposium.	Completed symposium highlighting student research efforts.	Yes , in concert/as part of ADAC's Arctic CICE Conference.
Support ADAC Fellows entry into suitable 10- week summer internship;	All ADAC Fellows conclude a 10- week summer internship.	Yes
Support post-graduate student placement with Homeland Security Enterprise (HSE).	All graduated ADAC Fellows complete one year minimum service in an HSE related position or alternatives as described in the DHS OUP Terms and Conditions.	Yes
Recruit and conduct an abbreviated Minority Serving Institute (MSI) Arctic Summer Intern Project (ASIP) for June 2021.	Successful completion of an Abbreviated MSI ASIP in June 2021.	Yes

ADAC Program Year 7 Strategy implementation:

As established in Program Year 3, ADAC leadership continued practices, which formed a comprehensive “implementation plan” to deliver on the Center’s Program Year 7 strategy. The following summarizes results from this strategy implementation plan:

- Success in ADAC’s efforts to investigate, develop approaches, and resource and initiate new research.
- Solid execution of approved research work plans, which were appropriately resourced and detailed.
- Graduated and placed ADAC student Fellows into the homeland security enterprise. Please see education section of this report.
- Matured and readied research for transition in accordance with U.S. Coast Guard Project Champion direction to meet acquisition and/or commercialize needs. This is discussed within each project.
- Continued progress to adapt Center activities, learn and collaborate with an array of ADAC partners, and expand the reach of the Center across the U.S. and Canadian public officials, operators, researchers, and industry partners.

The following paragraphs outline associated personnel, management, and communications summaries, providing additional details in support of overall ADAC management efforts.

Center Personnel:

ADAC’s Center staff and leadership experienced continuity in Program Year 7. Center staff who joined in Year 5 and 6 continued their vital service for the Center’s efforts. ADAC continued to receive communications assistance from personnel assigned to UAA Business Enterprise Institute (BEI) and

BEI's Applied Environmental Research Center.

As of the end of Program year 7, ADAC accredited leadership comprised of the following:

- Douglas Causey, PhD, Principal Investigator, University of Alaska Anchorage (UAA).
- Nettie Labelle-Hamer, PhD, Research Director, University of Alaska Fairbanks (UAF)
- Randy Kee, Maj Gen (Ret) USAF, MS, Executive Director, UAA.
- Jason Roe, USCG (Ret.), Associate Director and Senior Research Professional, UAA.
- Heather Paulsen, MBA, Finance Director, UAA.
- LuAnn Piccard, MSE, PMP, Project Management Director, UAA.
- Elizabeth Matthews, MS, Education and Administrative Manager, UAA.
- Connor Keesecker, BA, Research and Communications Associate, UAA.
- Kelsey Frazier, MS, EIT, Research Associate, UAA
- UAA BEI Affiliate for media support: Jeffrey Kee, BA, Business Enterprise Institute, Media Specialist, UAA.

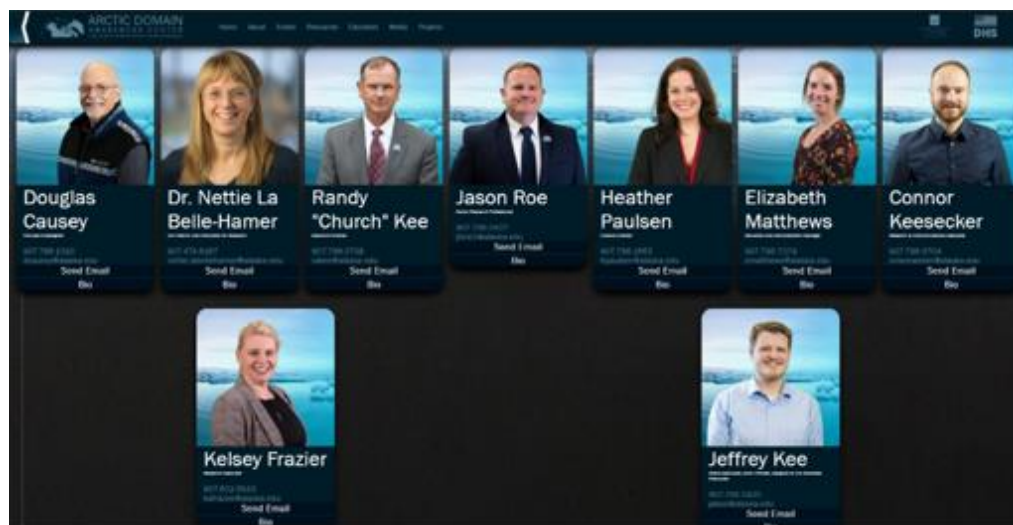


Figure 1: ADAC Personnel as of August 2021

ADAC Executive Counselors

ADAC continued to receive excellent support from the Center's team of advisors, the Executive Counselors team. ADAC's Executive Counselors continued to provide unfunded/pro-bono support by participating in teleconferences and other engagement opportunities. The Counselors advise ADAC

leadership on overall strategy of Center efforts and connect ADAC to greater research collaboration with international, federal, and Alaskan partners.

ADAC's Executive Counselors in Program Year 7 continued to meet either individually or collectively with Center leadership and conducted three Strategic meetings with ADAC leadership via a dedicated forum.

The following are ADAC's Executive Counselors who served in the Center's Program Year 7 efforts:

- **Tom Barrett**, VADM (Ret), USCG, President, Alyeska Corporation, Anchorage, Alaska. Admiral Barrett is a former USCG Vice Commandant and District 17 Commander.
- **John Farrell**, PhD, Executive Director, U.S. Arctic Research Commission, Washington, D.C.
- **Tom Case**, Chancellor Emeritus, University of Alaska Anchorage, and Lt. Gen, USAF (Ret).
- **Rudy Peschel**, RADM USCG (Ret), Fellow, Center of Arctic Study and Policy (CASP) U.S. Coast Guard Academy
- **Gail Schubert**, President & CEO, Bering Straits Native Corporation
- **Vaughn Cosman**, Executive Officer (XO) for Canada's International Collaborative Environment Program for Polar Research (ICE-PPR) team
- **Michael Duxbury**, Former Deputy Commissioner, State of Alaska Department of Public Safety
- **Casey Gon**, CDR, USN, USN Prospective Director, U.S. National Ice Center Prospective Commanding Officer



Figure 2: ADAC's Executive Counselor Team (as of August 2021)

The following Executive Counselors have completed their service in Program Year 7. ADAC Leadership extends their sincere thanks and appreciation for their years of support.



Paul Hubbard, PhD, Canada Department of National Defense, Ottawa, Canada.

Figure 3: Paul Hubbard, Emeritus ADAC Executive Counselor



Heather Quilenderino, CDR, USN, Director, National Ice Center, Suitland, Maryland.

Figure 4: Heather Quilenderino, Emeritus ADAC Executive Counselor

ADAC Affiliated Researchers.

ADAC continued to maintain affiliated researchers on pro-bono, non-compensated basis due to their professional interests and support to the Center. At the close of Program Year 7 Ms. Nicole Kinsman, NOAA, Mr. Riley Owen, LCDR Adriana Gaenzle, USCG, LT Kristopher Thornburg, USCG, Mr. Alexander Evers, OSD, Mr. Scott Blough, Tiffin University, and Ms. Brenda Dunkle, Booz-Allen-Hamilton (BAH). Note, ADAC has a very active affiliation with Ms. Dunkle as she is pursuing a PhD with a strong Arctic operations nexus.

ADAC Student Fellows.

The events and progress of the Workforce Development (WFD) Fellowship Program are more comprehensively covered in the ADAC Student Activities section of this report. To summarize, ADAC Fellows perform a variety of support functions for the center while gaining valuable professional skills to succeed in a career within the Homeland Security Enterprise (HSE) and beyond. Fellows have the opportunity to participate in almost every aspect of the Center's activities: from performing critical technical support for project research teams to participating ADAC hosted or affiliated events. ADAC's student fellows aided with a number of ADAC supported or hosted events including but not limited to ACCUSARS I Workshop in September 2020, the 2020 Maritime Risk Symposium in October, the January 2021 Alaska Marine Science Symposium, the May 2021 COE Summit, and ADAC's 2021 Program Year 7 Annual Meeting.

The program is made possible by two distinct funding streams: a small number funded via DHS S&T OUP Supplemental Career Development Grant (CDG) and a larger number resourced via Education Outreach and Workforce Development, as part of the overall ADAC Award. ADAC Fellows participated in projects associated with ADAC DHS S&T OUP approved Program Year 7 Workplan or directed studies managed via Center leadership. Upon graduation, ADAC Fellows seek employment within the Homeland Security Enterprise (HSE).

Ultimately COVID-19 did not limit the opportunity for students to present their research to the public as students instead participated in virtual opportunities through Program Year 7. Due to the risks associated with the COVID-19 crisis, ADAC had to cancel its traditional in-person Arctic Summer Internship Program in 2020. In its place, the ADAC Team transitioned ASIP into an entirely virtual 10-week summer internship. With the leadership of the program's Principal Investigator, Dr. Craig Tweedie from the University of Texas at El Paso (UTEP), and program development coordination by

ADAC's Education & Administrative Manager, Ellee Matthews, ADAC's new online internship program began on June 2nd, 2020, and ended on August 6th, 2020.

In total, 9 students graduated during Program Year 7: one student graduated in the summer of 2020, three graduated in the Fall of 2020, and remaining five graduated in Spring 2021.

Summary of Center Research Management Process.

Quarterly Reviews. Center Leadership continued to provide oversight and accountability for the ADAC's research projects through Quarterly Reviews. These forums are scheduled to provide an opportunity for research teams to share results, milestones, and challenges encountered in each Quarter of the Program Year. ADAC originally established this mid-year review to help ADAC prepare for its first Bi-Annual review in March 2016. These Reviews occurred on 24 September 2020, 8 January 2021, 29-30 April 2021, and 17 June 2021,

Transition Planning. A critical function of ADAC's activities is to prepare technology and research developed through the Center for real-world, end-user applications. A principal focus of Year 7 remains the preparation of research teams for the transition of mature research to industry, HQ USCG CG-7 (Assistant Commandant for Capabilities), and HQ USCG CG-9 (Assistant Commandant for Acquisitions) through the adoption of ADAC's "Research-to-Capabilities Process" (RTCP). The Quarterly Review process provided dedicated time between Center Leadership and research teams to coordinate transition planning activities. Additionally, Center leadership and respective research teams prepared teams for the RTCP process by engaging with USCG Project champions and planned destination "end-users" via meetings or electronic communications to ensure research was progressing in a manner to meet the ends of the planned end user and USCG "Customer." Details on the transition status and plan for ADAC research projects can be found in the project report sections

Reporting. ADAC Center leaders achieved the necessary engagement and reporting requirements of DHS S&T OUP through close coordination between Center's leadership and research teams, to include routinely scheduled weekly meetings between DHS S&T OUP Program Manager and ADAC leadership. Comprehensive, project by project reporting was accomplished via the ADAC Virtual Annual Meeting in June 2021, Program Year 8 Workplan, approved in July 2021, and the Year 7 Annual Report. For ADAC Annual meeting details, please see https://arcticdomainawarenesscenter.org/AnnualMeeting_2021_Hub

Summary of ADAC's Communication Efforts

ADAC has continued to remain engaged with strategic partners and the broader public through the Center's Communications efforts in Program Year 7. ADAC conducted high level of direct engagement with the Center's Federal partners at DHS, USCG, and other Federal departments and agencies. ADAC has also continued to have a broad reach of engagement with academic institutions, commercial enterprises, tribal organizations, and local communities within Alaska, the United States, and the Arctic Region.

Customers' and Partners' Roundtables. ADAC's Customers' and Partners' Roundtable teleconferences continue to serve as important point of engagement for ADAC's Leadership and Researchers with a wide range of interested partners. ADAC continues to find these teleconferences especially useful for inform the development of research at the Center and to inform potential use-cases of ADAC produced technology. Conducted quarterly, ADAC Customers and Partner's Roundtables serve as an exchange opportunity with:

- Arctic-focused community of USCG operators (seen by ADAC as the Center’s “customers”).
- Federal government research entities.
- State of Alaska, primarily, environmental response agencies.
- Academic Institutions engaged with Arctic Research.
- Industry and Commercial enterprises focused on the Arctic.
- International research collaborators.

As these forums were conducted virtually in previous program years, these tele-conferences have remained relatively unaffected by COVID-19. In Program Year 7, ADAC conducted these teleconferences on 30 September 2020, 15 January 2021, and 1 April 2021. ADAC conducted an equivalent session through Annual Meeting in June 2021 which served the same function as a Customers’ and Partners’ Roundtable.

Beyond the structures of these forums, ADAC also conducts other leadership and researcher engagement activities through both in-person and virtual meetings, workshops, symposiums, and affiliated events. ADAC also produces high-quality content to educate interested parties in research achievements, staff accomplishments, and other center activities on a consistent basis. In these efforts, ADAC strives to relate to importance of the investing in science and technology that advances domain awareness in the strategically vital region of the Arctic to a variety of audiences. The following illustrates ADAC’s comprehensive communications efforts.

ADAC Video Shorts. ADAC has continued to produce and release video shorts to highlight the Center’s activities, research, and people. These videos are published online through the website and are available to wider audience on YouTube. In total, ADAC personnel have published 20 videos on YouTube within the past year covering a variety of topics from updates on research projects to ADAC hosted events. These videos are an essential tool engage both federal customers and a wider audience in importance of ADAC’s work and mission. These videos have help to expose ADAC’s work to previously unreached audiences within the Arctic including Alaskan Native and Rural communities as well as international researchers. URL: <https://arcticdomainawarenesscenter.org/Media.html>.

Social Media. ADAC has continued to advance its messaging around Center Activities through Facebook and other social media platforms in Program Year 7. Updates include not only center activities but highlight important and interesting events happening the Arctic, facilitating greater interest in the geostrategic importance of the Arctic. These updates serve as an important point of engagement for University students, aiding with the recruitment of Center fellows. URL: <https://www.facebook.com/ADACAlaska/>

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 disseminating information about current and future activities and opportunities. Achieving an IARPC Collaborative Network strongly connects ADAC research to the U.S. Arctic scientific community, enabling the Center to reach more comprehensive audiences. Throughout ADAC Program Year 7, the Center has continued to leverage the Arctic Domain Awareness Center’s vast Network on several IARPC Collaborations. Such access is important to further research idea generation and to widely advertise ADAC activities and opportunities, thereby cementing the Center as a universally recognized Arctic institution.

Quarterly Newsletters. ADAC has continued the Center’s practice of publishing Quarterly Newsletters throughout Program Year 7. Traditionally, these publications featured significant Center activity by highlighting various research projects, interaction with key ADAC customers and partners, and showcasing ADAC student Fellows and their contributions to the Center. ADAC’s Quarterly Newsletters provide a platform to update and inform of recent Center activities, ongoing research, and upcoming events to ADAC’s customers, transition partners, and research collaborators. In Program Year 7, Center staff expanded the scope of these Newsletters to include more Arctic content featuring topics outside of ADAC’s research projects and activities. ADAC published Newsletters in September 2020, December 2020, May 2021. URL:

<https://arcticdomainawarenesscenter.org/Publications>

Updates and improvements to ADAC’s webpage. ADAC’s webpage continues to serve as an accessible point for the public and partners to learn about ADAC’s objectives, activities, and history. The webpage functions in part as a repository of Center activities, reports, workplans, specific research, current and prior newsletters, student events, and other items of interest. This product is continuing to mature as an increasingly robust resource 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.

The amount of content available on the website has expanded significantly as ADAC continues to host materials, recordings, and reports from previous convening events. Event hubs from previously hosted ADAC events are preserved on the website, allowing ADAC’s partners and the public to benefit from Center supported events long beyond the conclusion of an event.

Figure 5 Front Page of ADAC’s Website



III. ADAC PROGRAM YEAR 7 PROJECT DESCRIPTIONS ALIGNED TO DHS CMR FOA THEMES:

THEME 1: Maritime Risk, Threat Analysis, and Resilience Research Projects:

1. Mitigating the Damage to Arctic Copepods from Surface Oil Spills: When to Apply Dispersants.
2. Photo-enhanced toxicity of dispersed and burned crude oil to Arctic mussels.
3. Marine Induced Polarization Methods for the Detection and Mapping of Oil in an Arctic Marine Oil Spill, including investigation of Oil within and Under broken ice fields.
4. Oil Spill Modeling for Improved Response to Arctic Maritime Spills: The Path Forward.
5. Arctic Facilities and Infrastructure Environmental Change Risk Index.

PROJECT: Mitigating the Damage to Arctic Copepods from Surface Oil Spills: When to Apply Dispersants

Project Investigators: Dr. Christoph Aeppli, Dr. David Fields.

Lead Institution: Bigelow Laboratory for Ocean Sciences, East Boothbay, Maine.

Supporting Team: Erin Beirne and Maura Niemisto, Bigelow Laboratory for Ocean Sciences.

Project Champion: CAPT Kirsten R. Trego (USCG) HQ CG-5RI

Project Description:

Abstract:

While dispersants are a highly efficient and proven tool for oil spill response in sub-Arctic and Arctic environments, there is concern about negative impacts on *Calanus* spp. copepods, which are critical zoo planktonic organisms in the overall Arctic food chain. Current risk assessment of oil toxicity towards copepods do not account for their vertical movement, potentially leading to a significant spatial separation between toxic compounds and animals, even in the presence of dispersants. This ADAC research project advanced and applied a novel and more environmentally realistic system to measure the impacts of dispersed oil towards Arctic copepods. A new research method using seawater towers (2-m vertical mesocosms) that allow chemical introduction to Calanoid copepods in a vertical regime allowed researchers to test the main hypothesis of this project: in the ocean, Calanoid copepods can spatially separate themselves from surface oil spills during portions of their developmental cycle. Therefore, they might be exposed to much lower concentrations and for much less time than has been assumed based on currently used laboratory studies.

Objective/Purpose:

In Program Year 7, this project worked to address the research question: what is the impact of an oil spill, *with* and *without* dispersant, on copepods that are able to move vertically in the water column, thereby potentially avoiding the oil? In order to address these questions, the research plan was focused on addressing three objectives:

- Objective 1: Determine whether *C. finmarchicus* copepods actively and effectively avoid oil in mesocosm experiments (Phase I of this project).
- Objective 2: Investigate how dispersants influence the exposure of subsurface animals to oil products (Project Phase II).
- Objective 3: Determine how water column stratification influences the contact between copepods and oil (with and without dispersants) (Phase III).

In order to achieve these objectives, researchers investigated this migration behavior in a novel mesocosm system, which allowed us to determine the effects of dispersants and oil in a more environmentally-relevant condition than the traditionally-used systems using a water-accommodated fraction (WAF) or chemically enhanced WAF (CEWAF, i.e., oil with dispersants). Specifically, investigators performed experiments using 2-m vertical mesocosms in which copepods could move vertically in the water column. Furthermore, this system allowed us to investigate the effects of water column stratification on the distribution of oil and copepods. Researchers used *C. finmarchicus* as a model *Calanus* species to test associated project hypothesis. These results, once finalized, fill critical knowledge gaps about the toxicity of oil and dispersants on *Calanus* spp. copepods, which are essential organisms for the Arctic food web as well as for commercial fishery. This knowledge is useful to support USCG led federal on-scene response of an Arctic maritime oil spill.

Methodology:

The project's research method was a sequenced set of scientific laboratory experiments conducted by a select and qualified team of marine biologists. The research team is underway in investigating the effect of dispersed oil and vertically migrating copepods.

In Project Year 6, experiments with 100-L mesocosms ("Copepod towers"; constructed in Year-5) were conducted. These mesocosm systems allowed for measurable vertical migration of copepods (*Calanus finmarchicus*) as well as for oil/dispersant concentration gradients along the depth of the mesocosms. Test protocols were developed where 5 mL of pre-evaporated Alaskan North Slope (ANS) crude oil per column was added, producing a 100-um thick oil sheen. For the dispersed oil treatment, Corexit EC9500 (NALCO Environmental Solutions LLC), was mixed with crude oil at the recommended 1:20 dispersant-to-oil ratio and added on top of the copepod towers. The dispersion was formed by adding wind energy through an air pump that directed an air stream on top of the water surface.

During the experiments, the copepod behavior was observed using video observations of free-swimming copepods, and hydrocarbon concentration (total particulate oil and aqueous concentration of individual PAHs) are measured. The resulting data sets were used to determine:

1. If copepods avoid the oil actively (by swimming), passively (by being immobilized and sinking) or not at all.
2. How a stratified water column affects this behavior.

Note: as this project was investigating invertebrates, Institutional Animal Care and Use Committee (IACUC) protocols have not been required.

Student Involvement:

Two students, who started participating in remote summer research internships during Year 6 (June 2020) ended their internships in the beginning of Year 7 (August 2020). The internships consisted of student involvement in analysis of data captured during Copepod experiments. Students reviewed video and imagery of Copepod behaviors when exposed to oil and dispersants and annotated results.

2020-2021 Key Accomplishments:

Phase I: Oil Avoidance of Copepods: The evaluation of the experiments conducted in Year 6 was completed. As shown below (Figure 1, left panels), the copepod reacted to sub-lethal levels of oil, and a significant decrease of copepods was observed throughout the water column. The oil concentrations were low and were around 5 to 10 ppm after 5 hours. This is a realistic oil concentration for oil spills in the field. The results of all the Phase I experiments were synthesized as a manuscript for submission to a peer-reviewed scientific journal.

Phase II: Dispersants & Copepod Contact: All proposed experiment for Phase II were performed, and analyses and data evaluation were performed. As expected, the addition of dispersants significantly increased the oil concentrations in the water column. As a result, the copepods reacted faster and to a greater degree to the oil addition (Figure 1; right panels). The top of the water column was depleted by > 95% at the end of five hours. At lower depths, a pulse of copepods was observed traveling down the water column. Accompanying experiments showed that the pulse of oil led to copepod deactivation, which makes copepod sink in seawater. These copepods were able to recover in clean seawater. The implication for field application of dispersants is that a pulse of oil likely leads to copepods sinking to depths with lower oil concentrations, where these animals can recover. If these animals recover completely (which has not yet been tested), the dispersant application will only lead to a temporary effect on a copepod population. The combined results of Phase I and Phase II experiments were synthesized as a manuscript for submission to a peer-reviewed scientific journal.

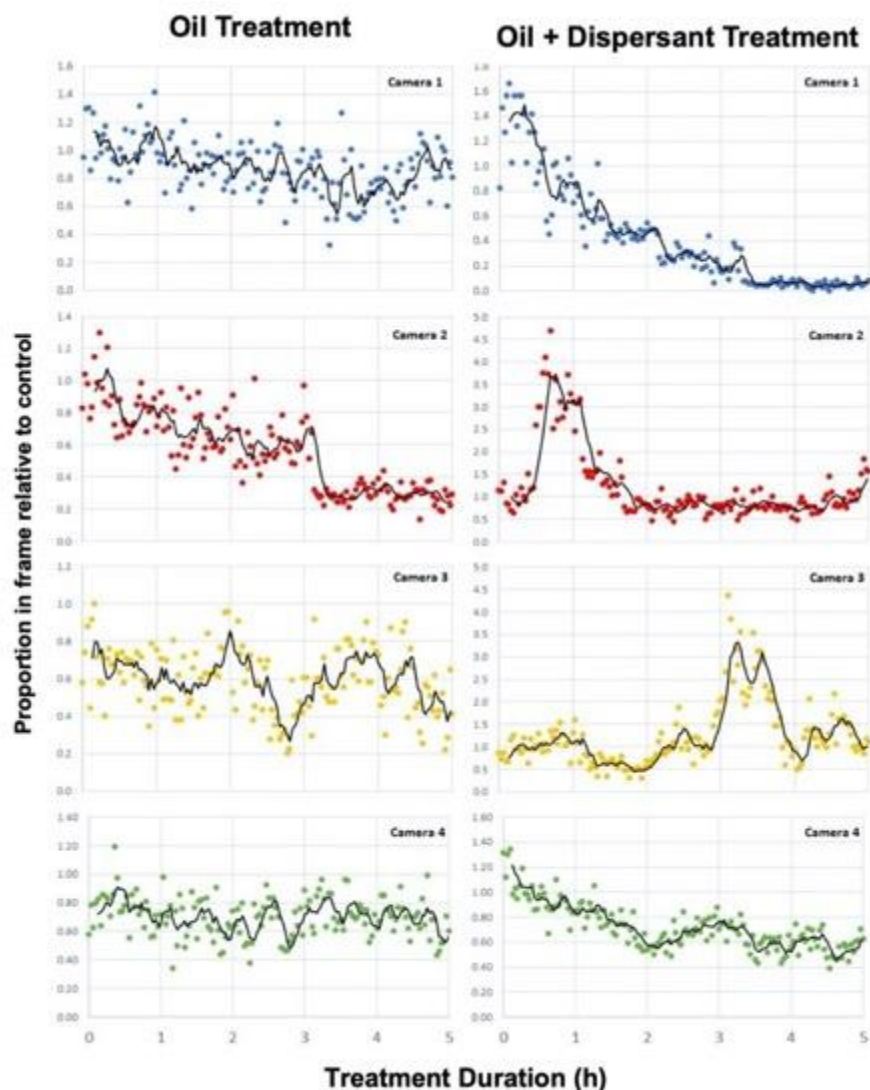


Figure 6: Copepod distribution in the water column during non-dispersed oil treatments

Figure 6 illustrates (Phase I; left panels) and dispersed oil treatments (Phase II; right panels). Shown are the proportion of copepods counted in camera 1 (top of the water column) to camera 4 (bottom of the water column) relative to the start of the experiment.

Phase III: Influence of Stratification: Experiments were conducted to test the influence oil/dispersants on copepods in a *stratified water column*. To this end, researchers equipped the towers with a circulating cooling plate fueled by a water chiller to cool the water column from below. An incandescent red light hangs just above the water surface to warm from the top. Seven temperature-loggers were distributed through the tower at 25cm intervals to collect continuous light and temperature data. Using this setup, experiments were conducted with dispersed and non-dispersed oil. The stratification led to a decreased advection and diffusion of oil compound between the top and bottom water column, which led to low oil concentrations throughout the experiments.

This is a realistic scenario for an oil spill in summer conditions, where the warm top water column is separated from the cold bottom water column. Apparently, this barrier between the top and bottom water column was passable for copepod, as an increase in copepods was observed in the lowest water column depth in our experiments. The implications from this observation are that impacts of dispersant application in a stratified condition is limited to the top water column, and that copepods can escape to lower, cleaner water depths, where they can recover. The results of this investigations were written up as a manuscript for publication in a peer-reviewed scientific journal.

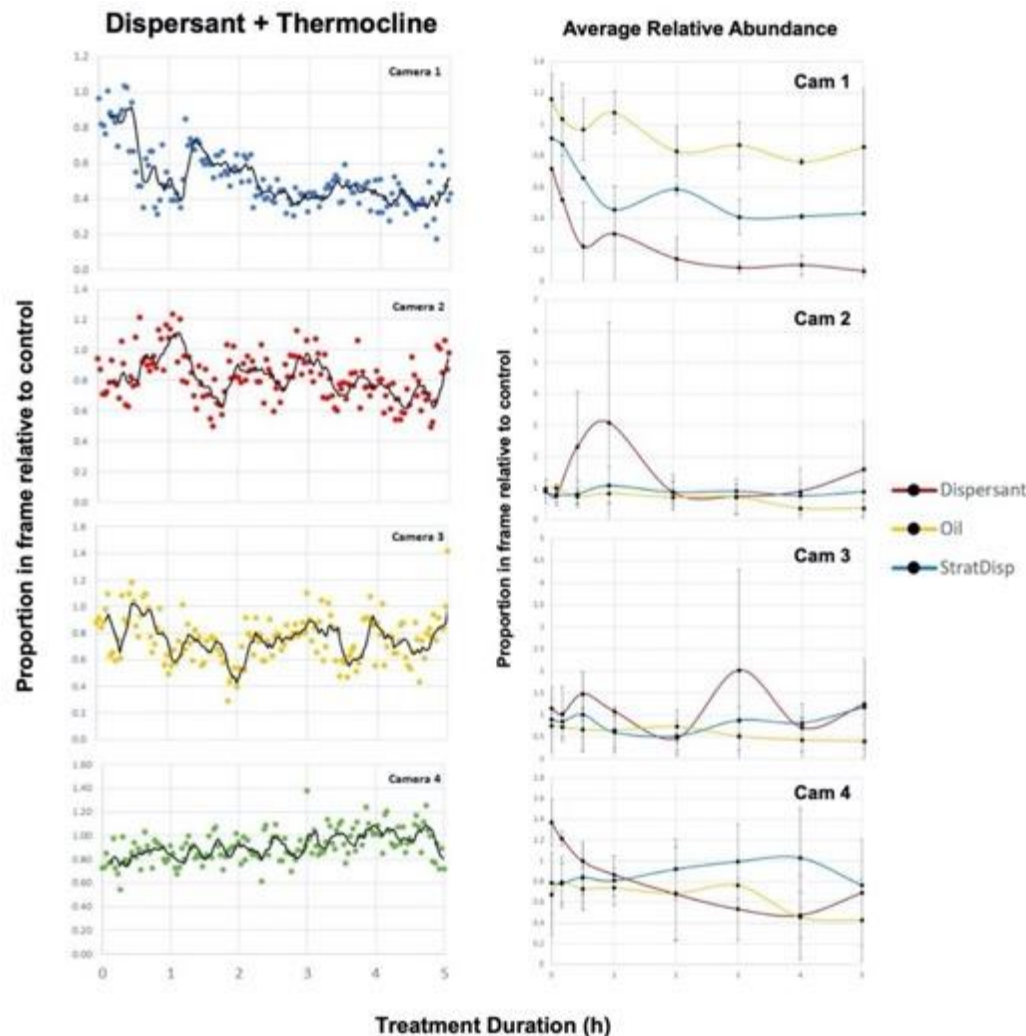


Figure 7: Copepod distribution in the water column during oil treatment in a stratified water column

Figure 7 illustrates (Phase III; left panels) and a summary of three different treatments (non-dispersed, dispersed, and dispersed in a stratified water column; right panels). Shown are the proportion of copepods counted in camera 1 (top of the water column) to camera 4 (bottom of the water column) relative to the start of the experiment.

Key Stakeholder Engagement:

Project team participated in four ADAC Customers and Partners Roundtables. During the Customers and Partners Roundtable, the project team provided a brief technical summary of their project and answered questions from federal customers and interested parties including representatives from the US Coast Guard and National Oceanic and Atmospheric Administration.

Key Publications (peer reviewed):

Two manuscripts were written for submission to peer-reviewed scientific journals, in addition to the final knowledge product. At the time of writing the annual report, those papers were under review^[KF1].

Key Presentations:

The Project team presented at ADAC Program Year 7 Annual Meeting. The Annual Meeting was held virtually.

The Project team presented the results of this project at the 2020 C-ICE conference, which was held as a virtual conference.

Changes from Approved Year-7 Workplan:

N/A

Project progress against each milestone:

Table 5; Copepods Project Milestones

MILESTONE	COMPLETED	WHY NOT REACHED? (IF APPLICABLE)
Phase I: Oil avoidance of copepods (Tasks 1-4 were completed in Year 6)	Completed	N/A
Task 5: Manuscript 1: Oil avoidance	Completed	N/A
Phase II: Dispersants and copepod contact	Completed	N/A
Task 6: Experiments with dispersed oil	Completed	N/A
Task 7: Copepod data evaluation	Completed	N/A
Task 8: Chemical analysis and data evaluation	Completed	N/A
Phase III: Influence of Stratification	Completed	N/A

Task 9: Stratified water column: Experiments with copepods	Completed	N/A
Task 10: Copepod data evaluation	Completed	N/A
Task 11: Chemistry analysis & data evaluation	Completed	N/A
Task 12: Manuscript: copepod and oil interactions	Completed	N/A
Task 13: Final Report	Completed ^[MOU2]	N/A
Other		
Presentation at 4 quarterly reviews, 4 quarterly customers & partners roundtables, and the annual meeting	Completed	N/A

Project progress against each metric:

Table 6: Copepods project metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Task 2: Successfully perform 8 experiments: with and without oil (2 treatments) in 4 replicates, and record data. (Task 1 was completed in Year 6)	Completed	N/A
Task 3-5: Evaluate and quality control 100% of the data recorded in Task 2: copepod behavior and chemical data, Prepare one manuscript for publication in a peer-reviewed scientific journal.	Completed	N/A
Task 6: Successfully perform 6 experiments: with and without oil/dispersant mixture (2 treatments: control, oil/dispersant), in 3 replicates, and record data	Completed	N/A

Task 7-8: Evaluate and quality control of 100% of data recorded in Task 6.	Completed	N/A
Task 9: Perform 9 experiments with a stratified water column; 3 treatments (control, oil, oil/dispersant), in 3 replicates.	Completed	N/A
Tasks 10-11: Evaluate and quality control 100% of data recorded in Task 9.	Completed	N/A

Outcomes/output and TRLs:

Outputs: Overall Outputs for the entire project include:

- Technical Report (Task 13): Project Team created a report with all the results of this research for USCG and DHS S&T UP.
- Manuscripts for Peer-Reviewed Publications (Tasks 5 and 12): Researchers produced manuscripts two peer-reviewed scientific publications from this project, where all the results from this project will be described and discussed: (i) Do copepod avoid oil? (ii) The effect of surface oil and dispersed oil on vertically mobile copepod.
- Ensure Publicly Available Data: All data produced during this project are publicly available through electronic supporting information associated with the publications
- ADAC posted all data and reports to the Center's website.
- Technology Readiness Level (TRL): This project outcome is in the form of a knowledge product in support of USCG Federal On-Scene Coordinated spill response as a result of fundamental research and accordingly operates in TRL 1-3. As planned research tested the Hypotheses 1: Subarctic copepods and dispersants are spatially separated in a stratified ocean, and Hypothesis 2: Subarctic copepods can actively avoid hydrocarbons, in a mesocosm setting.

Outcomes: Overall Outcomes include:

- Informing Oil Spill Response. Adding dispersants to the oil spill may redistribute the oil deeper into the water column reaching copepods well below the surface. Our data help to provide seasonal and time of day protocols to minimize harm to copepod populations.
- Establishing an Environmentally Relevant Testing System. The toxicity of oil to copepods is well known. However previous studies have exposed the copepods to homogeneous concentrations of oil with no opportunity for the animals to avoid the oil. This study provided a more realistic scenario where copepods were free to move vertically in the water column to actively avoid the hydrocarbons or passively avoid the oil through pre-programmed behavioral patterns.
- Training Next Generation of Scientists. This project trained two undergraduate students during the summer 2020 (May-August 2020) academic year in evaluation of experimental data (copepod video data, oil droplet distribution data).

Technology Readiness Level (TRL): This project is fundamental research and is currently in TRL 1-3, which tested the Hypotheses 1: Subarctic copepods and dispersants are spatially separated in a

stratified ocean, and Hypothesis 2: Subarctic copepods can actively avoid hydrocarbons, in a mesocosm setting. Advancing this research into TRL 4-5 (verification of oil impact on zooplankton in a larger-scale environment) would be possible in the future with a new set of experiments, such as investigations in large-scale (>2,000 L) _mesocosm tanks.

Unanticipated problems and plans for addressing them in Year 7:

N/A

Transition Activities: [MOU3]

Transition plans and progress made: ADAC and Project team is ensuring the results of this fundamental research are useful for the USCG and DHS mission and is oriented to support USCG-led spill response for decisions making in dispersant application. Transition is straightforward:

- Completion of comprehensive knowledge product (Technical Report) to provide to U.S. Coast Guard Project Champion. ADAC and Project Investigators will iterate and coordinate Knowledge Product with Project Champion and Project Champion designated advisors as desired and directed, to include providing a summary users guide.
- As discussed, ADAC and Project team will conduct a structured inquiry to the Alaska OSRO and the response community to discuss how to make the findings widely available to response decision makers, advisors, dispersant experts, and the general response community. ADAC and research team will also advance peer-review journal submissions to inform the scientific and spill response community.
- The final project technical report, as well as the scientific publication resulting from this research, provides scientific data about the extent and timing the use of dispersant could impact a key player in the Arctic food web, useful to FOSC decision making.
- ADAC leadership, in partnership with the research team, will communicate knowledge products with ICCOPR and Regional Response Team in Alaska [KF4].
- Research team will provide full range of research products to ADAC's web portal at completion and any further research destination as determined by the HQ USCG Project Champion.

PROJECT: Photo-enhanced toxicity of dispersed and burned crude oil to Arctic mussels

Project Investigator: Patrick Tomco, PhD

Lead Institution: University of Alaska Anchorage

Supporting Team: Colin McGill, UAA Chemistry Department, Katrina Counihan, Alaska Sea Life Center, Phoebe Zito, University of New Orleans

Project Champion: LCDR Clifton Graham, USCG, HQ CG-MER

Project Description:

Abstract:

This project studied the direct effects of oil, dispersants, and *in-situ* burning, along with photo-enhanced effects, on several physiological, biochemical, and metabolic aspects of a cold-water species of mussel (*Mytilus trossulus*). Sunlight-exposed oil is potentially more toxic to aquatic organisms than non-weathered oil, yet there remains little information on what effects (if any) dispersants and in-situ burning have on bay mussels in the arctic environment when exposed to sunlight, which in the summer months is continuous. This study sought to determine if dispersed oil or herded/burned oil are more toxic to bay mussels than oil alone and if these effects are more pronounced during periods of long sun exposure. Researchers also sought to determine the changes in chemical composition of Alaska North Slope (ANS) crude oil as it is exposed in each of these scenarios. Since these concentrations that marine life would be exposed to during an oil spill are realistic, these results are applicable to management decisions on the use of recovery methods.

Objective/Purpose:

The goal of this project was to understand which response method (dispersants vs in-situ burning) has a greater effect on Arctic mussel toxicity and whether the extreme seasonal differences in sunlight can affect acute sublethal response. Accordingly, this project sought to address the following objectives:

- **Objective 1:** Conduct static exposure tests with bay mussels in seawater with oil, Corexit 9500, oil dispersed with Corexit 9500, and oil subjected to *in-situ* burn with three different photoperiods.
- **Objective 2:** Assess physiological and biochemical responses of bay mussels to the oil, dispersant, and *in-situ* burned oil in the exposure tests at different time points.
- **Objective 3:** Evaluate metabolic health of mussels in the exposure tests using metabolomics.
- **Objective 4:** Profile the chemical constituencies of oil, dispersed oil, and burned oil treatments used in the mussel exposures and how each treatment chemically weathers throughout the experiment.

Methodology:

Project method was a laboratory-based exposure study coordinated through three entities (Alaska Sealife Center, UAA, and UNO) designed to generate a substantial, scientific research derived knowledge product.

Note: as this project was investigating invertebrates, Institutional Animal Care and Use Committee (IACUC) protocols have not been required.

A principal question this research addresses in support of U.S. Coast Guard decision makers leading Unified Command in an Arctic maritime is: *Disperse or Burn? Is one strategy more toxic at different times of year due to sunlight?* Despite some of the benefits dispersants and *in-situ* burning appear to have in oil spill mitigation, opinions on the utilization of these strategies are polarized, and the issue required careful consideration and study. The presence of continuous sunlight in the summer months potentially confounds our knowledge of the seasonal toxic effects that these treatment strategies pose in comparison to no action.

The goal of this project was to understand which response method (dispersants vs in-situ burning)

has a greater effect on Arctic mussel toxicity and whether the extreme seasonal differences in sunlight cause each response strategy to be more toxic in the summer than in the winter.

In order to achieve this goal, the research team had methodology to proceed in five phases. During Program Year 7 reporting period, the project team pursued Phases 2-5 (see section on “Key Accomplishments”). All five phases of the project are listed below

- Phase 1: Construct exposure apparatus, collect mussels, and conduct laboratory-based exposures (completed in Year 6)
- Phase 2: Conduct physiological and biochemical assays
- Phase 3: Perform metabolomics analysis
- Phase 4: Profile chemical constituencies of water-accommodated petroleum and photo-degraded petroleum
- Phase 5: Synthesize data and prepare knowledge products

Student Involvement:

Three graduate students received training and been involved in this project. Anastasia Hanson, Kevin Fitzpatrick, and Katherine Humpal (ADAC graduate fellow) have been involved with and received training on appropriate methods for sample collections, experiment design, instrument analysis, and data curation.

2020-2021 Key Accomplishments:

Program Year 7 completed activities include:

Phase 2 (complete):

Phase 2 was completed during the first half of program year 7. These include the following physiological and biochemical assays.

- **Cytochrome P450.** The digestive gland was used to measure P450 activity by homogenizing it in buffer (25 mM Hepes, 125 mM NaCl, 0.1 mM EDTA, 0.1 mM dithiothreitol) at a 1:5 weight to volume ratio. The mixture was centrifuged at 1,500 x g for 10 minutes at 2 °C and the supernatant transferred to a clean tube. The supernatant was centrifuged at 10,000 x g for 20 minutes at 2 °C. The supernatant was discarded, and the pellet re-suspended in microsome buffer (25 mM Hepes, 140 mM NaCl, 1 mM KH₂PO₄). A microsome sample was incubated with 30 uM rifampin for 48 hours to be used as a positive control. A 96-well plate was inoculated with each microsome sample in triplicate. A media only blank was included, as well. Each well had 50 µM BFC solution (7-benzyl-4(trifluoromethyl) coumarin in phenol red-free Dulbecco's Modified Eagle Medium) added and the plate incubated for 4 hours at room temperature. Stop solution (80% CH₃CN, 20% 0.5 M Tris base) was added to each well and the plate read on a SpectraMax Gemini EM fluorescent microplate reader (Molecular Devices) at 410 excitation, 530 emission.

Results indicate P450 response was elevated in all treatments above controls. Oil, Dispersant, Dispersed oil, and Burned oil each induced P450 activation under all

light conditions with the exception of dispersant-only under 24 hrs.

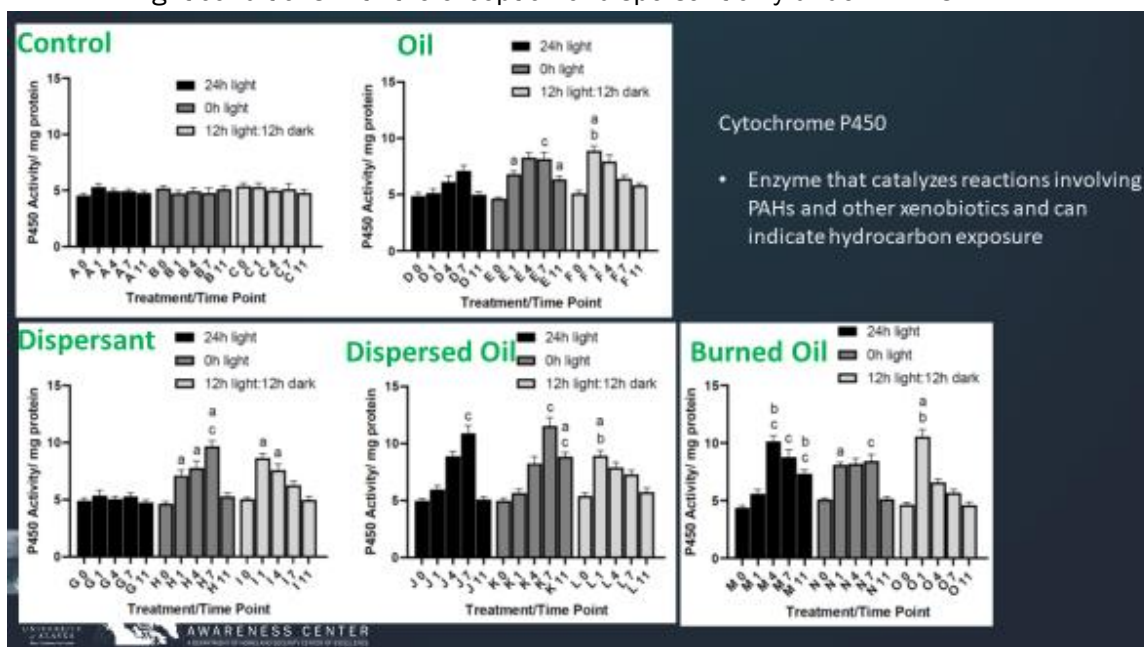


Figure 8: Cytochrome P450 measurements

- Measure Heat Shock Protein.** A portion of the gill was homogenized and lysed in buffer (150mM NaCl, 1% Triton-X 100, 0.5% sodium deoxycholate, 0.1% sodium dodecyl sulphate, 50mM Tris, 1mM phenylmethylsulfonyl fluoride) at a ratio of 0.5mg tissue to 0.3ml buffer. An additional 2 volumes of buffer were added, and the solution agitated for 2 hours at 4 °C. The homogenate was centrifuged at 12,000 rpm for 20 minutes at 4 °C and the supernatant collected. The protein concentration was determined using a Bradford assay. The sample was mixed 1:1 with 2X Laemmli buffer and boiled at 100 °C for 5 minutes and then loaded on a gel. The gel was run using SDS-PAGE to separate the proteins. Each gel was run with a positive heat shock protein control and a molecular weight marker. The gel was electrophoretically transferred onto a polyvinyl difluoride (PVDF) membrane. Total protein was visualized by staining the gel with Pierce reversible protein stain (Thermo Scientific, Pittsburgh, PA USA). After the membrane was photographed, the stain was removed. A Western blot was then conducted to detect heat shock protein 70 by blocking the membrane with PBS that contains 5% BSA and 0.1% Tween 20. The membrane was probed with anti-heat shock protein. The membrane was washed, and a secondary alkaline phosphatase labeled anti-mouse antibody was incubated with it. The membrane was washed again, and an alkaline phosphatase substrate added. The membrane was photographed to document bands.

Results indicate that heat shock protein was elevated in dispersed oil and burned oil treatments relative to controls and relative to oil-only. 24hr light had a greater impact than 12h and 0h treatments.

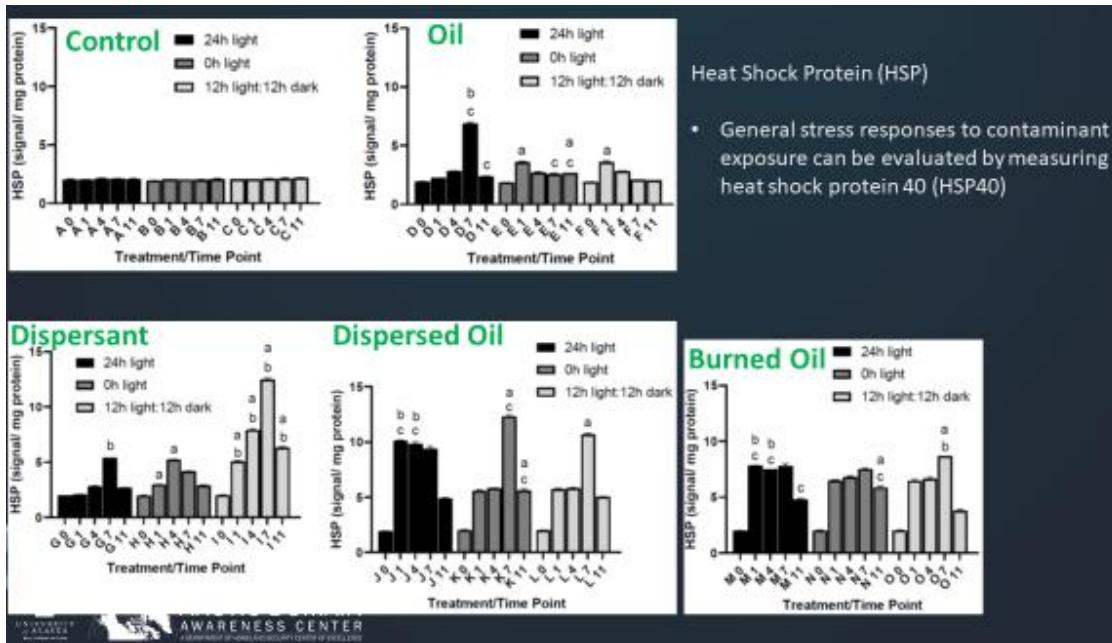


Figure 9: Heat Shock Protein measurements

- Measure Superoxide Dismutase.** Half of the digestive gland was homogenized in 1:5 w/v 0.05M phosphate buffer. The homogenate was centrifuged at 10,000 x g at 4°C for 20 minutes. The supernatant was collected and diluted 1:5 v/v with phosphate buffer. The diluted supernatant was tested in triplicate in 96-well plates to determine superoxide dismutase (SOD) activity. Each sample had reaction mixture added (1mM EDTA, 0.1M NaOH, 4.7mM xanthine, 0.2M cytochrome c, 6.7mU xanthine oxidase in 50mM sodium phosphate buffer). The amount of SOD activity in each sample was determined using a standard curve.

Results indicated that Dispersed Oil in 12 h light had the greatest impact on SOD activity.

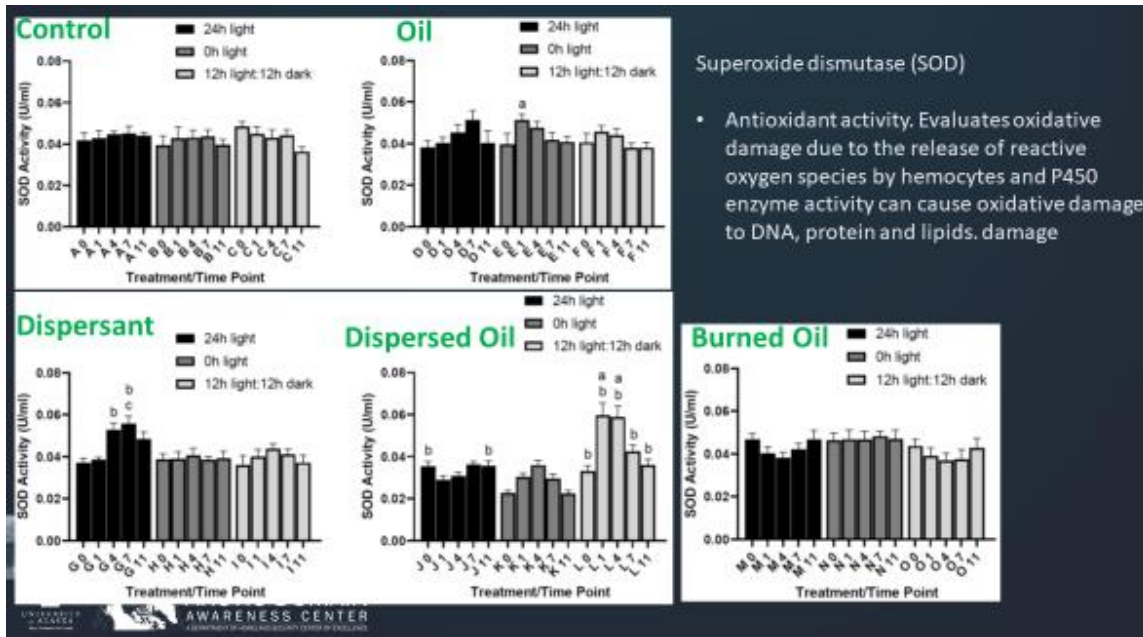


Figure 10: Superoxide dismutase measurements

- Measure Micronuclei.** Each mussel had 2 branches from their gills removed and each one was placed in a drop of 3:1 ethanol acetic acid on a microscope slide. The gills were dissociated with tweezers and the suspension spread across the slide to dry. Dried slides were fixed with methanol and stained with Giemsa solution. Stained slides were examined under a microscope at 1000x magnification to score micronuclei, nuclear buds, bi-nucleated and fragmented-apoptotic cells

Results indicate that nuclear bridging increases following exposure to oil, dispersant, dispersed oil, and burned oil, without significant differences between treatments or between light conditions.

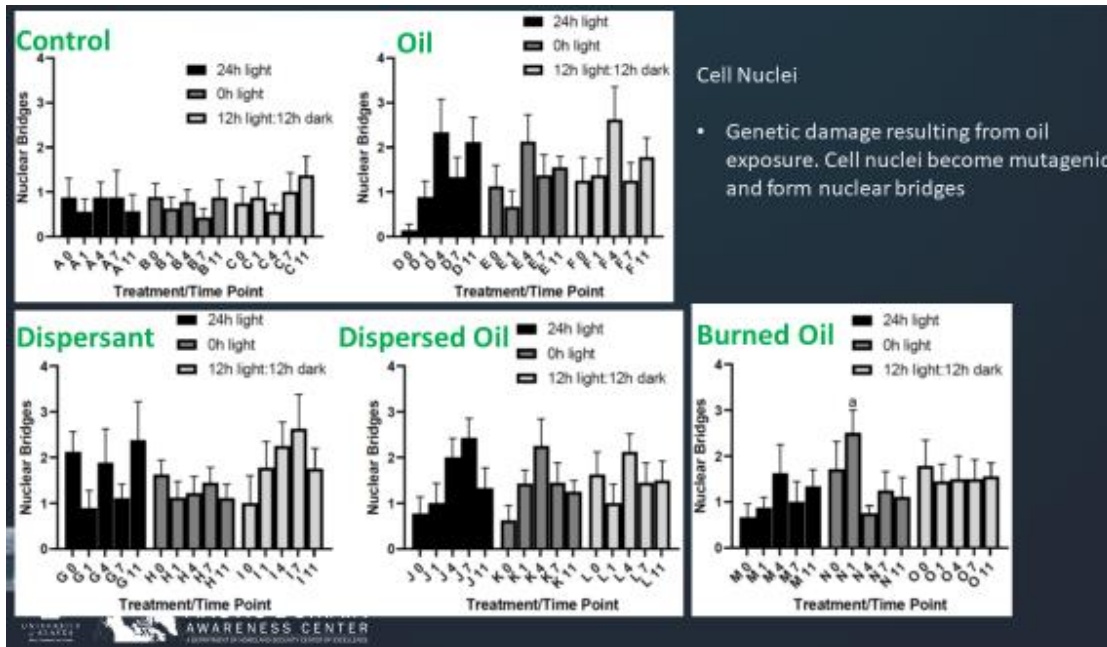


Figure 11: Cell Nuclei genetic damage measurements

Phase 3: Evaluate metabolic health of mussels in the exposure tests using metabolomics (completion in program year 8). Posterior adductor muscle samples were collected, then flash frozen in liquid nitrogen. The frozen samples were ground in a liquid nitrogen-cooled homogenizer and lyophilized overnight. The metabolites were extracted using a 2:1 methanol/water solution and dried in a SpeedVac and once again lyophilized overnight. The samples were kept frozen at -80 °C until analysis at UAA, where spectra are collected on a JEOL 400 MHz NMR spectrometer. After spectral acquisition, signals correlating to specific metabolites were assigned according to tabulated chemical shifts in Chenomx NMR software, then converted to a statistically analyzable format. Binned sample spectra were statistically analyzed.

Our preliminary data assess large-scale trends in the metabolic health of mussels. Further analysis by specific factors (e.g., treatment and light) is ongoing.

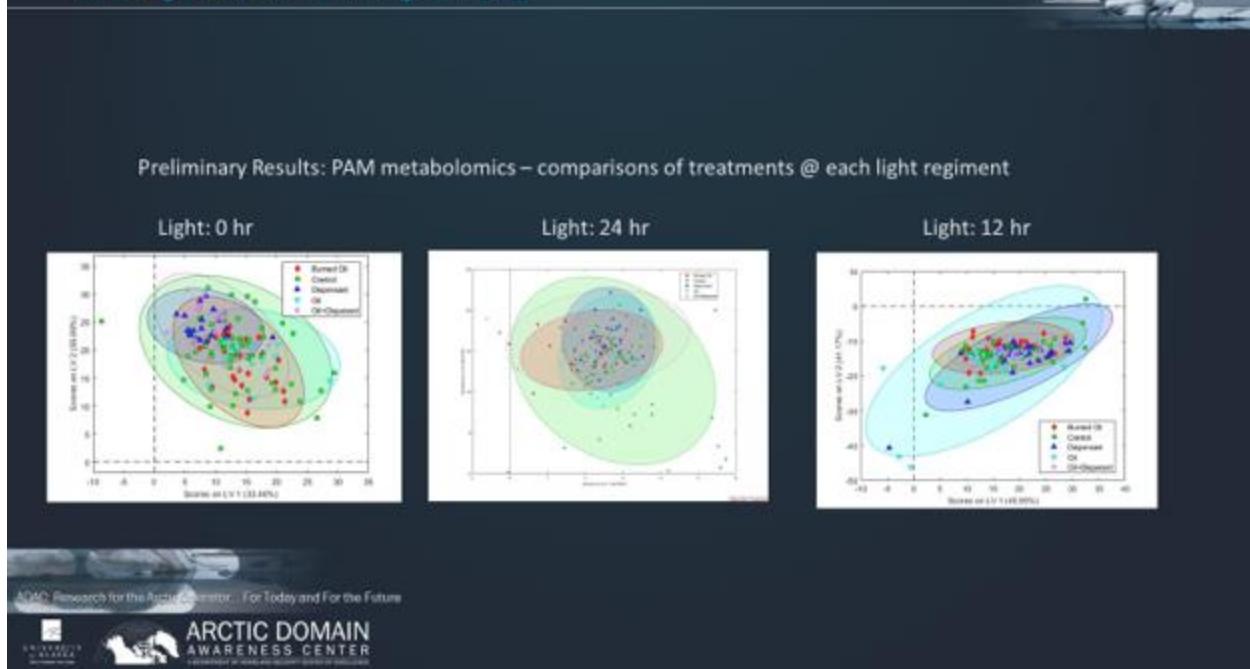


Figure 12: PAM metabolomics: Preliminary Results

Phase 4: Profile chemical constituencies of water-accommodated petroleum and photo-degraded petroleum (complete) Water samples from each treatment were taken at each timepoint throughout the experiment and frozen in HDPE vials. Samples were overnight mailed on ice to UNO for the following chemical analysis. Phase 4 concluded in Program Year 7.

1. **Conduct Dissolved Organic Carbon (DOC) Analyses.** Each sample was filtered through a pre-combusted (450 °C > 4 hours) Advantec GF-75 0.3 µm glass fiber-filter into a pre-combusted (550 °C > 4 hours) amber glass vial. The pH of each sample was immediately adjusted with hydrochloric acid to pH < 2 and samples were stored in the dark and refrigerated (< 4 °C) until subsequent DOC analysis. Dissolved organic carbon was measured by high temperature combustion with a Shimadzu TOC Vcsn analyzer.

Results indicated that DOC concentrations rose throughout the exposure (From day 0-7) with differences between dispersed oil and the remaining treatments noted at endpoint day 7.

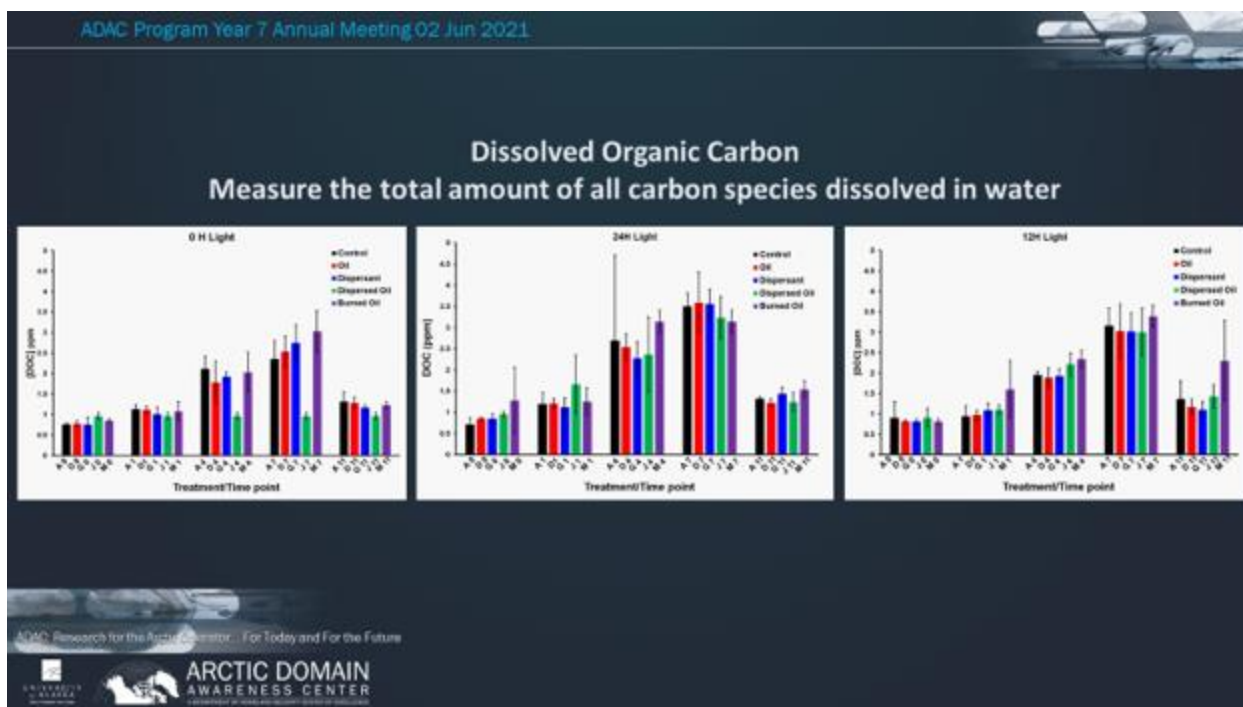


Figure 13: Dissolved Organic Carbon

2. **Conduct Optical Analyses.** Each sample was filtered through a pre-combusted (450 °C > 4 hours) Advantec GF-75 0.3 µm glass fiber-filter prior to pH adjustment (pH 8) for absorbance and fluorescence measurements with an Aqualog® fluorimeter (Horiba Scientific, Kyoto, Japan). Measurements were completed in a 10 mm quartz cuvette at a constant temperature of 20 °C. Absorbance and excitation scans were collected from 240 – 800 nm in 5 nm increments with an integration period of 0.5 s. Milli-Q water (18.2 MΩ cm⁻¹) was used to dilute each sample to an absorbance of 0.1 at 254 nm to reduce inner filter effects. Spectra were blank subtracted and corrected for instrument bias in excitation and emission prior to correction for inner filter effects. Fluorescence intensities were normalized to Raman scattering units and dilution corrected prior to Parallel Factor (PARAFAC) Analysis. PARAFAC of excitation-emission matrix spectra obtained for the water samples were used to develop the model with the drEEM toolbox (MatLab code). The spectral properties for each of the components were examined and then validated by residual and split-half analysis. Several optical proxies were calculated to assess changes in aromaticity, size and reactivity of DOM_{HC}.

Results indicate that the exposure water contained 5 unique fluorophore components, with Component 1 matching a database entry of petroleum-derived dissolved organic matter. This allowed us to assess “oil-like” chemical features.

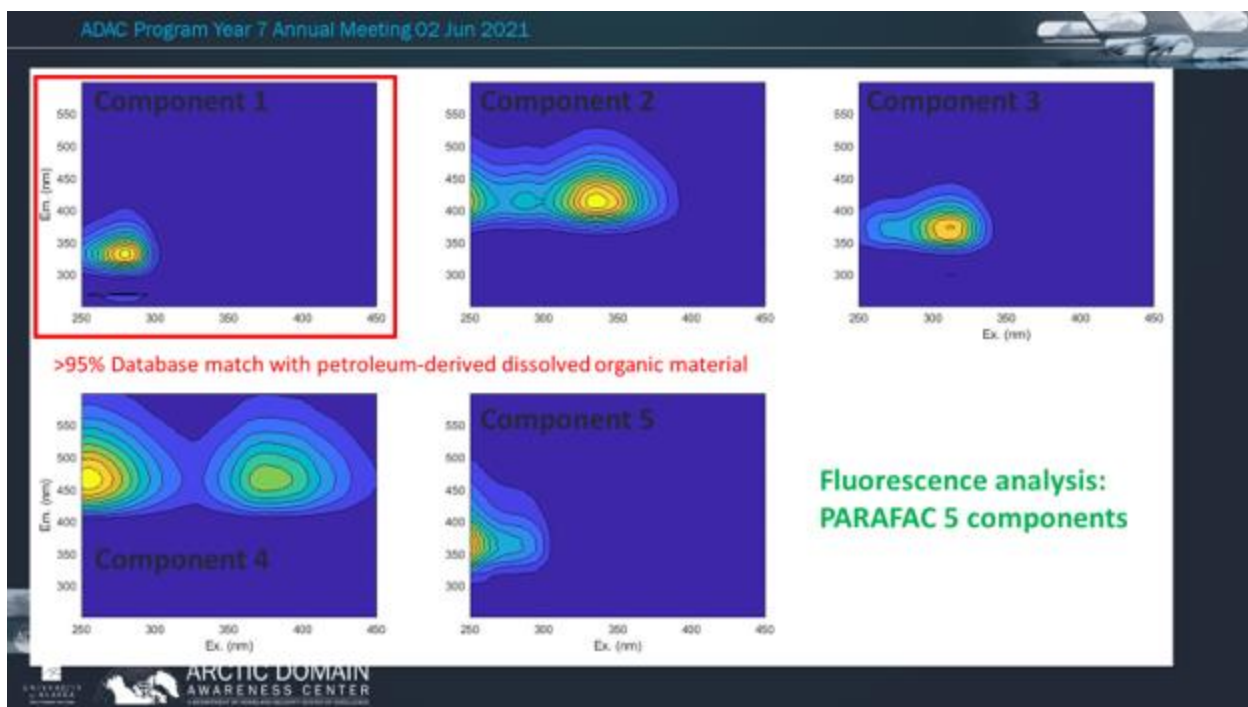


Figure 14: Fluorescence analysis: PARAFAC5 components

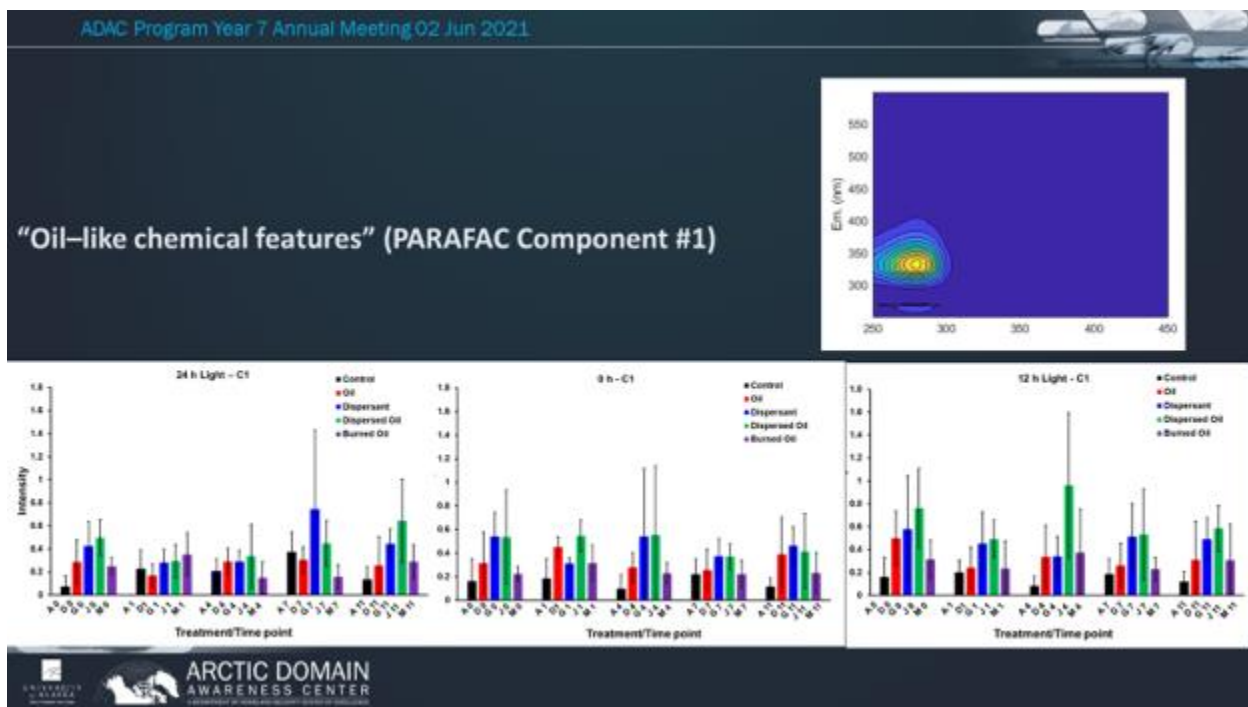


Figure 15: PARAFAC Component #1 "Oil-like chemical features"

3. *Conduct Fourier Transform Ion Cyclotron Mass Spectrometry.* Water samples were collected and pre-concentrated by the solid-phase extraction. Briefly, each sample was passed through a pre-combusted 0.27 μm glass-fiber filter and acidified to pH 2 prior to loading onto a Bond Elut PPL (Agilent Technologies) stationary phase cartridge. Each sample was desalted with pH 2 MilliQ water and eluted with methanol at a final concentration of 50 $\mu\text{gC mL}^{-1}$. The extracts were stored in the dark at 4 $^{\circ}\text{C}$ in pre-combusted glass vials until analysis by negative-ion electrospray ionization coupled with a custom-built Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS) equipped with a 21 tesla superconducting magnet at the National High Magnetic Field Laboratory (NHMFL), Florida State University, Tallahassee. Each mass spectrum was internally calibrated with a “walking” calibration equation followed by molecular formula assignment with internally developed software provided by the NHMFL.

Results indicate that FT-ICR MS subtraction plots showed unique molecular formula present after each treatment, suggesting the formation of new compounds in the water as a cumulative result of photooxidation of the crude oil, dispersed oil and in-situ burned oil.

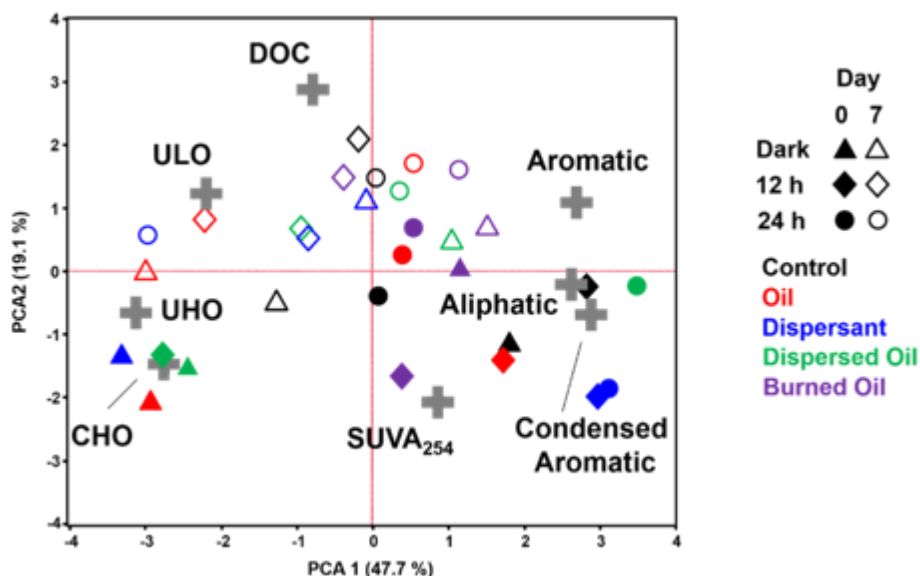


Figure 16: FT-ICR MS subtraction plots

Key Stakeholder Engagement:

The PI and the team in program year 7 have worked with the USCG in close coordination with ADAC leadership and the HQ USCG Project Champion and other stakeholders to ensure that the project is useful for USCG knowledge needs. We have discussed with the relevant USCG personnel, foremost the Project Champion throughout the experiment and received input on relatability of experiment outcomes.

Project Champion: During program year 7, the project team engaged LCDR Clifton Graham on a frequency basis as determined by LCDR Graham, including mostly email and teleconference communication. Critical coordination has occurred between team members, the PI, and project

champion.

Throughout the research, the project team has remained in close coordination with ADAC leadership and USCG mission users. Investigation team has been represented at the following ADAC events:

1. Coordination with Project Champion LCDR Clifton Graham.
2. Weekly All Hands meetings.
3. Quarterly Reviews.
4. Quarterly Customer's and Partner's Roundtables.
5. ADAC Annual meeting.

Key Publications (peer reviewed):

N/A for Program Year 7. In accordance with Year 7 carry-forward plans into Program Year 8, research team will develop a manuscript for peer review in addition to program knowledge product.

Key Presentations:

Project team presented at ADAC Program Year 7 Annual Meeting. The Annual Meeting was held virtually as COVID-19 prevented an in-person gathering in Washington D.C. as in previous program years. The meeting was well attended by DHS S&T OUP, HQ USCG ADAC Project Champions, NOAA leadership, ADAC Executive Counselors, and many other customers and partners participated ADAC's Year 7 Annual Meeting.

Students Stacey Hanson, Kevin Fitzpatrick, and Katherine Humpal all presented their findings at the Alaska Marine Science Symposium (AMSS) 2021 conference. Additionally, Katherine Humpal presented her water chemistry findings at the 2020 Maritime Risk Symposium and received a "best of" student poster award.

Changes from initially approved Workplan:

Following are summaries of how investigators (in coordination with ADAC leadership) made changes from the originally approved workplan, which were necessitated as a result of the COVID19 pandemic:

- As a result of loss of laboratory access and access restrictions for in-person work due to COVID-19, the timeline of this project has been extended. Nearly all analytical work was completed along with a manuscript draft but will require carry-forward into program year 8 to fully finalize.
- As a result of unanticipated family death, graduate student Katherine Humpal was not available to assist during the end of program year 7; her supervisor Dr. Zito ensured analytical work was completed.
- Consistent with annotations from the year 6 annual report, expected number of peer-review journal article submissions on this modified timeline have been adjusted to one manuscript from the originally scoped two manuscripts.

Project progress against each milestone:

Table 7: Arctic Mussels Year 6 milestones.

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
1. Cytochrome P450 Assay	Completed	N/A
2. Heat Shock Protein Assay	Completed	N/A
3. Superoxide dismutase Assay	Completed	N/A
4. Micronuclei Assay	Completed	N/A
5. Caspace Assay	Completed	N/A
6. Metabolomics analysis	Incomplete, anticipated completion September 2021	Covid-19 related lab access restrictions to laboratory space
7. Chemical analysis	Completed	N/A
8. Data synthesis	Incomplete, anticipated completion October 2021	Covid-19 related delays

Project progress against each metric:

Table 8: Arctic Mussels Year 6 metrics.

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Student Training: Three graduate students and their projects are underway.	Completed	N/A
Documentation of physiological and biochemical measures of stress.	Completed	N/A
Statistically compare key measures of physiological and biochemical changes between treatments, across time, and between individuals.	Completed	N/A
Documentation of NMR spectra from tissue extracts.	Completed	N/A

Using NMR spectra, identify small molecule metabolites present in tissues based on database matches.	Completed	N/A
Statistically compare differences in metabolite profiles between treatments, across time, and between individuals. Tomco to evaluate and quality control the data.	Completed	N/A
Obtain necessary instrument time permissions for 180 FT-ICR MS samples at the National High Magnetic Field Laboratory.	Completed	N/A
Document dissolved organic carbon concentrations in water samples	Incomplete, completion anticipated Sept 2021	COVID-19 lab delays
Document spectrofluorescence and FT-ICR MS data from water samples.	Completed	N/A
Statistically compare differences in DOC, spectrofluorescence and FT-ICR MS data between treatments, across time, and between replicates. Zito to evaluate and quality control the data.	Completed	N/A
Prepare manuscript and submit to peer-reviewed journal of the project.	Incomplete, anticipated completion October 2021	COVID-19 lab delays
Prepare technical report detailing the project.	Completed	N/A

Outcomes/output and TRLs:

Outputs:

Scientific Data Collection: The primary outputs of this project in Year 7 were the collection and analysis of scientific data. Scientific data was collected in support of phases 1-4. Updates have been reported during quarterly reviews, weekly all-hands, customers & partners round table events, and annual meetings. Furthermore, data evaluation and synthesis were performed, as the basis of the knowledge products. These outcomes form the foundational basis of forthcoming knowledge products.

Outcomes

Scientific data collection is designed to inform USCG led Arctic region oil spill response. As of Program Year 7, data collection and analysis occurred; refining and reporting of this data occurred during Program Year 7 and finalization will occur in Program Year 8.

Technology Readiness Level (TRL):

This project is fundamental research and achieved TRL 1, creating a knowledge product to inform USCG Federal On-scene Coordination in Arctic region oil spill response.

Unanticipated problems and plans for addressing them:

The COVID-19 situation suspended access to research laboratories and prevented in-person presentation at conferences. Although delays occurred, the majority of work was completed in program year 7, and researchers plan to complete in program year 8.

The National High Magnetic Field Laboratory suspended user facility work due to COVID-19. This delayed receipt of water chemistry data, which was able to complete by the end of program year 7 but will require a small amount of additional time to synthesize this information with the broader dataset.

Transition Activities: [EM5] [EM6]

Transition plans and progress made: The major scope of this project has been to develop knowledge products to advance our broad understanding of the environmental toxicology of petroleum, chemically treated petroleum, and weathered chemically treated petroleum exposure in support of USCG led Federal on-scene coordination for Arctic pollution response. This is classified TRL 1-3 (fundamental research). During ADAC Program Year 7, scientific data collection and analysis was performed to advance the final knowledge product development. Transition has been advanced by the research team and in compliance with ADAC Research to Transition Process. As outlined in the “Key Stakeholder Engagement Plan”, research team has worked with USCG HQ Project Champion to ensure knowledge products are of interest, useful and disseminated widely to USCG, and HQ USCG Project Champion designated points of contact that support USCG led unified command for oil spill response.

The research team additionally presented their research at several key conferences. Students Stacey Hanson, Kevin Fitzpatrick, and Katherine Humpal all presented their findings at the Alaska Marine Science Symposium (AMSS) 2021 conference. Additionally, Katherine Humpal presented her water chemistry findings at the 2020 Maritime Risk Symposium and received a "best of" student poster.

Dr. Tomco participated in ADAC's C-ICE symposium and remained in close contact with LCDR Clifton Graham, who was briefed on project updates several times throughout program year 7. These presentations demonstrated key participation at significant conferences and disseminated the findings in the local community consistent with the ADAC Program Year 7 Workplan. [EM7]

Additionally, Research team has been in contact relevant federal agencies including the EPA and NOAA to provide further briefings on research findings. Research team will provide full range of research products to ADAC's web portal at completion and any further research destination as determined by the HQ USCG Project Champion.

PROJECT: Marine Induced Polarization Methods for the Detection and Mapping of Oil in an Arctic Marine Oil Spill; Including Investigation of Oil Within and Under Broken Ice Fields

Project Investigator: Dr. Scott Socolofsky, Texas A&M University

Lead Institution: Academic: Texas A&M University, College Station Texas; Industry: Induced Polarization Associates, Seattle, Washington

Supporting Researchers: Ms. Kari Walker and Mr. Kevin Hand, IntelliSense Marine LLC, Mr. Nathan Lamie, Lead Engineer/Facility Operator, CRREL (U.S. Army Corps of Engineers),

Key Project Team Members: Mr. Art Wright, Mr. Mike Williamson, Mr. Joseph Radler, and Mr. Todd Stedman, Induced Polarization Associates.

Project Champion : LCDR Clifton Graham, CG-MER

Project Description:

Abstract: Federal on-scene oil spill responders benefit from remote sensing tools to detect and map oil in the open-Arctic Ocean, broken ice fields, and oil under and in ice. Marine Induced Polarization (Marine IP) has demonstrated consistent potential to detect hydrocarbons in fresh, brackish, and open-ocean seawater as well as seawater sediments, and research in this project is directed toward assessing the suitability and performance of Marine IP in Arctic environmental conditions. ADAC Program Year 6 research tests performed at the Cold Regions Research and Engineering Laboratory (CRREL) demonstrated the potential of Marine IP to be an effective tool for mapping oil in Arctic waters and also underscored the need for a ruggedized, field kit to be more compact and resistant to the effects of temperature, as well as vibration and jarring during transport and setup. The Program Year 7 research effort worked to redesign the Marine IP kit to be a turn-key system that is easy to transport, set up, and deploy by trained personnel. Activities were also directed toward redesigning the software interface and functionality to guide a user through the steps needed to collect data using the Marine IP system. The research approach was to conduct a 2-phase investigation: re-design, build, and test hardware for the Arctic-Ready Marine IP System, and re-design, test, and deploy user-friendly software for the Arctic-Ready Marine IP System. The outcome of this research is one Arctic-Ready Marine IP System with a re-designed interface and data visualization software package, thereby augmenting the transition of the Marine IP technology into the hands of the U. S. Coast Guard (USCG).

Objective/Purpose: The objective of this project was to continue to validate the Marine Induced Polarization (IP) technology as a viable means to detect oil within ice and broken ice and to develop the hardware, firmware, software and testing to support creating a ruggedized field kit.

While the new field kit and field data created by this project are important and provide the spill response community a suitable prototype for commercialization and other applications, the principal outcome to meet HQ USCG needs was the creation of an associated knowledge product report, an Engineering Design Report, addressed to the assigned HQ USCG Project Champion that can be used to promote the further development of this technology; with the technology later being transitioned to the commercial market.

For the basic hardware and firmware aspects of the new ruggedized kit, researchers investigated the range of system settings that are effective for surveying. This work included power budgeting, including the length of available operating time based on the number of battery packs on hand, which is especially relevant for scenarios where shipboard power is unavailable. This operational information also contributed to a better understanding of the power budgets and requirements for the possible future deployment of the Marine IP technology on a variety of platforms, such as on autonomous vehicles or data buoys. Accordingly, this research augments future options for oil spill responders to detect oil in a broader range of environments. Detection is critical to support the planning and deployment of spill cleanup resources, in-situ burning, and use of dispersants, among other response options. Designing and deploying new, user-friendly software serves to advance the utility of Marine IP to practically support the spill community in remote and austere locations with less sophisticated response capabilities. In sum, the priority of the research team during Year 7 was for research that advances Marine IP technology, and the secondary priority was investigations that help develop the application suitable for deployment.

Strategically, this research sought to transition the Marine IP technology to expand the USCG's and the oil spill response community's capability to perform wide area assessments – cost-effectively and rapidly – for the presence of oil in Arctic waters. Accordingly, a key objective was to provide reliable insight into a catastrophic problem: the ability to detect oil in broken ice and under ice formations. In sum, this project worked to put Marine IP in the hands of the USCG and DHS to provide situational awareness of an oil spill's extent, migration, and potential areas of contamination in various (and probable) Arctic situations.

Research objectives focused on planning, designing, and building an Arctic-Ready Marine IP System that is resistant to the effects of Arctic temperatures and to the hardships of jarring and vibration during equipment transport and setup. It is during these investigations that the project team examined the flexibility in and range of effective amperages that can be used to detect oil in an ice-laden marine environment. The Program Year 7 investigations were conducted in a two-phase research effort. Phase 1 focused on planning, designing, and building an Arctic-Ready Marine IP System that is resistant to the effects of Arctic temperatures and working in a harsh environment. Phase 2 focused on planning, designing, building, and deploying new firmware and software for the Arctic-Ready Marine IP System, to make the system more user-friendly, automated, and easier for the user to visualize the data and identify targets.

Methodology: The project research method was a sequenced series of laboratory experiments oriented to a test plan examining Marine IP hardware design and engineering and investigating signatures of target contaminants simulating Arctic and open water conditions. Since much of the research tasks were conducted by the commercial team which has previously advanced Marine IP in coordination with U. S. Geological Survey (USGS), the project team was led by a Principal Investigator who objectively assessed the research from an academic vantage (Dr. Socolofsky, Texas A&M University).

During ADAC Program Year 7, the Marine IP Topside Control Unit, signal generator, power management system, data acquisition and real-time visualization software were re-designed to be suitable for deployment by the U.S. Coast Guard led, Federal on-scene spill responders. Previous project research in the CRREL facility served to increase the research team's understanding of how the Marine IP cable and topside control unit component materials performed in a low temperature environment and that understanding was applied to the work performed for the ADAC Year 7 workplan.

In Program Year 7, as of the June 30th, 2021, closing date, the following tasks were completed:

- The hardware for the Marine IP Arctic-Ready Marine IP system was designed, including high level block diagrams for the device prototype and laboratory testing device designs.
- Individual components were procured and tested in the laboratory for functional performance, revisions to the hardware design were made based on the laboratory tests of components, and a Bill of Materials (BOM) and final design drawing for the prototype were produced. The team was severely impacted by the COVID-19-related supply chain issues that caused shortages and backlogs of electronic components, and the BOM and the final design drawings needed to be reworked through multiple iterations to find components that would meet the specifications of all components within the system and that could be obtained in the shortest timeline possible in the greatest effort to meet project timelines.
- Designs for the device enclosure were completed and submitted for fabrication and off-board wiring schemes were completed. Design iterations were conducted to optimize for simplicity and safety, consolidating input and output plugs and cooling fans to the inside of the enclosure.
- The prototype was fabricated and assembled.
- The firmware was designed for the system and has been built for the receiver electrodes and for the command structure of the touch screen, and the transmission/receiver circuitry was tested in the laboratory.
- The software was designed, including the determination of requirements and specifications; development of a plan-design-implement-test-revise loop; selection of a suite of core usage and testing cases; and a mockup of a user interface, menu structure and software control systems.
- An engineering report reviewing design, fabrication methods and construction have been submitted.

Work is ongoing to complete the Marine IP system firmware for all system components and to implement the software design. This work is being completed in ADAC Program Year 8 under a no-cost extension due to COVID-19 project delays.

ADAC Program Year 7 Details:

Phase 1: Re-design, build, and test an Arctic-Ready Marine IP System – Hardware and Firmware:

The design of a rapidly deployable and simply mobilized hardware system for Marine IP was critical for highlighting the applicability of the technology for oil detection in Arctic environments. Therefore, the Marine IP field kit hardware was engineered to meet two design requirements:

- 1. The device needed to be resistant to vibrations and shock damage during transit to and from the project or incident site.*
- 2. The device needed to be able to be calibrated and operated in Arctic temperatures and conditions.*

The first criterion had been highlighted during the recent work with the proof-of-concept prototype. During the two shipments from Seattle to the CRREL facility in New Hampshire, the Marine IP data acquisition system experienced rough transits. Both trips resulted in internal components rattling loose from sockets and the second trip resulted in the internal power source breaking free when the system was dropped by one of the shipping companies. Fortunately, the Marine IP technicians were able to open the device, re-seat the cards as needed, service and replace damaged components and test that it was working properly, enabling a successful measurement program. However, for a turnkey solution, the potential need to conduct these kinds of repairs in the field hampers the ability of the device to be adopted for rapid mobilization and deployment.

The second criterion follows as a necessary requirement for the device to be consistently and reliably deployed in Arctic conditions. Most consumer grade electronics begin to behave in erratic fashion below -40 degrees Fahrenheit and batteries begin to fail entirely at these temperatures. The previous iteration of the Marine IP hardware device relied on chemical batteries to generate a stable transmission current and voltage. The redesign of the Marine IP system implemented an internal power supply and distribution architecture driven by industrial high-efficiency power converters. These converters and support circuitry were then affixed in the device enclosure with reinforced aluminum mounting hardpoints. These architectural changes mitigated and minimized the effects of extreme cold and mechanical shock in the redesigned Marine IP system.

Operations in extreme cold working conditions also benefit from minimal mechanical reconfiguration of hardware devices to achieve successful data collection. Mechanical connections and electromechanical components, such as electrical connectors and mechanical switches, can act as points of weakness for freezing and mechanical fragility of materials, such as vibration and shock damage. Therefore, an additional design consideration was to minimize electro-mechanical and mechanical components on the device except for those specifically rated for extreme cold and potentially damp environments.

The development of a new hardware stack for the Marine IP system – based on the most recent successful ruggedized design elements of previous prototype versions – was divided into three main tasks, as outlined below.

Task 1. Arctic-Ready Marine IP System – Design Hardware.

Task 1.1. Literature review and outline of engineering design and general functional requirements. The team started by conducting a literature review and building an outline of engineering design and general functional requirements, and the results of the research were incorporated into the decision process for system component selection and testing.

Task 1.2. Analyze any flaws or faults with existing design iteration and document to apply to design modifications. The existing design iteration was analyzed for identifiable flaws or faults and the results were incorporated into the requirements document, to be applied during design modifications. The system was also further optimized for performance and cost, based on the initially outlined design requirements. The design of the new system focused on both higher-level, functional requirements and detailed mechanical, electrical, and operational interface systems, outlined in detail in the Marine IP Requirements Document. Functional requirements were defined for the:

- Waveform Generation & Transmission
- Signal Reception & Conditioning
- Logging Received Signal Data
- Pre-Processing Signal Data for Complex Impedance Information
- System Management, User Interface
- Power Requirements
- physical form of the Marine IP case (Form Factor).

Task 1.3. Design a revised signal chain with functional block diagrams and accompanying high level design analysis. Once the design requirements were defined, a revised signal chain was designed, and functional block diagrams were produced with accompanying high level design analysis. The architecture of the system hardware was designed to have six subsystems: power supply and distribution, operator interface display and digital systems control (the touch screen), digital automated system management, transmitter and waveform generator subsystem (produces the square wave that is sent to the Marine IP cable and transmitted into the environment intended for measurement), receiver subsystem (receive the signals resulting from the transmitted signal coming in contact with the elements in the measurement environment), and the data acquisition (DAQ) system (records the raw data in digital format).

Interfaces between the subsystem assemblies are designed to facilitate direct, accurate communication of signal telemetry and settings data. The Block Diagram below represents the overall system architecture and signal flow through the Marine IP hardware. Additional details about the architecture have been provided in the Marine IP Engineering Report.

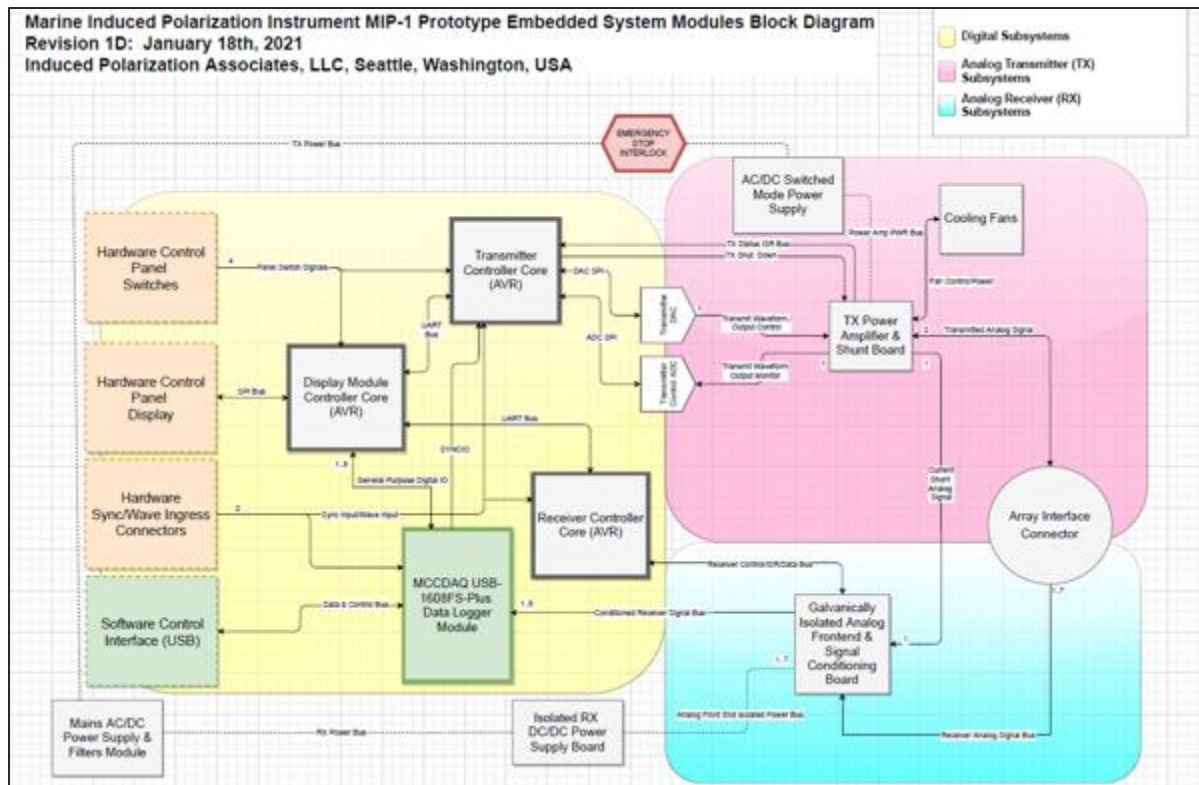


Figure 17: Marine IP Hardware Block Diagram

Task 1.4. *Select initial prototype components to meet design requirements.* Initial prototype components were selected to meet design requirements, as determined in the initial literature and systems review, and tested in the laboratory (see Left image below). Components were

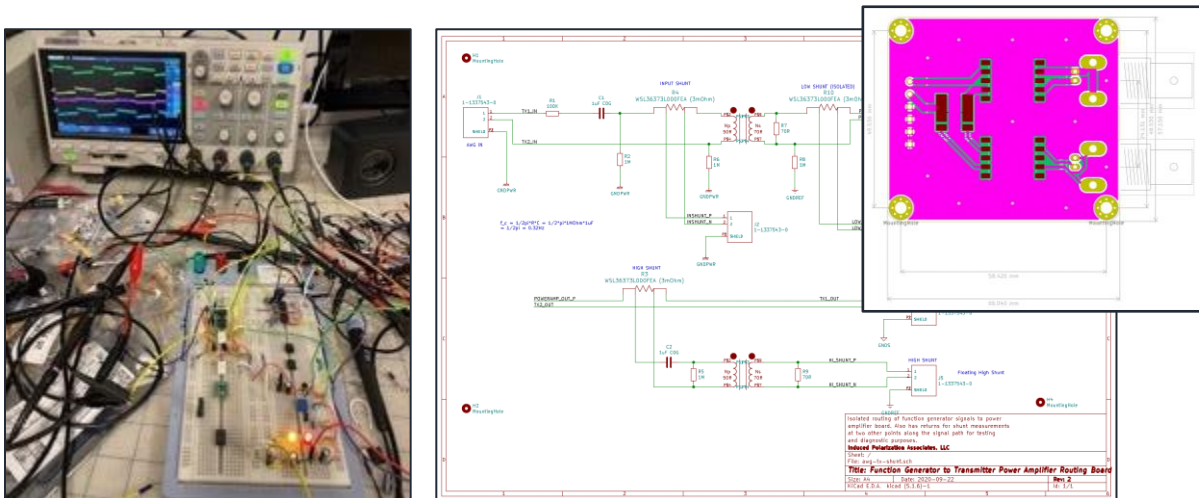


Figure 18: Laboratory testing of Marine IP system components

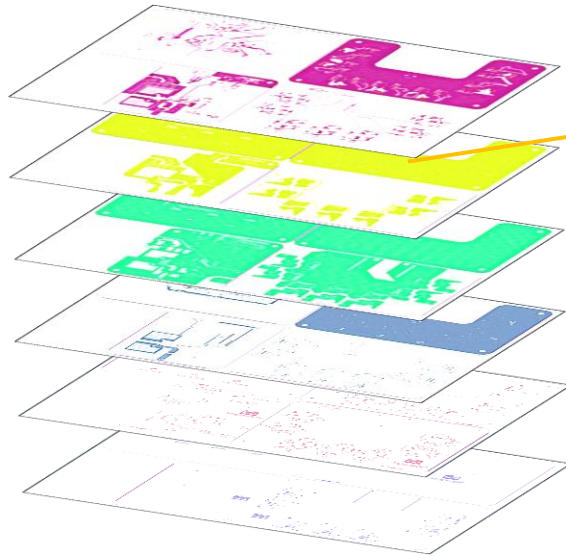
selected to reduce the power requirements, weight, and volume of the Marine IP system. This was conducted as an iterative process that was performed for each functional module of the device. The image on the Right, below, shows schematics for the prototype modules that were generated during this process. Testing was performed using six Marine IP channels, and the system was designed to ensure sufficient capacity to expand the number of channels to accommodate future cable designs.

Task 1.5 – 1.6. Complete layout drawings for prototype Printed Circuit Board (PCB), control interface panel, and enclosure and Design testing enclosure/jig for laboratory evaluation of circuit and peripheral functions. The layout drawings for the prototype Printed Circuit Boards (PCBs), the control interface panel, and the enclosure were completed, and the testing enclosure/jig for laboratory evaluation of the circuit and peripheral functions was designed.

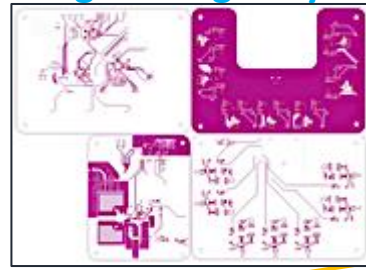
To complete the complex layout drawings for the prototype PCBs, designs for the circuitry needed to be defined in multiple layers and at multiple scales. The layered design of the PCBs increases functionality of the boards and provides high capacity and speed within a reliable, smaller footprint, furthering the goal to make the system more compact and flexible for possible future implementation on smaller platforms.

The PCBs were laid out by the IPA design engineer in KiCAD, an open-source electrical CAD software package developed and maintained by CERN in Geneva, Switzerland. The contract PCB manufacturer, Schipper's & Co. in Seattle, Washington, reviewed and validated the design rules used by the IPA design engineer and worked closely with the Marine IP team to finalize the PCB designs. The illustration below shows that each Single Design Layer of the four-layer PCBs was designed individually, stacked in order of printing, and made into a composite, Compiled Board Design. Additionally, individual Detailed Board Component Designs were produced for focused areas of each board, a few examples are shown in the illustration below.

Ordered Board Design Layers



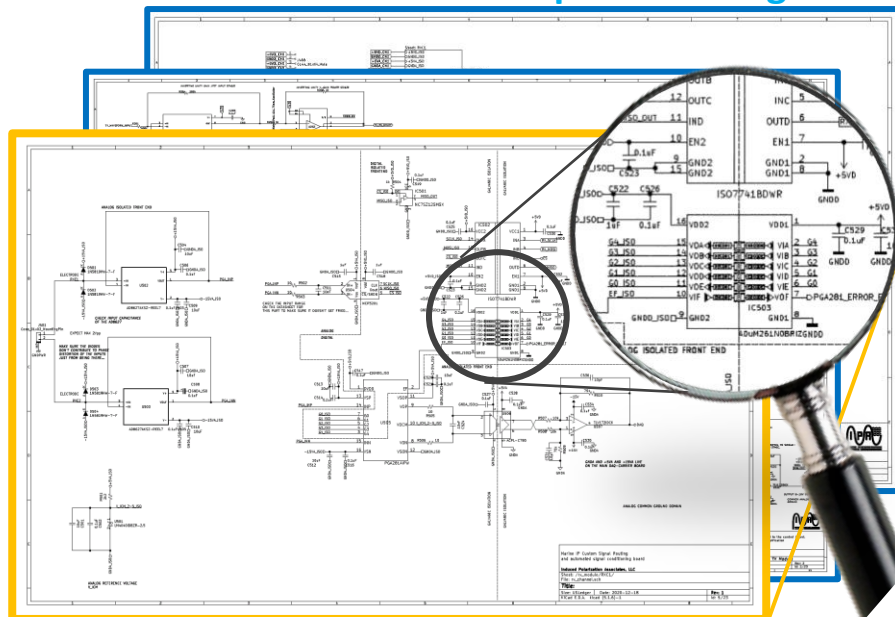
Single Design Layer



Compiled Board Design



Detailed Board Component Designs



Engineering designs for Printed Circuit Boards.

Figure 19: Engineering designs for Printed Circuit Boards

The Marine IP enclosure was designed, and mechanical CAD drawings were produced using the open-source CAD package, FreeCAD. A Pelican case was chosen as the base enclosure, which was then customized for the Marine IP hardware. The mechanical CAD drawings were provided to a local company, DataPro, a custom enclosure manufacturer in Seattle. Initial quoted design costs were above budget, so the IPA design engineer worked with DataPro to reduce the costs by generating a complete set of drawings for the enclosure, cooling fan cutouts, control panel, and side ingress panels. Additional details and drawings are provided in the Marine IP Engineering Report.

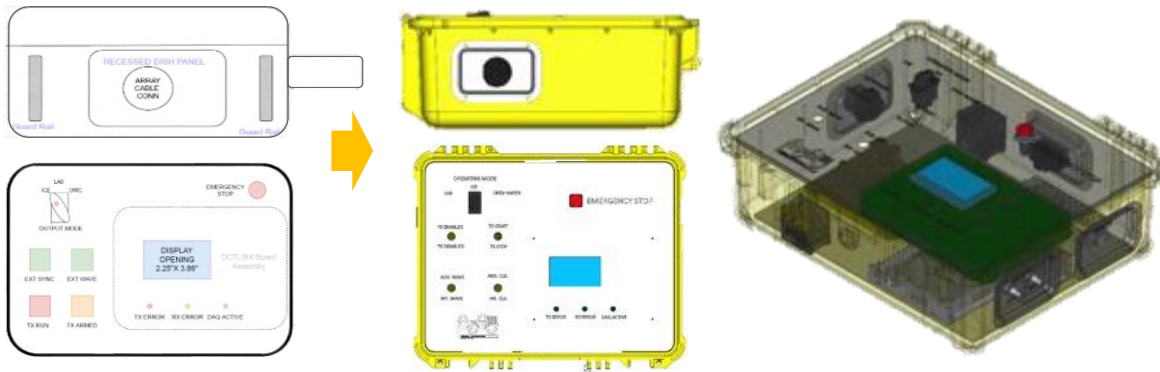


Figure 20: Initial and final drawings for the Marine IP enclosure

Task 2. Arctic-Ready Marine IP System – Build Hardware.

Task 2.1. Assemble a Bill of Materials (BOM). When the hardware designs were completed, a Bill of Materials (BOM) was assembled. The BOM document listed all part numbers, the required quantity of each part, distributors that supply the part, prices, and the total cost estimates for circuit board-mounted components, electromechanical devices, discrete device modules, and connectors for the prototype. Costs of the system were minimized while staying within the engineering constraints (i.e., temperature ratings, environmental ratings, performance specifications).

Task 2.2. Estimate and compare costs between in-house PCB assemblies versus external component placement services. Select the best fabrication option for meeting project timelines and budget. Costs were compared between in-house PCB assemblies versus external component placement services, and it was determined that the local contract PCB manufacturer, Schipper's & Co. in Seattle, Washington, was the most effective solution for the manufacturing of the PCBs, for cost, time efficiency and quality and reliability of the final product.

Task 2.3. Order first version prototype PCBs based on design drawings from Task 1.5 and order components from BOM. The prototype PCBs were ordered based on the design drawings from Task 1.5 and components were ordered from the BOM. Because the designs were laid out in electrical CAD software, a 3-D rendering of the drawings were also produced and provided to the PCB manufacturer.

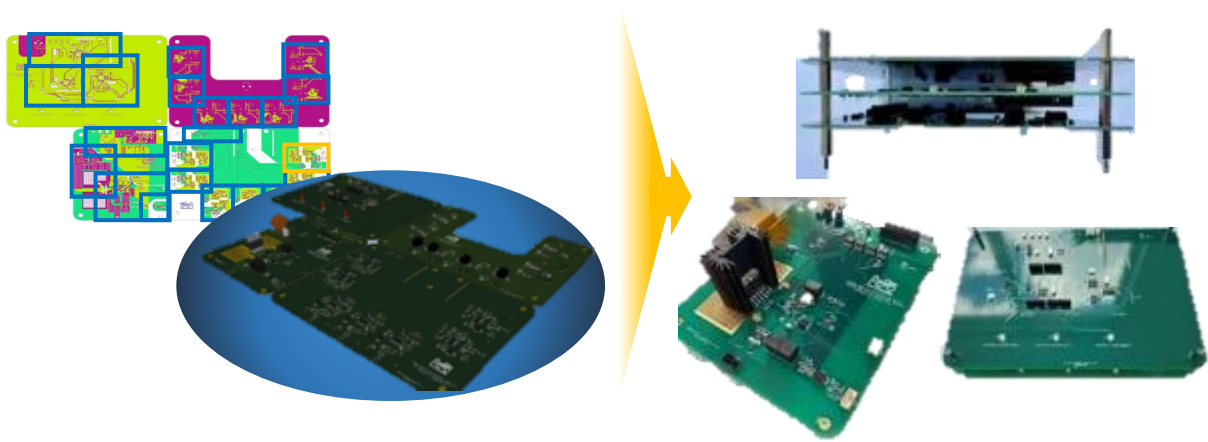


Figure 21: CAD drawing shown as 3-D engineering designs for PCBs and resulting manufactured PCBs

Task 2.4. Assemble the prototype PCB using the fabrication method chosen in subtask 2.2. The prototype PCBs were assembled using the fabrication method chosen in subtask 2.2, by Schipper's & Co. Due to component shortages in December 2020 and January 2021, the process of finalizing the designs required multiple rounds of revisions to obtain appropriate components for the designs. As components within the design and the associated BOM were found to be unavailable, a design revision was required, where the IPA design engineer (1) reviewed the detailed specifications of possible replacement components for system compatibility, (2) checked stocks and availability of the possible replacement components at U.S.-based suppliers, (3) contacted the Schipper's & Co. purchasing specialist to ensure it was accessible, (4) revised the BOM and PCB layouts, (5) sent the new production files to Schipper's & Co. This cycle was repeated for multiple components on the BOM. The BOM and PCB layouts were finalized and the BOM components were successfully sourced by the end of January 2021, at which time Schipper's & Co. was able to begin fabricating the PCBs. The final version of the BOM and final design drawings are included in the Engineering Report in full detail.

Task 2.5. Assemble the prototype enclosure and off-board (between the PCB and enclosure connections) wiring in-house. The prototype enclosure was manufactured and assembled by DataPro, and the off-board wiring (between the PCB and enclosure connections) was assembled in-house. Side panels of the enclosure include the external power supply to be plugged into standard vessel outlets and the plug for the Marine IP cable. The side panel connection ports are recessed and also include protection rails to help protect the plugs going into the Marine IP case. The top panel contains cooling fans, operating switches, and a touch screen, shown in the illustration below (Left).

Task 2.6. Construct laboratory testing apparatus ("jig") for basic startup and configuration tests of the prototype. The laboratory testing apparatus ("jig") for basic startup and configuration tests of the prototype was constructed. The testing apparatus was used for initial testing of components, for testing of the early re-designed prototype, and will be used for laboratory testing

of the completed Marine IP field kit. The laboratory testing apparatus is shown in the illustration above (Right).



(Left and Center) Customized Marine IP system enclosure showing cooling fans, operating switches, and a touch screen. (Right) The laboratory testing apparatus for testing components and laboratory system performance.

Figure 22: Customized Marine IP system enclosure

Task 2.7. Write prototype digital signal processing (DSP), system control, and signal-routing firmware for the digital and analog-to-digital/digital-to-analog conversion components in the design. The prototype digital signal processing (DSP), system control, and signal-routing firmware for the digital and analog-to-digital/digital-to-analog conversion components in the design were in progress at the conclusion of Year 7 and are being completed under a no-cost extension in ADAC Program Year 8, due to the COVID-19-related project delays. The firmware includes the low-level programs written for hardware control loaded directly onto the digital components on the PCBs. The firmware is necessary for controlling signals routed through the system, collecting readings,

Transmitter Microcontroller (TXuC) Core

- Controls DAC Output for Waveforms based on value received from DISPuC
- Controls DAC Output for Transmitter Max Current Setting (OPA549) based on Operating Mode switch position (ISR)
- Polls I2C Bus for Board Temperature Data from Fan Controller IC
- Disables Power Amplifier in the case of board overheat (ISR)
- Sends Board Temp. Value to DISPuC
- Monitors Output Voltage from TX Shunt ADC
- Converts TX Shunt ADC to Current
- Sends Current reading value to DISPuC for display.

Display Microcontroller (DISPuC) Core

- Receives Temperature Data from TX for Display
- Receives Voltage Data from TX for Display
- Controls Display Graphics
- Collects Touch Information FROM Display
- Relays User Touch Display commands to RXuC or TXuC via UART
- Shuts down system controllers in case of catastrophic fault.
- Illuminates Panel Status LEDs
- Collects panel switch toggle states and sends relevant information to screen.
- Monitors system status reports from TXuC and RXuC (via UART)

Firmware Requirements

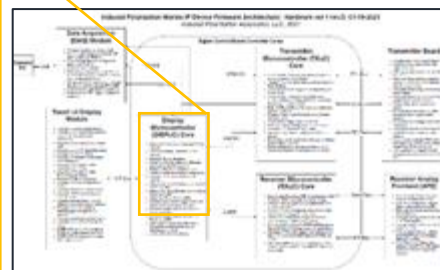
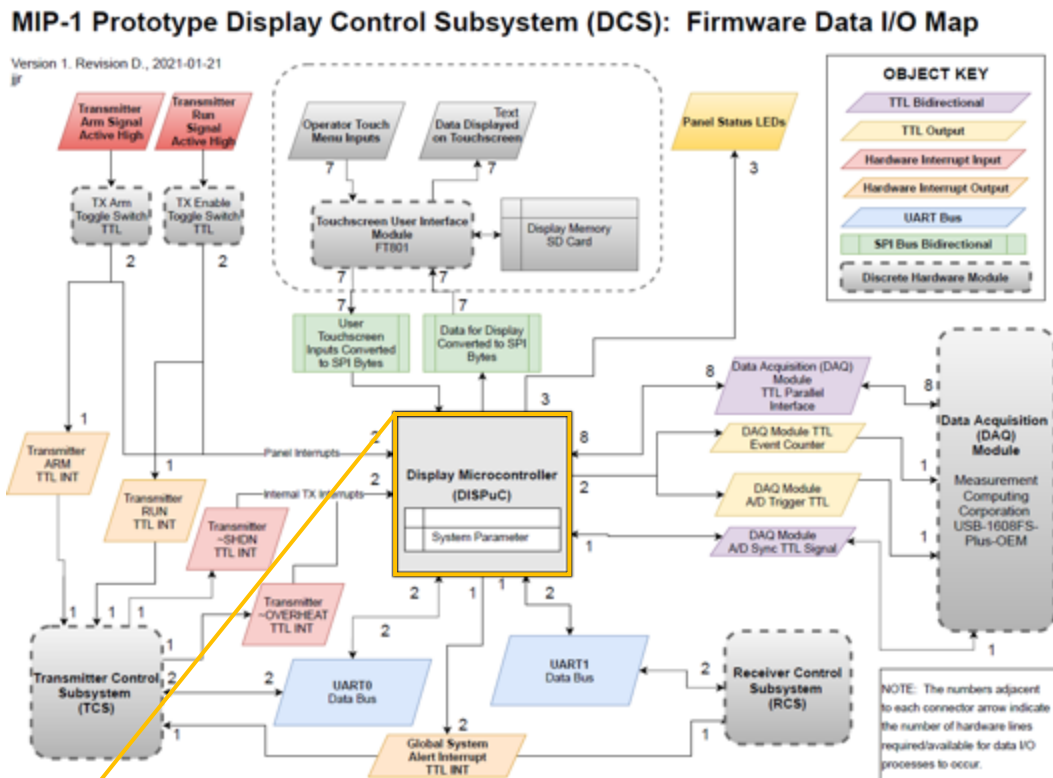


Figure 23: Example functionality requirements defined for each component of the Marine IP firmware architecture.

logging data to the user interface, and coordinating the various support modules in the design. Accordingly, prototype versions of the firmware must be constructed before comprehensive tests of the hardware can be carried out. The first step in the process was to define the requirements for the firmware before work was started on writing the code. This was conducted as part of Task 1 (see above). Two examples are shown in the illustrations below for the firmware before work was started on writing the code.



Marine IP Operator Display Interface and Digital System



(Top) Customized Marine IP firmware design. (Bottom) Digital display and touch screen. Example additional screens show manual input of transmit frequency if the user chooses not to use default settings.

Figure 24: Customized Marine IP firmware and interface design

The firmware for the system was designed to be modular, similar to the design of the hardware, with three primary parts: The Display Controller Subsystem (DCS), the Receiver Controller Subsystem (RCS), and the Transmitter Controller Subsystem (TCS). The RCS is the touch-screen interface with the operator and also communicates with the data acquisition module that records the data. The DCS was 80% complete at the end of Year 7 and will be completed under the no-cost extension. The RCS was 90% complete at the end of Year 7 and will be completed under the no-cost extension. The TCS will be completed under the no-cost extension.

Task 2.8. Startup tests for the new prototype. Startup tests for the new prototype hardware were conducted. Once the firmware is completed, additional tests will be conducted to check the stability and performance of the analog circuitry in the prototype. The tests conducted to date have shown the customized PCBs do energize and operate as designed. Further testing will compare theoretical analyses of the circuit performance, inputs, outputs, and stability to fluctuations in power and device movement. Additional tests will be conducted during the no-cost extension to ensure the device can properly energize and collect readings from a small-scale Marine IP cable and array in the laboratory.

Task 3. Arctic-Ready Marine IP System – Test Hardware. Testing of the Arctic-Ready Marine IP System hardware will be conducted during ADAC Program Year 8 under a no-cost extension due to the described project delays caused by COVID-19. Testing will include laboratory scale low-power tests of transmission/receiver circuitry as well as fully powered laboratory tests of the prototype device, and calibrations will be performed for the hardware and firmware. Beach testing of the device and its integration with the Marine IP cables will be conducted under a full range of power levels, and the system will then be tested in the field on a vessel and at CRREL. To be noted, all field tests that involve the potential of USCG or DHS S&T OUP participation will be conducted following the submission and approval of a Field Test Plan, authorized by the Project Champion or designated representative.

Phase 2: Re-design, test, and deploy user-friendly software for the Arctic-Ready Marine IP System.

Any device adapted for rapid, simple, and widespread usage must have a straightforward and robust software user interface.^{[EM8][EM9]} Accordingly, developing an easily used and trained user interface and software package structure is an important step in the development of digital signals processing and intelligence-generation software for Marine IP. The new system design will enable a user to be trained over the span of one day to operate the Marine IP System to collect data in the field. The additional step of data processing and interpretation will require more advanced training, but the ability for more users to be trained in data collection will enable a more rapid response in the event of a spill.

The usage cases for the end-user occurring in an extremely cold environment and under likely time-pressures requires robust automation as well as intelligent data-persistence and flexible data-storage options. These options should be configurable before deployments to best suit the workflow of the device operator to minimize downtime due to configuration or software bugs.

Developing both user-configurable and robust software requires not only careful planning for data flow and persistence, but also extensive testing and validation. Planning stages are critical in software development, while the testing follows from potential usage cases and design requirements developed in the planning stages. Accordingly, this work was divided into ordered tasks to design, build, and then test the software for the Arctic-Ready Marine IP System.

Research Task 4. Design Software for Arctic-Ready Marine IP System.

Task 4.1. Specify software interface and functional requirements. The software interface and functional requirements for the software were defined, and the necessary specifications for software were identified. The intent of the requirements was to ensure that the software was greatly simplified from the previous software design, such that the user would not need to be a specialist to collect data. This would ensure that a vessel of opportunity and available trained personnel could deploy and operate the system in absence of Marine IP data specialists.

Task 4.2. Select a suite of data management and persistence models. A suite of data management and persistence models were examined and selected to be used in the development of the software, which will support the design of how data and memory will be managed during the use of the software. The design will be flexible for future optimization.

Task 4.3. Implement a simple plan-design-implement-test-revise loop for the software development. The team follows a simple plan-design-implement-test-revise loop for the software development. The use of this model leads to the development of the software in a systematic and disciplined manner and guides the development process in a way that ensures continuous improvements to the software.

Task 4.5. Select a suite of core usage and testing cases for developing the test suite. A suite of core usage cases for developing the test suite software was selected. The software users are anticipated to be categorized into two primary subgroups. The first subgroup is a Marine IP technician, defined as personnel that is thoroughly trained in and knowledgeable about the components and functionality of the hardware and software, as well as the science behind Marine IP. The second subgroup is a survey technician that has been trained by a Marine IP technician, defined as personnel that has been trained to operate the Marine IP equipment and the software to collect data. The operation of the equipment will be similar between the two subgroups, but special considerations are considered within the design of the Marine IP's system setup and software to enable a trained survey technician to easily collect data using default settings and automated data management protocols.

Task 4.6. Select a documentation system and set data output formatting conventions. The documentation system selected to capture complete and incremental progress of the firmware and software development is GitHub. GitHub is a code repository hosting service that saves and tracks changes to programming code, and that also enables collaboration between developers through shared access to code, roll-back version control, wikis to document progress and findings, basic task management tools, and other features. Output formatting conventions have been defined to be binary for raw data. Binary formatting is the most efficient for file size and complies with industry standards. Binary data also has the benefit of enabling users to download

data incrementally when bandwidth is limited and retain file integrity. Output formatting conventions for processed data have been defined to be American Standard Code for Information Interchange (ASCII), comma-separated values (CSV).

Task 4.7. *Select core set of DSP algorithms to focus on implementing during development.* A core set of digital signal processing (DSP) algorithms were selected to be integrated into the data processing software. These algorithms will parse the raw, binary data packets, and perform a series of specialized signal processing procedures. The details of the finalized DSP algorithms will be documented and provided in the updated and finalized Engineering Report upon completion of the system in Program Year 8 through the no-cost extension.

Task 4.8. *Mockup a user interface and menu structure.* A mockup of a user interface and menu structure was designed. [EM10][EM11] The previous design of the Marine IP hardware required that all information about the settings and operations of the Marine IP system were displayed on the software interface due to the lack of a display on the hardware package. With this new design, the settings of the system can be defined through the interface on the hardware kit, and once set, the settings continue to be displayed throughout the survey as long as the system is on. This enabled the team to greatly simplify the software interface to display only operational information, such as the ship's position and track line, information about the file being recorded, the raw data coming in, and a view of preliminary processed data. As the design of the software progresses, the team will solicit feedback from the Project Champion and other stakeholders of the technology.

The previous iteration of the Marine IP software contained all information on the software interface, which forced summary information and input dialogues to be small. On a moving ship, it made it difficult to navigate the pointer and select desired information. The new design is intended to display only the information that the user needs to operate the survey, moving input dialogues to menus to be set up ahead of the survey. With the automated file naming protocols, the user will no longer be required to enter the name of each file before the survey line is run. Notes are to be added quickly and easily during the survey line, to be appended on the file at the end of the survey line.

The menu structure of the software mockup is designed to support the user's ability to set up the project before starting the survey, but also give the flexibility to make changes later. Under the File menu, a Project Setup would enable the user to enter information such as project name, location, operators, cable used, and all of the selected instrument settings. Under the View menu, the user can view information about the cable being used (selected by the user in Config/Cable). This allows the user to quickly access information such as cable length, how many electrodes are on the cable and their spacing, etc. Under the Config/Navigation menu, the user could set up the incoming Navigation string from a GPS. Under the Config/Cable menu, the user could select the cable being used from a drop-down menu (e.g., Ice Cable 1), and the associated information about the cable will fill in (number and spacing of electrodes, capacity of the strength member in the cable, etc.). Under the Help menu, the user could open the User Guide for tips and instructions on operating the system.

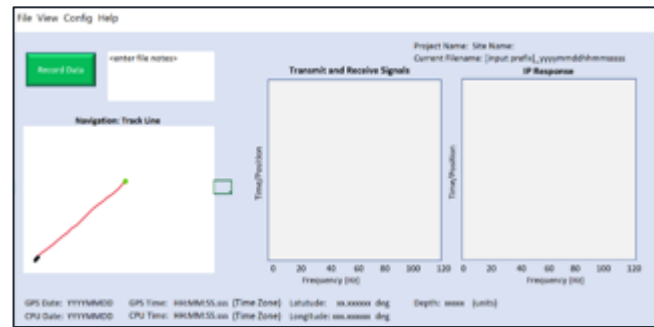
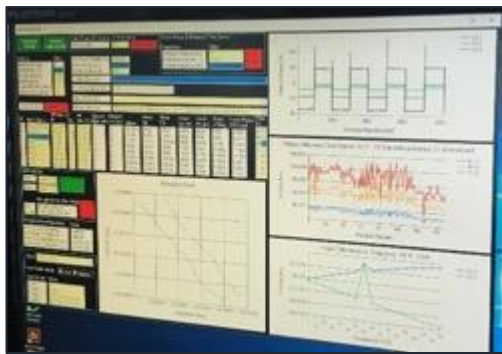


Illustration: (Left, Top) Previous version of Marine IP software interface. (Right, Top) Mockup of user interface of Marine IP software. (Right, Bottom) Menu structures of Marine IP software,

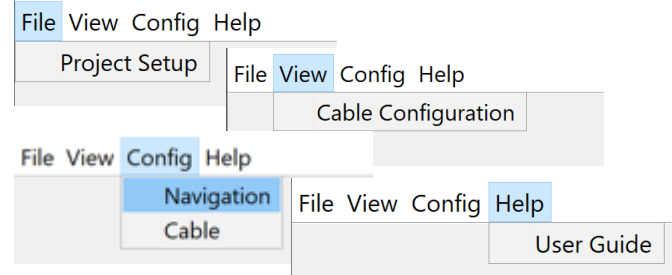


Figure 25: Marine IP software versions

Student Involvement:

N/A

Key Accomplishments:

- Hardware Design: Outlined general design requirements.
- Hardware Design: Produced high level block diagrams for device prototype.
- Hardware Design: Produced laboratory testing device design drawings.
- Software Design: Produced an engineering report outlining requirement and specification details
- Software Design: Developed a plan-design-implement-test-revise loop
- Software Design: Selected a suite of core usage and testing cases
- Software Design: Produced a mockup of a user interface and menu structure
- Procured and tested individual components for functional performance in the laboratory on small-scale.
- Completed any preliminary revisions to hardware design based on laboratory tests of components.

- Assembled a Bill of Materials and final design drawings for prototype.
- Completed designs for device enclosure and off-board wiring schemes.
- Fabricated the prototype.
- Completed mockups of user interfaces and software control systems.

Key Stakeholder Engagement:

On 6 July 2020, presented the Marine IP technology at Clean Pacific 2020. On 16 July 2020, discussed the Marine IP technology in a presentation to ADAC's Arctic Summer Intern Program (ASIP), a group of students learning about oil spill response techniques and technology.

Conducted a project meeting on 5 August 2020, including Project Champion LCDR Clifton Graham (USCG) and the Marine IP research team. Four project planning meetings were conducted with Nathan Lamie (CRREL) and the Marine IP research team to conduct planning for the CRREL research.

On 17 June 2021, discussed the Marine IP technology in a presentation to the Maritime Fire and Safety Association's Non-Floating Oil Workshop, with a focus on non-floating oil detection and mapping technologies in spill response. On 16 March 2021, presented the Marine IP technology and progress made toward a commercial system at ADAC's Arctic Challenges, Innovations, & Commerce Expo (Arctic C-ICE). The Marine IP team participated in ADAC Quarterly Reporting presentations and Round Table meetings, as well as the ADAC Annual Meeting. All tasks associated with program contracting, accounting and personnel were completed in close coordination with ADAC leadership and supporting staff.

Key Publications (peer reviewed):

Limitations due to COVID-19 have limited the ability to finalize the Marine IP system build. No publications have been submitted to journals as of the end of Year 7.

Key Presentations:

COVID-19 restrictions have prevented the ability to do presentations in person, but the team did give online, video presentations for the industry at Clean Pacific 2020 on 6 July 2020 and Clean Pacific 2021 on August 17th, 2021, and for the Maritime Fire and Safety Association's Non-Floating Oil Workshop on 17 June 2021. Within the ADAC community, presentations were given for ADAC's Arctic Summer Intern Program (ASIP) on July 16th, 2020 and for ADAC's Arctic Challenges, Innovations, & Commerce Expo (Arctic C-ICE) on 16 March 2021. The Marine IP team has also presented on the technology and ADAC project updates through ADAC Quarterly Reports, and the Annual Meeting,

Changes from initially approved Workplan:

No changes from approved overall Workplan. However, due to delays caused by COVID-19, some tasks will be completed in ADAC Program Year 8.

Project progress against each milestone:

Project progress toward milestones is summarized in the table below.

Table 9: Marine IP Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Hardware Design: Outline of general design requirements	Completed	N/A
Hardware Design: high level block diagrams for device prototype	Completed	N/A
Hardware Design: laboratory testing device design drawings.	Completed	N/A
Software Design: Engineering report outlining requirement and specification details	Completed	N/A
Software Design: Develop a plan-design-implement-test-revise loop	Completed	N/A
Software Design: Select a suite of core usage and testing cases	Completed	N/A
Software Design: Mockup a user interface and menu structure	Completed	N/A
Procure and test individual components for functional performance in the laboratory on small-scale.	Completed	N/A
Complete any preliminary revisions to hardware design based on laboratory tests of components.	Completed	N/A
Assemble Bill of Materials and final design drawings for prototype	Completed	N/A
Design and write prototype firmware.	Incomplete	In progress. The prototype firmware has been fully designed and the firmware code writing continues to be underway. Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month

		delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. The firmware is expected to be completed in early September.
Complete designs for device enclosure and off-board wiring schemes	Completed	N/A
Firmware developed and undergoing small-scale laboratory tests and bug fixes	Incomplete	In progress. The prototype firmware has been fully designed and the firmware code writing continues to be underway. Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. The firmware is expected to be completed in early September 2021. Small-scale laboratory tests and bug fixes are being conducted for each of the board components throughout development, and final small-scale testing will be conducted upon full completion of the firmware.
Fabricate prototype	Completed	N/A
Startup and initial performance and function tests	Incomplete	In progress. Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. Upon completion of the Marine IP firmware, startup and initial performance and function tests will be conducted, expected in September 2021.
Submit Field Test Plans for HQ USCG Project Champion review and approval.	Incomplete	In progress. Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware

		components, which compounded and further delayed firmware and software development and integration. Upon completion of the Marine IP firmware, system startup and initial performance and function tests, and the beach testing of the system, the team will schedule field testing. The location and timing of the testing will depend on the schedules of USCG guests that are able to attend; therefore, the Marine IP team will work closely with the HQ USCG Project Champion to develop an appropriate Field Test Plan for review and approval.
Complete performance and functional tests in laboratory	Incomplete	In progress. Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. Upon completion of the Marine IP system startup and initial performance and function tests, the system will be assessed, and system adjustments made, and performance and functional tests in the laboratory will be completed.
Submit engineering report reviewing design, fabrication methods, construction, and initial performance reviews of hardware system	Completed	N/A
Complete mockups of user interfaces and software control systems	Completed	N/A
Hardware: Beach testing of device and its integrations with the Marine IP cables	Incomplete	Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. Upon completion of the Marine IP firmware and subsequent performance and functional tests in laboratory, the device

		and its integrations with the Marine IP cables will be beach tested.
Complete implementation of Arctic-Ready Marine IP System – Hardware	Incomplete	Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. Upon completion of the Marine IP firmware and subsequent performance and functional tests in laboratory and integrations with the Marine IP cables during beach tests, the Arctic-Ready Marine IP System hardware will be implemented at CRREL and aboard a vessel in Puget Sound.
Complete implementation of Arctic-Ready Marine IP System – Software	Incomplete	Interruptions in the supply chain for electronics components caused by COVID-19 resulted in a three-month delay in acquiring hardware components, which compounded and further delayed firmware and software development and integration. The completion of the Marine IP software relies on the final design and configuration of the Marine IP hardware and firmware. Upon completion of the Marine IP firmware, the software will be completed, and the Arctic-Ready Marine IP System software will be implemented at CRREL and aboard a vessel in Puget Sound.

Project progress against each metric:

Project progress toward each metric is summarized in the table below.

Table 10: Marine IP Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
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Multiple metrics are delayed due to severe supply chain impediments caused by COVID-19. All tasks are to be completed in ADAC Program Year 8.		
Integration into an Arctic-Ready Marine IP System readily “mobilize-able” unit	Delayed, Incomplete	Building of the Marine IP Arctic-Ready field kit was delayed due to COVID-19 supply chain limitations and limitations on personnel. The system will be completed in Year 8 under a no-cost extension.
Achieve / assess practicality of successful <i>Marine IP equipment setup</i> by personnel that are not Marine IP technicians, such as a USCG crew member that has been trained in the operation of the technology	Incomplete	Building of the Marine IP Arctic-Ready field kit was delayed due to COVID-19 supply chain limitations and limitations on personnel. The system will be completed in Year 8 under a no-cost extension. Once completed, USCG personnel will be trained to use the new system, achieving this metric.
Achieve / assess practicality of successful <i>Marine IP data collection</i> by personnel that are not Marine IP technicians, such as a USCG crew member that has been trained in the operation of the technology	Incomplete	Building of the Marine IP Arctic-Ready field kit was delayed due to COVID-19 supply chain limitations and limitations on personnel. The system will be completed in Year 8 under a no-cost extension. Once completed, USCG personnel will be trained to use the new system, achieving this metric.
Achieve operational rate of ruggedized hardware and software system in field conditions of greater >90%.	Incomplete	Building of the Marine IP Arctic-Ready field kit was delayed due to COVID-19 supply chain limitations and limitations on personnel. The system will be completed in Year 8 under a no-cost extension. Once completed, the laboratory and field testing of the system will be used to assess success of this metric.

Outcomes/output and TRLs:

Outcome/Output: During ADAC Program Year 7 the research team has successfully completed the following:

- Arctic-Ready Marine IP System – Hardware: Provide a Marine IP measurement field kit designed for use in Arctic conditions.
- *Engineering Design Report:* Provide advanced information for the design parameters for applications of Marine IP with an autonomous underwater vehicle (AUV).
- *Informing Oil Spill Response community of suitability of Marine IP* for detecting and potentially characterizing contamination of hydrocarbons in Arctic waters, to include characterizing oil in partial ice formations as well as under pack ice. Included in the analysis is providing insights to preferred deployment mechanisms and ability to enhance planning for deployment of spill response mechanisms.

- *Informing marine AUV community* (including ADAC and the Center's Long Range Autonomous Underwater Vehicle project team) of additional understanding gained about the suitable design parameters for potential downstream integration of Marine IP.
- *Informing Oil Spill Response community of suitability of Marine IP* to detect and delineate contamination of seafloor sediments.

Technology Readiness Level (TRL):

- Following the field trials planned as part of the no-cost extension, this will represent a Technical Readiness Level of 7 – system prototype demonstration in a realistic environment.

Unanticipated problems and plans for addressing them:

As described in the Methodology above, build of the ruggedized field-ready Marine IP kit was delayed by supply-chain problems related to the COVID-19 pandemic. Component and supply chain interruptions were anticipated as a possible risk; however, the extent of the shortages was not anticipated. As planned, the Marine IP team worked to mitigate the risk by selecting common, typically readily available components, however COVID-19 shortages were unprecedented, and therefore unanticipated. Design of the system proceeded on schedule, resulting in the necessary bill of materials. However, at procurement, many component parts were not available, new parts had to be selected, and the system design modified to accommodate the new parts. This was completed in early 2021, so that the system could be procured and assembled. This delay, however, has shifted some of the project tasks into a no-cost extension, including completion of the firmware and software implementation and laboratory and field testing of the new system. This work is still planned and can be completed under the negotiated no-cost extension. Hence, although delayed, the original project goals, objectives, and milestones will still be met.

Transition Activities: [EM12][EM13]

Transition plans [EM14][EM15] and progress being made: One important outcome of this project has been creation of the Engineering Design Report detailing the procedures to manufacture a ruggedized field-ready Marine IP kit. This Engineering Design could be used by other researchers or commercial entities to manufacture Marine IP equipment meeting the specifications of the products created here. Once the firmware and software implementations are complete, these could also be made available, allowing the Marine IP system designed here to be built and used by others. The team will also work to inform the AUV community of the technical specifications of the Marine IP technology and to work with the AUV community to research ways to incorporate Marine IP into AUV platforms. The advancements in Marine IP through this and past ADAC research will continue to be presented at prominent Oil Spill conferences, such as International Oil Spill Conference (IOSC) and Clean Pacific/Gulf. Following the field trials planned as part of the no-cost extension, this will represent a Technical Readiness Level of 7 – system prototype demonstration in a realistic environment.

PROJECT: Oil Spill Modeling for Improved Response to Arctic Maritime Spills: The Path Forward

Project Investigator: Dr. Nancy E. Kinner

Lead Institution: University of New Hampshire Coastal Response Research Center (CRRRC), Center for Spills and Environmental Hazards (CSE).

Supporting Team: NOAA OR&R and USCG PACAREA and D17

Project Champion: Kirsten Trego (USCG) CG-5RI

Project Description:

Abstract:

As examined during an ADAC 2017 maritime oil spill response workshop, the Arctic region is projected to realize more maritime shipping and natural resource development. Accordingly, the probability of more and larger spills, particularly of petroleum, is increasing the need for response-relevant computer modeling. The National Oceanic & Atmospheric Administration (NOAA) Office of Response & Restoration (ORR) provides scientific support to the U.S. Coast Guard (USCG) Federal On-Scene Coordinator (FOSC) during oil spill response. One principal product NOAA ORR supplies is decision support models that include: predicting the path and future location of the spilled oil; characterizing the habitats and species at risk (including humans) and the extent to which they must be protected; and analyzing the potential performance of various clean-up alternatives.

NOAA ORR has access to multiple environmental models useful to characterize an Arctic spill response, including several specifically for ice conditions (such as ADAC's Arctic Oil Spill Modeling). The rising risk of an Arctic oil spill increases the urgency to identify the current state-of-the-art models and the potential for integration across current and emerging environmental models. Accordingly, this research investigation will create a knowledge project, as guided by a Project Core Team, Workshops and expert Working Groups, to assist future USCG-led spill response communities in strategizing new investment in model development and associated integration.

Accordingly, the ***Oil Spill Modeling for Improved Response to Arctic Maritime Spills, the Path Forward*** project provides a structured approach to solicit expert advice to develop such a strategy as driven by USCG FOSC core needs in an Arctic oil spill response. The project began with the formation of a project "Core Team" (membership consists of ADAC center representative, University of New Hampshire Coastal Response Research Center, Center for Spills in the Environment, Headquarters USCG Maritime Environmental Response (HQ USCG MER), USCG Pacific Area (PACAREA) USCG District 17 (USCG D17), Alaska Department of Environmental Conservation (ADEC) and NOAA ORR). This core team developed a list of needs/questions that Arctic response models should address. These served as guideposts to focus all of the project's efforts. Subsequently, the project developed and executed a workshop and established 4 expert Working Groups to produce stakeholder consensus on approaches to Arctic response modeling that yield more accurate results with clear uncertainty bounds in response timeframes. Working Group topics include Oil and Ice Interactions at the Meter/Sub Grid Scale, Oil and Ice Interactions at the Kilometer + Scale, New and Existing Technologies for Observing Ice and Informing Models, and Visualization/Uncertainty. Another

workshop will be held to compile the information gathered from these Working groups. The final knowledge product will recommend what new components/sub-models should be developed and validated and how best to coordinate further modeling efforts to aid a USCG-led FOSC in an Arctic maritime oil spill response.

Objective/Purpose:

The objective of this project is to create and publish a knowledge product (a comprehensive report) that will detail:

- Specific needs to be addressed to obtain models that will be functional and effective in the response time scale to advance FOSC decision making during an incident as well as improve the experience gained from exercises and drills.
- Current state-of-the-art Arctic maritime oil spill response models.
- Potential integration of these models and components from recent research efforts (integration of ice models with oil spill models).
- Gaps in current models that need to be addressed by future research

In addition, the knowledge product will clearly delineate the characteristics of oil spill response that makes some models inappropriate for the time-scales required to inform daily response planning and decision-making.

Finally, the knowledge product will recommend what specific new components/sub-models should be developed and validated so that Arctic maritime spill response models may better inform an FOSC's crisis decision-making. The Project Team will recommend which new components/sub-models are most suitable to coordinate further model development in Arctic oil spill response modeling. It is likely that such model development will need to consider the special requirements of the U.S. Federal incident command system where the USCG FOSC receives scientific support from NOAA's Office of Response and Restoration (ORR).

Methodology:

The objective of this project is to identify the: current state-of-the-art Arctic maritime oil spill response modeling, potential integration of these models, and specific needs to be addressed to obtain models that will be functional and effective in the response time scale to advance the FOSC's decision making during an incident and improve the experience gained from exercises and drills. The focus will be on making models that consider the complications unique to the Arctic (e.g., ice, adverse weather, international waters, and lack of response equipment) that make response modeling particularly challenging. ADAC Program Year 7 consisted of 3 phases:

- *Phase 4 (continued): Working Groups on Topics Determined by the Phase 3 Workshop*
- *Phase 5: Conduct a Two-Day Workshop to Review Working Group Drafts and Integrate Feedback into an Initial Knowledge Product.*
- *Phase 6: Complete Knowledge Product.*

Student Involvement:

Two ADAC Fellows were selected to work on this project: Megan Verfaillie, whose UNH Civil Engineering master's thesis was the basis for the Knowledge Product of this project and Jessica Manning, a UNH Environmental Engineering Undergraduate, who assisted Megan and used the project's ice modeling summaries as the basis of her senior honors thesis.

In late Program Year 5, ADAC and the PI successfully integrated Megan and Jessica into the ADAC Fellows Program. The Fellows helped write the Project Year 6 Annual Report and Year 7 Work Plan and will help with all other deliverable reports and the final Knowledge Product. During Program Year 7, they participated in conference calls and the final workshop. They helped with notetaking, database maintenance, and meeting organization. These students will continue to collaborate with key people in the field of oil spill response, assessment, restoration and research. This includes meeting with USCG experts and operators. Consistent with all ADAC undergraduate and graduate student fellows, once they graduate, ADAC supports and advocates for these student fellows for career placement in the Homeland Security Enterprise. Megan is pursuing a Ph.D. in Civil Engineering at UNH starting in June 2021 with Prof. Jennifer Jacobs. The topic of her dissertation will be remote sensing use in water resources management. Megan became interested in remote sensing during her work with the AMSM Remote Sensing Working Group. Jessica is continuing at UNH working on a master's in Civil and Environmental Engineering with the AMSM project PI Nancy Kinner. Jessica's thesis research will involve laboratory flume studies on movement of oil under ice, a topic to which she was exposed during the AMSM project.

The students participating in the program, who are ADAC Fellows, are shown in the table below.

Table 11: Oil Spill Modeling student activities

Name	University	Year (Fall 2020)	Duties	Benefit
Megan Verfaillie	University of New Hampshire	M.S.	Note taking, report writing, literature search, database maintenance	Exposure to and understanding of state-of-the-art Arctic and non-Arctic oil spill modeling
Jessica Manning	University of New Hampshire	Senior	Note taking, database maintenance	Exposure to and understanding of state-of-the-art Arctic and non-Arctic oil spill modeling.

The ADAC Fellows completed the following activities in Program Year 7:

- Participated in Core Team, Workshop Organizing Committee, and Working Group meetings as recorders and organizers
- Attended Arctic Maritime Spill Response Modeling (AMSM 2020) Virtual Workshop
- ADAC Fellow Jessica Manning:
 - Conducting senior thesis research on available and desired ice characteristics (e.g., ice distribution and thickness, under ice storage capacity) to improve oil

spill models in the Arctic

- Included review of accepted file formats and time required to integrate data during a response
- Continuing usual organizational and note taking tasks for Project Core Team and Working Groups
- Attended workshops/conferences on Related Topics:
 - CRRC NOS Hurricane Summit 2021 (June 2021)
 - CRRC Gulf of Mexico Marine Mammal NRDA Workshop (June 2021)
 - DHS COE Summit Tabletop (May 2021)
 - IOSC 2021 (May 2021)
 - UNH URC (poster presentation) (April 2021)
 - ADAC Arctic Spill Modeling Workshop – Part II (Nov. 2020)
 - CRRC NOS Hurricane Summit (Aug. 2020)
 - Arctic Summer Internship Program (June – Aug. 2020)
- ADAC Fellow Megan Verfaillie:
 - Conducting independent research on Arctic maritime spill modeling that served as the basis for her master's thesis
 - Continuing usual organizational and note taking tasks for Project Core Team and Working Groups as well as drafting documents and presentations as needed
 - Attended workshops/conferences on Related Topics:
 - NOAA/CRRC Hurricane Summit (2021, Remote)
 - International Oil Spill Conference (IOSC 2021, Remote)
 - DHS Center of Excellence Summit (presenter)
 - CRRC Alaska Marine Mammal NRDA Oil Spill Tabletop Exercise
 - UNH Graduate Research Conference (poster) (March 2021, Remote)
 - ADAC Arctic C-ICE (March 2021, Remote)
 - ADAC Program Year 7 Roundtable (January 2021, Remote)
 - ADAC Quarterly Review (January 2021, Remote)
 - ADAC Program Year 7 Roundtable
 - ADAC Quarterly Review
 - ADAC Arctic Spill Modeling Workshop - Part II, (November 2021, Remote)
 - ICCOPR R&T Plan Meeting (September 2020, Remote)
 - CRRC NOS Hurricane Summit (August 2020, Remote)

Key Accomplishments:

Phase 4: Arctic Maritime Spill Response Modeling Workshop Working Groups

Following the 3-day spill response modeling workshop, the Project PI facilitated the formation of Working Groups with help from the project Core Team and Workshop Organizing Committee. The Project PI designated a NOAA ORR co-group lead for each Working Group. The Co-Working Group Leads work with the Project PI to ensure that the Working Groups were making good progress and on task. The Working Groups met every three weeks via Google Meets conference calls. The Project PI provides administrative coordination for all Working Groups, including maintaining records and files for documents and relevant materials. Working Group meetings began in March 2020 and met approximately 11 times for 1 hour each leading up to the two-day workshop in mid-November (Project Phase 5). Detailed meeting notes are available to the group online through Google Drive.

The Project PI and Co-Working Group Leads coordinated and documented group outcomes in a spreadsheet and a detailed slide presentation summarizing the group's findings, their relevance to response modeling, resolution of issues and detailed research needs. The Project PI and Working Group co-leads completed all associated documents in time for presentation and discussion at the Phase 5 Three-session Virtual Workshop.

Working Groups centered on the following topics:

- Oil and Ice Interactions (Meter/Sub Grid Scale)
- Oil and Ice Interactions (Kilometer+ Scale)
- New and Existing Technologies for Observing Ice and Informing Models
- Visualization/Uncertainty

Key Finding and Research Needs for Individual Working Groups:

Oil and Ice Interactions (Meter/Sub Grid Scale):

- Much information is available from ice models, but not all are well suited to provide for oil spill model needs.
- Challenge to have resolution of ice models at small enough scale for time and place of spill. Ice models need boundary conditions and different physics for these smaller scales, as the ice rheology can break down.
- Some models are not sufficient for capturing stratification in the Arctic and require higher vertical resolution.
- Ice ocean coupling is rudimentary in several models.
- Quantify storage capacity beneath different types/ages of sea ice with statistical distribution.
- Use ice velocity and current data to potentially estimate stripping velocity.
- Explore the extent to which under ice velocity impacts storage capacity.
- Develop publicly available algorithms appropriate for oil spill models that use outputs readily available in ice models or outputs that can be derived from them or other

parameters that may be included in ice models in the near term.

Oil and Ice Interactions (Approximately Kilometer+ Scale):

- Many different parameters are needed from ice models, but on smaller spatial scales and timescales than those posted on the web on a routine basis.
- Spill responders want 1 km scale, hourly data to address transport.
- Oil in ice algorithms used in oil models are all similar.
- Determine if roughness and velocity are linked variables.
- Spill modelers need finer scale ice data than climate scale.
- Oil spill modeling depends on accuracy of coupled ice and ocean models.
- Difficult to accurately predict where the oil goes without accurate ice information.
- Must continually re-initialize oil spill model and run it forward using observations of location of the oil.

New and Existing Technologies for Observing Ice and Informing Models:

- Discussed existing technologies of relevance to oil and ice detection in the Arctic/ice-filled environment.
- How can we tap into and access these or learn more about them?
- Designed a list of questions for each type of technology
- Developed spreadsheet of satellite, airborne, surface and subsurface, and seafloor mounted technologies suited for two scenarios
- Large vessel traveling through Bering Strait in freeze up/fall.
- Pipeline spill under land fast ice.

Visualization/Uncertainty:

- Defined uncertainty and what the FOSCs thought uncertainty was and how they digest it.
- How can we help FOSCs understand what uncertainty looks like?
- Predetermined qualitative confidence level at low/medium/high level is sufficient for most decision making.
- Help FOSCs understand trajectory and how that output obtained.
- Developed Confidence Estimates of Oil Model Inputs and Outputs (CEOMIO) table.

Phase 5: Three Session Virtual Workshop to Review Working Group Drafts and Integrate Feedback into Knowledge Product

The goal of the three-session workshop, conducted on Zoom in November 2020, was to vet and

integrate working group findings. The Project PI leveraged deliberations from the four Working Groups to stimulate collaboration and consensus on a pathway forward for Arctic oil spill response modeling, including acceptance of standards, assumptions, algorithms and approaches to solve a variety of issues. The workshop was designed to maintain the open channel of communication among responders, scientists and modelers started at the first workshop and continued during the Working Groups. This workshop was essential to ensure that the final product is consistent and cohesive, especially because multiple groups will be working on the topics. The workshop also allowed responders to be sure that the proposed products are useful and that suggested model developments will conform to key criteria that fulfill the decision maker's needs. This workshop consisted of report outs from the Working Groups and feedback from the stakeholders (e.g., NOAA ORR, USCG, Core Team, Project Champion).

On Day 1 of the workshop (November 16), 78 people participated. Each of the working groups presented their objectives, findings, recommendations, and research needs identified. Participants asked questions about the findings and conclusions and made suggestions regarding modifications. Detailed notes on each presentation and the ensuing discussion were posted on the CRRC/CSE website along with the slides from each group. Overall, the groups' findings and recommendations were well received by the scientists and responders attending.

The two subsequent days were by invitation only as attendees were developing final recommendations and research needs. Discussion on November 23, when 34 people participated, centered on:

Data Assimilation for Oil Spill Models:

1. What kinds of data (e.g., location of oil with respect to ice) can be assimilated in Arctic oil spill models and how can this data be used?
2. How can data assimilation be used to help better align predictions with observations?
3. What kind of technologies can be used to acquire needed observational data at the start of a spill?

Ice Modeling and Observational Needs/Scale of Outputs:

1. How can the disconnect between the scales/resolution needed by oil spill models and those provided by ice models and observations be addressed?

Under Ice Roughness/Storage Capacity/Oil Migration:

1. What factors impact storage capacity (e.g., under ice velocity) and how can under ice storage capacity be quantified using existing knowledge?
2. Devise a better understanding of how oil moves under/through ice and what parameterizations can be used to simulate this movement.
3. What other ice properties/outputs at the sub grid scale could be used to inform oil spill models?

Discussion on November 30, when 28 people participated, focused on:

Data Assimilation for Oil Spill and Ice Models:

1. What kinds of data (e.g., location of oil with respect to ice; location of oil with respect to ice such as underneath or on top, and proximity to ice edge and MIZ) can be assimilated into Arctic oil spill models?
2. How can data assimilation be used to better align oil spill model predictions with observations?
3. What algorithms could be used to "nudge" oil predictions to better align with observations (e.g., changing initial conditions, updating trajectories, adjusting model input parameters)?
4. What scales/resolution are required for ice/current models and/or observations to accurately predict specific ice conditions/features (e.g., leads, ice edge, % ice cover)?
5. How can data assimilation be used to improve ice model predictions? At what space and time scale can we consider the models to be deterministic (accurate) in their predictions? Does present data assimilation in the Arctic capture mesoscale circulation?
6. What kinds of technologies can be used to acquire needed observational data on oil and ice at the start of a spill?

Visualization/Uncertainty Implementation of CEOMIO Table:

1. How can the proposed Uncertainty Model Matrix (incorporate modeler experience into inputs?
2. How can definitions/numbers be assigned to confidence levels?
3. What steps would be required to put the Model Matrix into practice?
4. What fine grain information needs to be conveyed through images, tables, etc. to the FOSC?
5. How can shortfalls in uncertainty be mitigated with additional input data? How do the uncertainties propagate in the oil spill model?
6. How can modeler experience be incorporated into outputs?
7. Determine how numbers can be put on confidence levels (e.g., present qualitative and quantitative confidence bounds to different end users and see how they interpret it; provide definitions of what characteristics are associated with a given confidence level).
8. Determine how to put recommendations for visualization into practice (e.g., in ERMA) to create a more integrated model including uncertainty in a common operating picture (i.e., how to convey the overall picture and fine grain/small scale information to the USCG FOSC).

Refinement of Research Needs and the Path Forward:

1. What can we do in the near term (1-5 years) to improve the operation of oil spill models in the Arctic?
2. What topics should be revisited in the future based on new developments?

Phase 6: Complete Final Knowledge Product

The final Knowledge Product will be a comprehensive report containing:

1. A list of the needs/questions related to oil spill modeling that must be addressed to support the USCG FOSC in decision-making during an Arctic response.
2. A review of the current state-of-the-art on oil spill response modeling for Arctic maritime oil spills.
3. A framework for an integrated response modeling suite to address oil spills under ice, in leads, in the MIZ and for 3/10 to 8/10ths ice cover, etc.
4. Recommendations for addition of modules on response technologies.
5. Recommendations on incorporation of local and indigenous knowledge into response modeling activities; and
6. Detailed recommendations/scopes of work on modeling research needed to fill gaps identified during the project.

The master's thesis and senior honors thesis successfully defended by ADAC Fellows Megan Verfaillie and Jessica Manning, respectively, are the backbone of the Knowledge Product reviewed by the Core Team and submitted to ADAC on or before August 20, 2021. The contents of the Knowledge Product will also serve as the basis for a peer reviewed publication on the state of the art of Arctic oil spill modeling and the research needs to improve predictions of movement of oil in ice infested waters. This paper, along with the journal article on uncertainty in model prediction published during Year 7 will be the major contributions to the literature for the AMSM project. UNH CRRC/CSE will also host/maintain, for a minimum of 5 years, a section of its website dedicated to this project entitled "Arctic Oil Spill Modeling." ADAC will correspondingly plan to cross-link this information to the ADAC website at: <https://arcticdomainawarenesscenter.org/>. The UNH CRRC/CSE website will contain all information for each of the project phases. A complete bibliography will be maintained as a part of the project in a database that will be searchable.

Key Stakeholder Engagement:

Key Stakeholder participation in the November 2020 workshop.

Regular Core Team meetings and Working Group meetings held monthly and triweekly, respectively.

Project team participated in four ADAC Customers and Partners Roundtables. During the Customers and Partners Roundtable, the project team provided a brief technical summary of their project and answered questions from federal customers and interested parties including representatives from the USCG and NOAA.

The Core Team is composed of the primary stakeholders for this project including NOAA ORR and USCG PACAREA and D17. As a result, there is frequent stakeholder engagement inherent in this project. In addition to regular Core Team Meetings, individual meetings have been held with NOAA ORR modelers in Seattle, WA (virtually) to discuss Working Group topics, project status and the path forward.

Key Publications (peer reviewed):

Manning, J.; Verfaillie, M.; Barker, C.; Berg, C.; MacFadyen, A.; Donnellan, M.; Everett, M.; Graham, C.; Roe, J.; Kinner, N. Responder Needs Addressed by Arctic Maritime Oil Spill Modeling. *J. Mar. Sci. Eng.* **2021**, 9, 201. <https://doi.org/10.3390/jmse9020201>

Key Presentations:

Project team presented at ADAC Program Year 7 Annual Meeting. The Annual Meeting was held virtually via Cisco WebEx as COVID-19 prevented an in-person gathering in Washington D.C. as in previous program years. DHS S&T OUP, HQ USCG ADAC Project Champions, NOAA leadership, ADAC Executive Counselors, and many other customers and partners participated ADAC's Year 7 Annual Meeting.

Changes from initially approved Workplan:

N/A

Project progress against each milestone:

Table 12: Oil Spill Modeling Year 7 Milestones Phase 1: Project Core Advisory Team

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Selection of Core Team members in coordination with Project Champion.	Completed	N/A
Project PI providing invitations to Core Team members with project description/schedule and explanations of Core Team duties	Completed	N/A

Table 13: Oil Spill Modeling Year 6 and 7 Milestones Phase 4: Facilitate Working Groups

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Project PI leads formation of Working Groups following the Phase 3 workshop.	Completed	N/A
Working Group co-lead selection.	Completed	N/A

Project PI facilitates monthly meetings of the 4 Working Groups.	Completed	N/A
Project PI facilitates monthly meetings of Core Team and Working Group co-leads for cross coordination.	Completed	N/A
Project PI conducts scheduled cross-team Working Group meetings.	Completed	N/A
Project PI coordinates drafting of Working Group reports with onward edits provided by co-leads, reviewed and approved by Working Group members.	Completed	N/A

Table 14: Oil Spill Modeling Year 7 Milestones Phase 5: Workshop to Review Working Group Drafts and Integrate Feedback into Knowledge Product

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Project PI facilitates monthly meetings with Core Team to plan workshop	Completed	N/A
Project PI coordinates delineation of Phase 5 workshop objectives.	Completed	N/A
Project PI facilitates OC solidify workshop objectives, dates/location, agenda including speakers and breakout groups, and participants.	Completed	Because the workshop was virtual, the location was on-line and breakout groups became smaller discussions sessions on specific topics

Project PI plans logistical support for workshop (e.g., venue selection, travel arrangements, audio/video supplies, room arrangements, lodging contracts, participant packet materials) in coordination with ADAC staff.	Completed	Most of this planning was not necessary as the workshop was virtual
Project PI executes corresponding workshop, with planned dates of November 2020.	Completed	N/A

Table 15: Oil Spill Modeling Year 7 Milestones Phase 6: Completion of Knowledge Product

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Discussions with Core Team on format for Knowledge Product.	Completed	N/A
Project Team commences writing of final Knowledge Product after the Phase 3 workshop	Completed	N/A
Project PI coordinates draft of final Knowledge Product in September 2020 for review and comments by Core Team and Working Group Co-leads.	Modified	Project PI worked with Working Groups in September and October 2020 to complete draft findings and recommendations for presentation at the Phase 5 workshop and inclusion in the Knowledge Product
Project PI commences second draft of final Knowledge Product for review by Core Team and Co-leads in October 2020.	Modified	Core Team and Project PI decided it was pre-mature to Knowledge Project until Working Group findings and recommendations were reviewed by practitioners during the November 2020 workshop
Project Team writes third draft of final Knowledge Product in November 2020 after final workshop.	Modified	Project Team writes first draft of final Knowledge Product in February 2021 based on edited notes posted from the November 2020 workshop sessions
Project PI completes Fourth (final) version of final Knowledge Product and submit to ADAC December 2020	Modified	Project PI completes final version of Knowledge product in August 2021 (Year 8)

Project PI and ADAC collaborate to draft and submit a peer review journal article	Modified	This manuscript will be started after to final Knowledge Product is submitted to ADAC in August 2021 (Year 8)
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Project progress against each metric:

Table 16: Oil Spill Modeling Year 7 Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Is the project on time, based on the schedule set forth in the detailed work plan established between ADAC, the Core Team, and the Project PI?	Completed for Phases 1, 2, 3, 4 and 5. Working on Phase 6 (Final Knowledge Product)	Completion date of August 15, 2021, anticipated for Final Knowledge Project.
Is the project at, or under, cost based on the budget established by ADAC and Project PI?	Completed for Phases 1, 2, 3, 4, and 5. Working on Phase 6.	Completion date of August 15, 2021, anticipated for Final Knowledge Project.
Are resources (e.g., references, workshop/working group participants) being gathered/recruited in sufficient numbers for the project tasks?	Questions are completed, literature database completed. Spreadsheets completed.	N/A
Is the scope of the project adequate or does it need to change to meet unforeseen components that arise in response modeling?	Yes, Completed	N/A

Is the quality of the project products acceptable to the Project Champion/Core Team/ADAC? Are the products useful to responders and decision-makers in exercises and spills? Are they advancing the ability to model Arctic oil spills and inform decision making by an FOSC?	Workshop 2 report completed, reviewed, and accepted by Core Team and Project Champion. Final Knowledge Product will be evaluated by the Core Team and Project Champion.	Will be continuously evaluated by Core Team and Project Champion.
What actions need to be taken to continue the project/maintain quality/or improve quality?	None [EM16].[MOU17]	Activities are going according to schedule and cost, stay the course.

Outcomes/output and TRLs:

As with all ADAC products, research team and center leadership will ensure dissemination of all suitable data. In sum, all data produced during this project will be made publicly available.

Outcomes:

Project provides a comprehensive review of existing oil spill modeling research and existing capabilities. Because this project performs a review of existing oil spill modeling technology and will ultimately result in updated oil spill models for an Arctic context, specifically NOAA's GNOME, it spans multiple possible levels of TRLs, and Technology Phases as defined by DHS.

Output:

This project will produce a comprehensive Knowledge Product to inform future oil spill research and is useful to inform USCG led oil spill response.

Technology Readiness Level (TRL):

This project performs a Needs Assessment, which is an entirely different Technology Phase outside of TRLs. This project has already met some definitions of TRL 3 because the customer/user has been identified and has actively participated (and continues to actively participate) in generating and defining project requirements.

Additionally, since this project has also evaluated the capability of state-of-the-art oil spill modeling in an Arctic context, this project has also fulfilled the TRL 3 objective of "Preliminary system performance characteristics and measures have been identified."

Finally, since this project will update and modify existing oil spill models to meet various end users' Arctic oil spill modeling needs, this project could also satisfy a TRL 8 or 9.

Unanticipated problems and plans for addressing them:

COVID-19 affected University of New Hampshire in-person operations due to the limited capacity with 6 ft spacing of personnel and students in campus buildings and facilities. As a result, all meetings of the project team (Kinner, Verfaillie and Manning) occurred weekly via ZOOM. Otherwise, there has been minimal impact on the project during Year 7 as the Phase 4 working groups were always planned to be virtual. The main impact was that the planned Year 7 two-day workshop was transitioned to remote participation in order to accommodate travel restrictions. In addition, the PI gave the Year 7 presentation at the ADAC Annual Meeting in June 2021 using ZOOM.

Transition Activities:

Transition plans and progress made: Principal transition plan is to create a Knowledge Product to support USCG led Federal On- Scene Maritime Environmental Response in an Arctic context. The Knowledge Product is almost completed and will be submitted on or before August 20, 2021. In addition, a new transition activity was funded for the AMSM project for Year 8 of ADAC. The project team will facilitate an expert working group starting in early September 2021 to determine the exact data feeds from the existing ice forecasting models and services that will be input into the existing U.S. oil spill models (e.g., NOAA's GNOME) to predict the trajectory of oil in ice. Discussions with NOAA modelers has already started to outline the specific topics for consideration among the experts. Once the individual data feeds are determined, coding will occur to get the necessary information from existing ice models/services in the correct format to ingest into the oil spill models. Finally, a tabletop exercise will be conducted to test the speed and seamlessness by which the ice inputs are feed into the spill models and the reliability of the subsequent oil trajectory outputs. The result of this effort will be a modification to GNOME that will allow NOAA to provide better predictions of where oil will move in ice infested waters, helping USCG make more informed decisions. In addition, the CEOMIO table will be tested to gauge its utility in providing detailed information to FOSCs on sources of uncertainty associated with the model predictions during spill response.

The Knowledge Product and corresponding peer-review journal article will be promulgated across USCG, ICCOPR, and NOAA and via the ADAC and CRRC/CSE networks. The knowledge gained from this project will be directly transferable to HQ USCG Maritime Environmental Response, NOAA ORR and its Emergency Response Division (ERD) team, which is represented on the Core Team. This is important because NOAA ORR is responsible for providing scientific support to USCG during maritime incidents, so its oil spill modeling must be fully adapted to the varying and unique conditions in the Arctic. The Project PI also anticipates that much of the knowledge gained and consensus reached will be used by the private sector and other government agencies within and outside of the U.S., as well as NGOs. Many proprietary models exist (e.g., SIMAP) for use in the Arctic during spills, it is likely that they will also benefit from the consensus approach to modify their oil spill response modeling products, as needed.

PROJECT: Arctic Facilities and Infrastructure Environmental Change Risk Index

Project Investigators: Dr. Craig Tweedie, University of Texas El Paso, El Paso TX, and Dr. Matthew Calhoun, College of Engineering, University of Alaska Anchorage (UAA), Anchorage AK

Lead Institutions: University of Alaska Anchorage UAA and University of Texas El Paso

Project Supporting Researchers:

- Dr. Ben Jones, Institute of Northern Engineering, University of Alaska Fairbanks, Fairbanks AK.
- Ms. Kelsey Frazier, ADAC Research Associate, UAA.
- Mr. Jeff Libby, Director, Applied Environmental Research Center (AERC), UAA
- Dr. Molly Grear, Pacific NW National Laboratories, Richland WA.
- Mr. Nagruk Harcharek, Ukpeaġvik Iñupiat Corporation, Utqiagvik, AK.

Project Advisors:

- Tom Douglas, Cold Regions Research and Engineering Laboratory, Ft Wainwright AK.
- Givey Kochanowski, Alaska Senior Advisor for the U.S. Department of Energy (DOE) Office of Indian Energy, Anchorage, AK.

Project Evaluators: ¹

- Dr. Nancy Kinner University of New Hampshire, Durham NH, and two additional evaluators who are experts in Coastal engineering and/or permafrost degradation or risk assessment.

Project Champion

- Ms. Galia Kaplan and MSTC Douglas Furman, Office of Port and Facility Compliance CG-FAC, Headquarters (HQ) U.S. Coast Guard (USCG), Washington D.C.

Project Stakeholders:

- Mr. Dan Lawrence, CG-OES, HQ USCG Washington D.C.
- CDR Wes James, Office of Marine Environmental Response CG-MER, HQ USCG Washington D.C.
- Mr. Shannon Jenkins, Senior Arctic Policy Advisor, CG 5PW, HQ USCG Washington D.C.
- Dr. Phil McGillivray, Science Advisor USCG Pac Area, Alameda CA
- Mr. Phil Thorne, Arctic Planner, USCG District 17, Juneau, AK.
- Mr. Mark Everett, USCG District 17, Juneau, AK.
- LCDR Jerome Altendorf, USCG District 17 Sector Anchorage, AK.

¹ Project require subject matter experts to monitor and evaluate scientific progress based in part on the project evaluation criteria for objectivity and quality.

Project Description:

Abstract:

As the Arctic region is exposed to the impacts of climate change, increased coastal erosion, and more frequent precipitation, structures once protected by shore-fast ice and securely anchored in permafrost are now exposed to an increasingly dynamic and adverse environment. The imminent threat of infrastructure failure has the potential to cause significant environmental harm and disrupt socioeconomic stability and food security of U.S. Arctic residents. Recognizing that (i) the Arctic is experiencing the most dramatic impacts from climate change on the planet; ii) there is a prevalence of ageing oil and other infrastructure constructed upon increasingly unstable permafrost coastlines and riverine landscapes; and iii) there has been multiple small to large scale infrastructure failures documented in the Arctic over the past decade.

This project responds to these concerns as expressed by U.S. Coast Guard (USCG) District 17 to provide an environmental risk index oriented to Arctic coastal regions as a decision support tool to assess environmental impacts to coastal facilities and infrastructure that are under the purview of USCG inspections. This research will focus on conducting a coastal facilities and infrastructure engineering risk analysis along western and northern Alaska. The study will draw experts from a range of disciplines and utilize a collaborative set of workshops and smaller standing working groups to solicit expert opinion that will be used to derive data to apply to models, and test, and deliver an “Arctic facilities and infrastructure environmental change” risk index. The project team will actively seek to coordinate with relevant international Arctic scientists, engineers, and other stakeholders to share and co-develop approaches that are mutually beneficial to those similarly challenged by Arctic environmental change.

The project primarily focuses on bulk oil/fuel containers and pipelines, and piers, docks, and platforms in permafrost coastal and riverine landscapes of the Bering, Chukchi and Beaufort Seas. Analysis uses appropriate qualitative and quantitative approaches for the data being used and questions posed with attention to uncertainty. Products inform responders and inspectors of the current and predicted future structural integrity of those facilities, and the bearing capacity, stability, and susceptibility to erosion of the surrounding/ supporting landscape. The research effort will produce three products: a comprehensive Arctic facilities and infrastructure environmental change knowledge product, an operationally relevant Arctic facilities and infrastructure environmental change risk index, and an Arctic inspector and responder structural environmental impacts training guide.

Objective/Purpose:

This project addresses direct concerns regarding structural risks of facilities and infrastructure in Arctic Alaska due to cumulative effects of environmental change.

Based upon analyzing these concerns, this research addresses two principal questions:

1. What are the risks and severity to USCG monitored facilities along the Arctic coastal regions of the Bering, Chukchi and Beaufort Seas?

2. What are the risk weightings related to the USCG monitored facilities along the Arctic coastal regions?

In order to address these questions, three primary objectives are being conducted, and each objective contains a series of underlying questions and/or sub-objectives and supports the generation of one of the three project outcomes for the research:

1. Synthesize published literature, existing data from available sources,² USCG infrastructure and incident reporting, and consolidate expert opinion to establish a baseline knowledge project in support of USCG Project Champion and USCG Project stakeholders. This information will guide and inform the project's interdisciplinary workshops and focused working groups.
 - a. Core supporting questions:
 - i. What environmental phenomenon, and/or structural engineering, and other factors are associated with infrastructural degradation or inspection failure?
 - ii. How are environmental phenomenon associated with infrastructure degradation or inspection failure changing?
 - iii. How adept are past and present engineering and inspection practices suited to the changing environment?
 - b. Associated product/deliverable(s):
 - i. Research team developed knowledge product, which provides USCG Project Champion a report of investigations accomplished, associated Literature Review, annexes of acquired data and research findings. The research knowledge product provides Stakeholders a source document, potentially useful for additional applications/follow-on research, beyond the scope of the investigations.
2. Drawing from the knowledge product to be established in Objective one, develop an "Arctic facilities and infrastructure environmental change" risk index, as a USCG decision support tool.
 - a. Core supporting questions/ sub-objectives:
 - i. What key engineering and or environmental factors, conditional states, and thresholds best predict infrastructure or inspection failure in the US Arctic?
 - ii. Can a risk index model for infrastructure failure adequately predict known infrastructure failure events?
 - iii. Using a validated risk index of infrastructure failure, what are the forecast spatiotemporal patterns for infrastructure failure in the US Arctic?
 - iv. How can facilities and infrastructure inspection and monitoring be modified to improve the early detection of infrastructure failure?
 - v. What are the key uncertainties, priorities for risk reduction, and future research priorities that arises from this project?
 - b. Associated product/deliverable(s):

² Examples provided: Alaska District U.S. Army Corps of Engineers, State of Alaska Department of Environmental Conservation, Denali Commission, University of Alaska Fairbanks Institute of Northern Engineering, Associated State of Alaska Boroughs, Ports and Villages associated with USCG designated infrastructure and facilities of concern and others as determined by the research team and established project research groups.

- i. Integrated environmental, infrastructural data set drawn from published literature, data archives, change analyses, inspection and incident reports, and associated environmental characterization models³.
 - ii. Validated risk index and associated analysis of uncertainty.
 - iii. Tangible and rationalized review of USCG inspection and structural monitoring approaches.
- 3. Transition products from Objectives one and two into products that can be promulgated to the USCG, stakeholders, and the broader scientific and engineering community.
 - a. Core supporting questions/ sub-objectives:
 - i. Develop an optimized and operationally relevant transition plan and guidelines for improved infrastructure inspection and monitoring.
 - ii. Share findings with project stakeholders.
 - iii. Share findings with the broader scientific and engineering community.
 - b. Associated product/deliverable(s):
 - i. Deliver products as well as provide supplemental briefings to inform USCG Project Champion and USCG Project Stakeholders.

Definitions: The focus of the research is to study environmental change on infrastructure and facilities built on permafrost coastal and riverine landscapes in the U.S. Arctic. The project team is concerned with infrastructure and facilities that are of prime interest to the USCG, even if the jurisdiction of these facilities and infrastructure are not owned or operated by the USCG or the Department of Homeland Security.

For the point of research definitions, the term “**facilities**” for this project is principally oriented to bulk oil/fuel facilities and/or piers, platforms, pipelines and loading docks near coastal regions or nearby/adjacent waterways. Facilities may be horizontal or vertically constructed. **Specifically**, for research associated with this project, the investigators will focus on bulk oil facilities regulated under 33CFR154. U.S. Coast Guard D17 will provide a list of those facilities to the project team.

The term “**infrastructure**” is associated with buildings that have foundations anchored in permafrost landscapes, are principally vertically constructed, and are permanent in nature near or adjacent to ports, waterfront or adjacent to waterways in the U.S. Arctic. **Specifically**, for the research associated with this project, the investigators are focused on USCG Forward Operating Base Kotzebue, port facilities at Nome, and the pier and surrounding uplands in Dutch Harbor where USCG has a use agreement with the City of Unalaska.⁴

This project is in the process of creating and producing three knowledge products (supporting Arctic facilities and infrastructure environmental change knowledge product, operationally relevant Arctic

³ As examples, the Barrow Area Information Database, which monitors coastline for permafrost degradation and coastal erosion along Beaufort and Chukchi Seas, developed by Project Investigator Dr. Tweedie, and ADAC Storm surge and coastal flooding model project for Western Alaska.

⁴ USCG D17 List of infrastructure includes Airports in Utqiagvik, Nome and Bethel; CG Aviation Support Facility Cold Bay; CG Aviation Support Facility St Paul; CG Forward Operating Location Kotzebue; Port facilities in Nome; Pier and uplands of the of the dock facility that CG utilizes in Dutch Harbor.

facilities and infrastructure environmental change risk index, and Arctic inspector and responder structural environmental impacts training guide) that collectively detail:

- Existing environmental models useful for predicting vulnerability to coastal erosion and permafrost degradation in Alaskan Arctic Coastal communities. Note, the research team may discover, identify and recommend adaptations to existing models that support/inform the overall environmental risk index.
- Identify Arctic coastal facilities (i.e.: tanks, platforms) and design components (i.e.: risers, above or below ground pipelines) that are most at risk of significant structural impairment from erosion and permafrost degradation.
- Identify specific signs and symptoms of infrastructure degradation and structural stress which can serve as accurate indicators of high risk of near-term structural failure. A follow-on activity of modeling indications may prove useful and feasible (beyond the scope of the research).
- Identify or establish needed technologies, methodologies, and practices for identifying structurally stressed or high-risk facilities.
- Correlate specific environmental changes and infrastructure engineering design typologies to create an operationally relevant Arctic facilities and infrastructure environmental change risk index and validate these against independent inspection and incident reports.
- Describe critical observational data collection procedures, structural change documentation procedures, and on-site risk analysis methodology in an Arctic inspector and responder structural environmental impacts training guide.
- Address how these Arctic-specific datasets can inform responses in other regions.
- While principally focused on the needs of the U.S. Coast Guard and their operations in the United States, the project team will actively seek to coordinate with relevant international Arctic scientists, engineers, and other stakeholders to share and co-develop technologies that are mutually beneficial to all those similarly challenged by Arctic environmental change.
- Note: While these knowledge products will be oriented to support U.S. Coast Guard decision makers, the products and associated research outcomes will also benefit the community of Arctic science and engineering, in accordance with ADAC's efforts to support the public good.

Methodology:

The research approach for the project utilizes a multidisciplinary team of Arctic scientists and engineers. This team studies the environmental changes of U.S. Arctic coastal regions to assess overall soil degradation and its impacts to infrastructure and facilities, focused on developing an associated risk index. The research team has organized and commenced preparations for follow-on expert workshops, acquired initial related data to support the research and the planned workshops, and established an initial core team to develop an environmental risk index to assess and prioritize risk to USCG designated facilities and infrastructure in Arctic Coastal Alaska.

These combined impacts include such factors as permafrost thaw, reduction of protective persistent shore fast ice, and associated coastal region erosion. From studying available data and reports, accessing known models, and by soliciting input from a number of additional expert analysis via

working groups, investigators are creating an Arctic coastal region environmental risk index that incorporates investigative review of associated effects to key infrastructure and facilities, focused on the particular locations identified by USCG. The research provides decision makers an overall environmental risk index by assessing specific locations of interest.

The investigative team is comprised of Arctic engineering experts who are leading focused studies regarding environmental change that is causing degradation of Arctic coastal regions. The team is expanding their expertise via establishing working groups, groups that provide multidisciplinary analysis of fine scale changes of Arctic climate change, leading to an analysis of the deterioration of structural stability of associated infrastructure and facilities.

The overall approach designed for this project is conceptualized in the below figure:

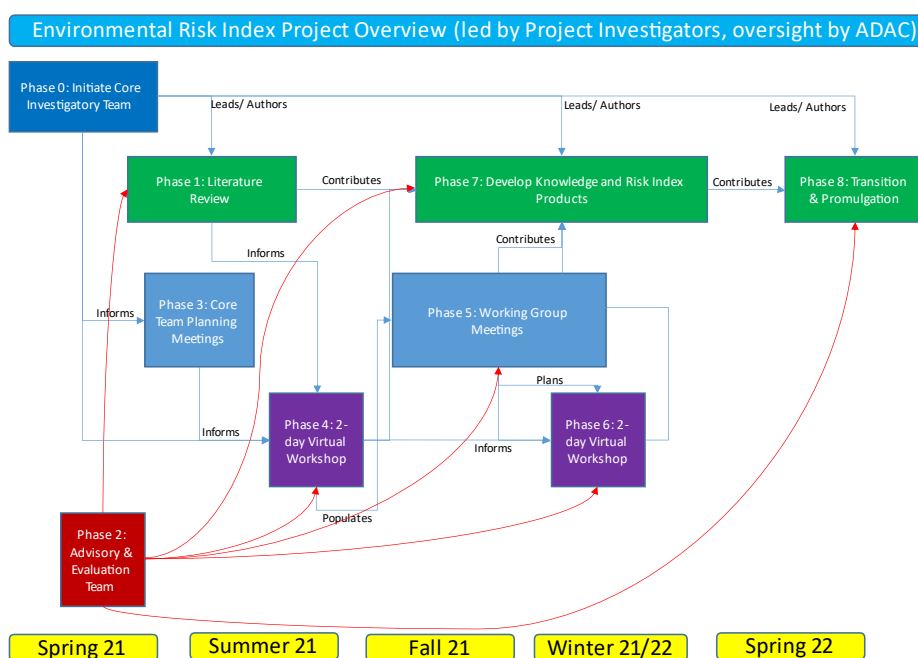


Figure 26: Environmental Risk Index Project Overview

The Investigatory (Phase 0), and the Advisory and Evaluation Teams (Phase 2) will be initiated in Spring 2021. The Investigatory team will author the primary products arising from the project (Phases 1, 7, 8 ~ green boxes), and inform both the planning (Phase 3) and working group meetings (Phase 5; light blue boxes) and virtual workshops (Phases 4, 6 ~ purple boxes). The Advisory and Evaluation Teams will advise/evaluate product development and working group activities and virtual workshops (red arrows). The Literature Review (Phase 1) will contribute to the generation of other products and inform the workshops (Phases 4, 6) and working group activities (Phase 5).

Data collected for this research is associated with qualitative and quantifiable attributes of environmental changes of Arctic coastal regions, principally oriented to USCG focused areas of interest. This includes such factors as coastal erosion and permafrost thaw, and available survey

and engineering reports associated with the facilities and infrastructure identified by USCG D17⁵. Data of environmental changes/associated structure changes/risk factors to specific USCG identified facilities and infrastructure is also included. As identified in the literature review, existing data from sources of coastal erosion and monitoring data (such as the Barrow Area Information Database) will be leveraged. Modeled data (such as that associated with prior ADAC Western Alaska Storm Surge and Coastal Flooding project) that helps characterize changing conditions of coastal structural stability will also be accessed.

Implementation of the methodology includes a sequenced set of coordinated and collaborative virtual meetings and Working Groups to facilitate the convergence of multiple scientific disciplines and the formulation of a knowledge product (or series of knowledge products) useful and relevant to USCG management of both risks to operational personnel and of a future regulated facility incident.

- Phase 0: Initiate investigative team led studies that forms the core of the knowledge product.
- Phase 1: Conduct a comprehensive Literature review and establish project communications schedule. Project team created an initial Literature review in Program Year 7 and will continue to refine and develop in Program Year 8.
- Phase 2: Formation of Project Core Advisory Team and establishment of Project Evaluation Team. Project team will accomplish this task in ADAC Program Year 8.
- Phase 3: Initial Meeting of the Core Team and key Stakeholders to formally establish the project Working Group categories and initiate group efforts to investigate principal and supporting research questions. Project team established initial Core Team functions in Year 7 and will expand in Year 8.
- Phase 4: Conducting a Two-Day Virtual event on permafrost degradation, coastal erosion, associated modeling technologies, to establish baselines on USCG focused infrastructure and facilities. Project team will accomplish this task in ADAC Program Year 8
- Phase 5: Establishing virtual Working Groups and conducting meetings. Project team will accomplish this task in ADAC Program Year 8.
- Phase 6: Conducting a Two-Day Workshop to Review Working Group Drafts and Integrate Feedback into Knowledge Product. Project team will accomplish this task in ADAC Program Year 8.
- Phase 7: Completion of comprehensive Arctic facilities and infrastructure environmental change knowledge product. Project team will accomplish this task in ADAC Program Year 8.
- Phase 8: Transition: promulgation of completed knowledge product across USCG community of interest (specifically, as designated by USCC Project Champion and USCG Project Stakeholders) and onward manuscript development and submission to peer review professional journals. Project team will accomplish this task in ADAC Program Year 8.

⁵ Project team will inquire with Alaska District U.S. Army Corps of Engineers, State of Alaska Department of Environmental Conservation, Denali Commission and associated village and port authorities to gain access to survey and engineering reports associated with USCG D17 identified facilities and infrastructure.

Details describing each phase of the project for Program Year 7 are as follows:

Phase 0: Initiate investigative team led studies that forms the core of the knowledge product. Co-investigators and funded research team, informed by prior research analysis and modeling in storm surge, coastal inundation and erosion in Western and North Slope Alaska establish qualitative and quantitative baselines of regional and localized effects of Arctic climate change in deteriorations to existing infrastructure and facilities. In particular, in Year 7, research team initiated outreach to obtain existing engineering analysis to characterize degradation of facilities and infrastructure risks to USCG determined assets in order to ascertain initial estimates of structural stability. These studies will continue throughout the tenure of the project. Co-investigators and funded research team, informed by prior research analysis and modeling in storm surge, coastal inundation and erosion in Western and North Slope Alaska made initial inquiries to establish qualitative and quantitative baselines of regional and localized effects of Arctic climate change in deteriorations to existing infrastructure and facilities.

Task 0.1 Program Establishment. This work includes the iteration, coordination and associated implementation of the project workplan, and the establishment of contractual and reporting mechanisms for all members of the research team.

Task 0.2 Initiation and onward conduct of engineering analysis. In order to form the baseline knowledge product, the funded research investigative team has established initial framework for engineering analysis to address the principal research question to understand the changing conditions of the Arctic coastal region for vulnerabilities from permafrost thaw and associated deteriorations due to regional warming and the associated safety impacts to infrastructure and facilities. This analysis in addressing the research question includes characterizing changing conditions of localized Arctic environmental change applied to a modeled index in order to assess risk to facilities and infrastructure of specific interest to USCG in the U.S. Arctic coastal region.

Phase 1: Conduct a Literature review and establish project communications schedule A project literature review was initiated in Year 7 to identify the key components of existing coastal erosion and permafrost degradation research and modeling in the U.S. Arctic. The literature review will continue to develop in Year 8 to inform the project and aid in the development of specific questions assigned to the project Working Groups to orient and guide associated investigations asked of the groups. As discussed, this literature review is leveraging prior reviews conducted through USCG research teams. Note, the literature review includes information and insights from previously accomplished USCG research products.

Task 1.1 Kick-off meeting with HQ USCG Project Champion. This meeting was accomplished in April 2021 to provide Project Champion to the Project Team and provide a forum for detailed discussion of the project vision, the objectives, and the anticipated outcomes. This meeting was an opportunity to gather post workplan approval project directions from HQ USCG, and to describe methodological nuances, while examining program risk and outlining associated risk mitigation strategies.

Task 1.2 Virtual event platform and associated tools. To accomplish this task, an investigation into available synchronous and asynchronous content delivery tools is needed. This activity was initially established in Year 7. The tools identified through this investigation will need to be flexible enough to support the needs of all project stakeholders and be able to work effectively with departmental constraints.

Task 1.3 Conduct team coordination meetings. Established late in Year 7, this task includes regular, remote, and bi-weekly team meetings among core team members, with additional ad hoc meetings as needed for iterating on the program and completing deliverables. Monthly meeting with all stakeholders will also be held to gather feedback and share successes. These meetings will assist investigators gain team cohesion and external buy-in from the broader project community.

Task 1.4 Prepare and participate in ADAC Quarterly reviews, Weekly All-Hands, Customers and Partners Roundtables, Annual Meetings, and write Semi-Annual, and Annual Reports. In accordance with ADAC's management processes, the project team initiated activities and participated in applicable ADAC Quarterly reviews, weekly All-Hands calls, Customers and Partners Roundtables, and Annual meetings. Note, due to the late start of the efforts in Year 7, this activity was limited, but effective.

Key Stakeholder engagement:

The Project Team did not receive approval to start in time to participate in the ADAC "Customers and Partners" Roundtables for Year 7 (but Center leadership did describe the project during appropriate sessions to inform ADAC's customer base of the developing research project). The project team plans to engage in these roundtables in Year 8 in order to inform and receive feedback on project progress. This project seeks collaboration from academics, industry, NGO, and state, local and indigenous representatives, including ADAC student fellows, as much as they could in the shortened project year. Students of participating academics were also invited to attend the virtual events.

Despite limited time, the Project PI worked with the Project Champion, proposed Core Team members, in particular USCG D17, and Sector Anchorage throughout the short project season to ensure a clear understanding of the impacts of rapid environmental change upon coastal facilities stability and structural integrity. Through engagement of the USCG D17 and Sector Anchorage, the Project PI lead the development of questions the team needed answering in advance of facilities inspection operations. This set of specific questions will be further vetted by the Core Team and once accepted in Year 8, will serve as guideposts for the rest of the project. These guideposts will be used in all engagement with the virtual event OC and participants, and the Working Groups. They will help to ensure that the driving force behind all of the Project Team's efforts are addressing these needs and answering these questions – not to be confused with those questions that are solely research-focused (e.g., to increase understanding of the entire Arctic ecosystem).

The Project PIs worked closely with Project Champion and Project Stakeholders as confirmed by HQ USCG. The Project Champion serves as the principal advisor to the Core Team for the project and in

that role will ensure that input from USCG PACAREA, USCG D17, USCG Sector Anchorage, and associated facilities inspectors will be at the forefront of the Project Team's consideration.

The Project PIs engaged with the Project Champion at the project kick-off meeting but had limited time for further engagement in Year 7. The Project PIs plan to engage in the future on a monthly basis for a pre-scheduled conference call meeting in Year 8. Subsequent to these future meetings each month, the Project PIs plan to meet with the Core Team via conference call. ADAC Center leadership will be informed of all of these meetings and included on all conference call meeting invitations. The Project PIs or designated representative will participate in ADAC's Quarterly Review, quarterly ADAC Customers and Partners Roundtable, the ADAC Annual meeting in Washington D.C. as well as on all Core Team calls. In addition, the Project PI or designee will participate in the weekly ADAC "all hands" team meetings.

The project researchers plan for the representation of the project team at the following ADAC/ADAC supported events:

- Designated meetings with HQ USCG Designated Project Champion and any Project Champion Directed USCG and/or other Agency/Department Advisors.
- Weekly All Hands meeting (Normally Thursdays, 1130-1230 Alaska Time via teleconference).
- Quarterly Reviews and Quarterly Customer's and Partner's Roundtable.
- Annual ADAC meeting at HQ USCG, Washington D.C.
- Meetings coordinated by ADAC with industry, such as conferences and symposia.

Student Participation:

ADAC and project team assigned current fellow Brenda Almanza to work with project PI, Dr. Craig Tweedy, from the environmental science perspective, who will be jointly managed via ADAC Education and Administrative Manager and the research investigators at UAA. The project team is actively recruiting an additional undergraduate research assistant to help with the engineering aspect of the project from the UAA campus.

Project progress against each milestone.

Table 17: Project Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Program Establishment	Completed	Note: DHS approved the workplan on 24 March 2021. DHS S&T Compliance Assurance Program Office (CAPO) informed the team the same day that the project could not start until University of Alaska Anchorage led Institutional Review Board (IRB) review of the planned investigations to confirm the project was not conducting Human Subject Research (HSR). Following UAA IRB review and approval, DHS S&T CAPO conducted a follow on review and ultimately all concluded that HSR was not planned for the project and approval was obtained. This process took an unplanned 7 weeks of time, and the project team did not obtain CAPO approval to commence work until 3 June 2021.
Initiation and onward conduct of engineering analysis.	Incomplete	The team has initiated this process during core team meetings and continues to form the framework and conduct engineering analysis on the principal research questions.
Conducting a Comprehensive Literature review and establishment of project communications schedule	Incomplete	The core team has been working to develop the comprehensive literature review from public and academic sources. Per CAPO requirements, sources did not include interviews or discussions with those outside the listed project team members, and were strictly limited to academic journal databases, and public facing websites for local, state, and federal entities. The team established a cloud-based database system to collect documents and websites relevant to the project. Further, the core team has drafted a table of contents and task allocations for moving the literature review forward.
Kick-off meeting with HQ USCG Project Champion	Completed	The team accomplished this milestone 13 April 2021. The team held a virtual kickoff over Zoom and with the project team and ADAC leadership, and both project champions in attendance. This was the extent of work that could be conducted prior to CAPO approval. No one outside of the workplan or Center leadership was invited, nor were discussion held outside of this group.
Identify asynchronous (webinar) and synchronous instructional tools	Completed	The team identified Zoom as the primary platform for engaging stakeholders, champions, and supporters

Conduct team coordination meetings	Incomplete	Once approval from CAPO was granted, the core team initiated weekly coordination calls over zoom. These meetings occur Thursday mornings and help the team review work accomplished and align efforts for the next week. All project support members and ADAC leadership have been invited to participate. Due to starting delays, the core team endeavors to begin regular, remote, bi-weekly meetings with the extended team to include the supporting researchers and project advisors. Many supporting researchers are performing field work, which is typical for the summer season. However, all supporting researchers have been invited to, and have access for, the weekly core team virtual meetings. Regular project team email communications began 23 Jun 2021 and is sent out every Wednesday.
Prepare quarterly, semi-annual, and annual reports to DHS (lifecycle of project)	Incomplete	While the team was unable to start the investigation process for the project, they were not restricted in participating in regular ADAC events. Since 24 March 2021, the core team has participated in ADAC quarterly reviews, weekly all-hands calls, customer and partners roundtables, and the Year 7 annual meeting. Despite the limited time in year 7 to resume project work, the team has prepared an annual report for year 7. Due to IRB and CAPO required reviews, the project start was delayed until 3 June 2021. The delay caused the team to miss multiple milestones originally intended to occur in spring and early summer 2021.
Formation of Project Core Advisory Team and establishment of Project Evaluation Team	Incomplete	Project team did not get full approval to proceed until 3 June 2021, approximately 4 weeks from Program Year 7 conclusion.
Initial Meetings of the Core Team and key Stakeholders to formally establish the project Working Group categories and initiate investigations in support of principal and supporting research questions.	Incomplete	Project team did not get full approval to proceed until 3 June 2021, approximately 4 weeks from Program Year 7 conclusion.

Project Management and Performance Metrics:

The Core Team, chaired by the Project Champion, on a quarterly basis will evaluate the project's management progress and assess project performance on Scientific and Technical metrics. A parallel review will be conducted by ADAC and the Project PI, in accordance with ADAC's Annual management plan.

Table 18: Project Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Is the project on time, based on the schedule set forth in the detailed work plan established between ADAC, the Core Team and Project Investigator? [Assessment: conformity with project GANTT schedule]	Incomplete	Effective start date for the project was 3 June 2021.
Is the project at, or under, cost based on the workplan budget established by ADAC and the Project Investigator? [Assessment: budget analysis of expenses and obligated funds]	Incomplete	Effective start date for the project was 3 June 2021.
Are resources (e.g., references, workshop/working group participants) being gathered/recruited in sufficient numbers for the project tasks? [Assessment: comparison of actual vs. time & effort by participants]	Incomplete	Effective start date for the project was 3 June 2021.
Is the scope of the project adequate or does it need to change to meet unforeseen components that arise in environmental modeling? [Assessment: comparison of attainment of actual vs. project goals]	Incomplete	Effective start date for the project was 3 June 2021.
Does the literature review highlight unanticipated technical advances that may benefit Alaskan and U.S. Arctic Federal, State and local facilities inspection and management communities? [Assessment: comparison of documented literature review with the results of online resources (e.g., Web of Science, Google Scholar, PubMed, etc.) review using same search terms]	Incomplete	Effective start date for the project was 3 June 2021.
Does engagement of project stakeholders and community provide unanticipated discoveries in how infrastructure and facilities managers reduce their operational risk as related to changing environmental conditions? [Assessment: comparison of actual vs. novel findings or realities by brief, targeted, and web-based survey instruments]	Incomplete	Effective start date for the project was 3 June 2021.
Evaluation of methods for literature review and information gathering:	Incomplete	Effective start date for the project was 3 June 2021.

I. Has an appropriate search strategy been developed and executed to identify unpublished or “gray-literature” source documents, artifacts, and individuals to consult in the course of this study? [Assessment: assessment of attainment of actual vs. project goals] II. Have the data gathered during the course of the study been interpreted and organized using a systematic taxonomy, data fields or framework? [Assessment: assessment of attainment of actual vs. project goals]		
Scientific and Technical Metrics: Validation of data and recommendations: I. How complete is the set of documents, artifacts and individuals that were consulted in the study? [Assessment: comparison of known vs newly acquired resources through broadscale publishing among project participants] II. Is the data gathered in the study accurate, as assessed by the third-party independent reviewers, or by consulting additional sources? [Assessment: comparison and evaluation of data and results using standard criteria in the subject matter field of study] III. Are the recommendations’ objective, and supported by the data gathered in the study? [Assessment: evaluation by SME using standard field of study criteria]	Incomplete	Effective start date for the project was 3 June 2021.

Outcomes/Outputs:

The principal outcome of the project will be a comprehensive assessment and public document on the approaches to, and solutions for, improving risk mitigation and operational decision-making for USCG facilities inspections and response operations. The long-term goal is to establish a credible and useable framework for categorizing Arctic infrastructure and facility status and calculating risk of future failure based on the various erosion, permafrost, and facilities engineering conditions that routinely occur in the Arctic. If such a risk framework can be available for use by government entities such as USCG, it will be useful scheduling the frequency of facilities inspections, and identifying the most at-risk locations. The development of an Environmental Risk Index is planned as fundamental research activity, particularly, as this project is less than 15 months in overall length. Accordingly,

the final project is anticipated to meet at least TRL-3 threshold requirements. If/as USCG was interested in advancing the Environmental Risk Index to higher level of technology readiness, ADAC and the research team are at the ready to support additional investigations via ADAC's Basic Ordering Agreement (BOA).

The final knowledge products will contain:

1. A completed Arctic Infrastructure and Facility Environmental Risk Index that is at least at TRL-3, oriented to address USCG D17 designated Infrastructure and Facilities in Arctic Alaska. This a core deliverable from the research.
2. An associated product containing an Arctic operator and Facility Inspector's Arctic environmental factors training guide. This is a companion document to implement the Environmental Risk Index. A supporting knowledge product that includes the following:
 - A summary of all associated meetings, workshops, with key findings, data, reports and associated information.
 - A list of the key parameters related to coastal erosion, permafrost degradation, and facilities structural decline that are the best predictors of increased operational risk and near-term structural failure in the rapidly changing Arctic environment.
 - A review of the current state-of-the-art on permafrost and coastal erosion modeling for Arctic coastal areas that identifies gaps and weaknesses in current capabilities.
 - Recommendations for addition of modules on response technologies that assist with identifying and categorizing coastal Arctic changes.
 - Recommendations on incorporation of additional natural processes into models.
 - Detailed recommendations/scopes of work on potential research needed to fill gaps identified during the project.
3. The Project Investigators will draft a corresponding peer-review journal article following the conclusion of the research.
4. In consultation with the Project Champion, ADAC will correspondingly post all information related to this research to the ADAC website at: <https://arcticdomainawarenesscenter.org/>.

Unanticipated problems and plans for addressing them:

The project lost approximately 7 weeks of time in late Program Year 7 due to the unanticipated request of DHS S&T CAPO's request for IRB review. The project was never intended to conduct HSR, and this unanticipated delay following project approval resulted in less accomplishment/activities in Year 7 than planned. Project team and ADAC leadership reflowed the Year 8 project timeline and tasks (and submitted a Project Change Notice to DHS S&T OUP Program Manager) to account for this delay in order to accomplish planned work in Program Year 8. Since most of the work was planned to be completed by 31 March 2022, the team expects to now conclude this work by late May 2022, and still be fully complete before the end of the planned program year (30 June 2022).

Transition:

Transition plans and progress made: As discussed in Project Phase 8, the Comprehensive Research Report and corresponding peer-review journal article will be promulgated across USCG and ADAC networks. The knowledge gained from this project will be directly transferable to USCG Facilities Inspections and Maritime Environmental Response, which are to be represented on the Core Team. The Project development team anticipates that much of the knowledge gained and consensus reached will be used to manage facilities inspections schedules, inform inspectors as to the severity of observed environmental changes, and predict expected future condition of USCG supporting infrastructure and Regulated Facilities.

THEME 2: Maritime Domain Awareness (MDA) Research

1. Arctic Ice Conditions Index (ARCTICE).
2. The Arctic All-Hazards GIS Platform.
3. Arctic Vessel Monitoring Geofencing/Alert Awareness.

PROJECT: Ice Conditions (ICECON) for the Arctic (ARCTICE)

Project Investigator: Dr. Jifeng Peng, University of Alaska Anchorage.

Lead Institution: University of Alaska, Anchorage

Supporting Team: Dr. Shawn Butler, University of Alaska Anchorage; Dr. Jinlun Zhang, University of Washington; Kelsey Frazier, University of Alaska Anchorage. Sam Cheung, U.S. Coast Guard Research & Development Center (RDC). U.S. National Ice Center and Canadian Ice Services.

Project Champion: CDR Christopher B. Tuckey, HQ USCG CG-WWM.

Project Description:

Abstract:

In collaboration with USCG and other government agencies, the project team developed an Arctic ice condition index (ARCTICE) for the Arctic region, which was initially focused on the ice laden waters of the Bering, Chukchi and Beaufort Seas. Building on the successful Ice Conditions Index for the Great Lakes Region, ADAC's Arctic Ice Conditions Index, or "ARCTICE," produced an easy-to-understand numeral to communicate ice conditions relevant to the specific capabilities of an individual vessel. This index is available for current and future ice conditions, providing forecasts up to 1 month in advance. Based on Great Lakes ICECON investigations, the project team provides marine operators a transition destination website, with ready access to this information (in particular the U.S. National Ice Center and the Alaska Ocean Observation System), and now supports vessel captains and officers in route planning and in determining associated risk with traveling through a particular region in the Arctic Waters.

Similar to ICECON for the Great Lakes region, ARCTICE research, guided by the USCG-led "council of experts" created a visualized decision support product, a numeric index that combined marine vessel size, gross tonnage and hull strength to contrast against current and forecast ice of the

planned route of sail, providing USCG and shipmasters improved safe passage insight in Arctic ice laden waters. In order to achieve improved usefulness, ARCTICE included an inclusive and iterative process principally with meteorological, marine traffic, and safety experts. Accordingly, project researchers conducted coordination activities (using distant technologies as appropriate) in coordination with USCG D17 to collaborate with ice and maritime transportation experts. These experts were from a range of organizations including (but not exclusive to): NOAA, the U.S. National Ice Center, the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL), USCG RDC, USCG D17, Transport Canada, the Canadian Ice Service, the Finnish Meteorological Institute, and the University of Alaska. Transitioned ARCTICE products are published and available to the U.S. National Ice Center, USCG D17, and Arctic mariners.

Objective/Purpose:

In combination with experience from Great Lakes ICECON, extensive research, and customer input, ARCTICE created a mariner decision support tool for vessels principally operating in the U.S. EEZ, specifically the Bering, Chukchi, and Beaufort Sea regions, and secondarily operating in the waters of the North American Arctic. This planned research investigation leveraged guidance from a USCG led Council of Experts and utilized environmental models for sources of ocean currents, sea ice presence, movement, thickness, and ridging. Researchers developed ice indices based on the International Maritime Organization's Polar Code "POLARIS amendment" as the communication tool for mariners, providing these indices on a current and forecast basis, with the possibility providing hindcast data as well.

ARCTICE delivered the mariner support tool to a web-based operational destination as determined and coordinated via the planned USCG led, Council of Experts. This website is hosted by Axiom Data Science and is under construction as part of Year 8 transition activities. The website can be located here (temporarily): <https://adac.portal.axds.co/#>.

Methodology.

ARCTICE is adapting research associated with Great Lakes ICECON to the Arctic Ocean environment. A specialized team of engineers, sea-ice geophysics, sea ice modelers and computer architecture experts, guided by a USCG-led council of experts to accomplish a series of research tasks to (a) refine a ARCTICE vessel classification index, (b) investigate ice models, in particular, High-resolution Ice-Ocean Modeling and Assimilation System (HIOMAS) model developed at ADAC, and Canadian Pressured ICE Model, (c) determine suitable environmental factors, (d) investigate suitable access, (e) create, then optimize a forecast numeric Arctic ice condition index for Arctic waters. In conjunction with developing the Arctic Ice Condition Index (ARCTICE), the research team will (f) integrate the index to a visualization tool as an aid to vessel mariner planning and underway activities, then (g) conduct validation, then finally (h) transition the ARCTICE to an operational destination, leveraged by Arctic mariners for route planning and decision making. ARCTICE creates a mariner decision- support tool oriented to vessel categorization principally focused, but not constrained to existing U.S. EEZ of the Bering Chukchi and Beaufort Sea regions. ARCTICE seeks to leverage Arctic vessel automated information systems (AIS) data from existing ADAC research, gain guidance from a USCG led Council of Experts and utilize sources of ocean

current, sea ice presence, movement, thickness and ridging environmental model. ARCTICE plans to deliver the mariner support tool to operational destinations as determined and coordinated via the planned USCG led, Council of Experts.

In creating an ice conditions index for Arctic Mariners, (oriented principally to the Bering, Chukchi and Beaufort Seas), researchers seek to develop and transition readily accessible Arctic Ice Condition Index as a decision support tool for Arctic marine operators, useful to ships Captains, first mates and navigation officers. Arctic ICECON is distinct from Great Lakes ICECON in the following:

1. Little to no available “local” ice observations.
2. Research team has higher resolution environmental inputs than available in the Great Lakes region due to completed ADAC project, HIOMAS.
3. Sea ice is inherently different than lake ice.
4. There are new international standards for communicating ice conditions.
5. USCG District 17 has operational challenges quite distinct in its region of responsibility compared to the operational environment faced by USCG District 9.

While there are significant differences between creating an Ice Conditions Index for the Great Lakes region and an Ice Conditions Index for the ocean regions of the U.S. Arctic EEZ, overall research methodologies are similar and experiences in creating Great Lakes ICECON are useful and complementary. Accordingly, ARCTICE investigations suitably leverage prior research associated with creating an Ice Conditions Index for the Great Lakes region.

Key Stakeholder Engagement:

The Project team engaged with Project Champion CDR Christopher B. Tuckey (CG- WWM)/his designated POC on a frequency basis as determined by CDR Tuckey. Critical coordination is planned with all team members, the PI, and project champion. Project advocates include HQ CG-926, USCG RDC, the U.S. National Ice Center, and USCG D17. As with the Great Lakes ICECON project, ARCTICE researchers were in frequent contact with project champion, key project support at USCG RDC, USCG D17 and USCG-led Council of Experts. As part of the Center’s Year 7 effort towards commercialization, ADAC also inquired as to suitability of completed research to potentially support Arctic oriented commercial shipping and tourism industries, e.g., the Qilak LNG project

In addition to dedicated efforts to establish and transition ARCTICE in the same manner as ICECON, research findings were disseminated throughout the academic/research community through oral presentations and by production of academic journal type manuscript submitted for peer review.

Investigators ensured that representation of our team was at all of the following ADAC events:

1. Meetings with Project Champion CDR Tuckey.
2. Weekly All Hands meeting (Normally Thursdays, 1130-1230 Alaska Time via teleconference).
3. Quarterly Reviews and Quarterly Customer’s and Partner’s Roundtable.

4. ADAC Annual meeting.

Student Participation:

While the research team planned for at least one participating student fellow on ARCTICE, the global coronavirus pandemic made recruitment challenging. For this reason, there was no student participation on ARCTICE during year 7.

Key Accomplishments:

Finalize a forecast numeric Arctic ice condition index for Arctic waters.

Accomplishment 1.1: Researchers completed coding the ARCTICE algorithm. The coding of the forecast numeric Arctic ice condition index for Arctic waters was completed in the first quarter of Year 7. This experimental algorithm was written in the scientific software package MATLAB. The algorithm uses environmental data from HIOMAS, calculates the risk index outcome (RIO) for the Arctic region based on methodology from the Polaris amendment to the Polar Code, and provides output color maps illustrating RIO values for a given vessel polar class.

Accomplishment 1.2: HIOMAS was updated from 8 to 24 ice categories. During the development stage, the research team discussed increasing the accuracy of the ARCTICE algorithm using more refined environmental data from HIOMAS. In HIOMAS, there are 8 categories for partial sea ice concentration provided as output. The ARCTICE algorithm received these categories, then linear interpolation was employed to calculate the 12 partial sea ice concentrations the Polaris RIO requires. It was determined that if the 8 categories could be increased, then the accuracy of the Polaris RIO would be increased. Dr. Zhang agreed that the partial sea ice concentrations in HIOMAS could be enhanced. He completed work to change the partial sea ice concentration output from 8 categories up to 24. Axiom Data Science integrated these changes and updated the HIOMAS model.

Accomplishment 1.3: ARCTICE (based on the 24-ice category input) is automatically calculating RIO plots. Once the experimental algorithm was completed, the research team worked with the team at Axiom Data Science to automate the algorithm. This ensures that, as HIOMAS output is available, the algorithm automatically receives the environmental data, runs its RIO calculations, and generates output plots. The algorithm is currently running on Axiom servers and providing output for validation efforts in the third quarter. The algorithm was updated to use the 24-ice category input once data from the new model was available in the third quarter.

Integrate the index to a visualization tool as an aid to vessel mariner planning and underway activities.

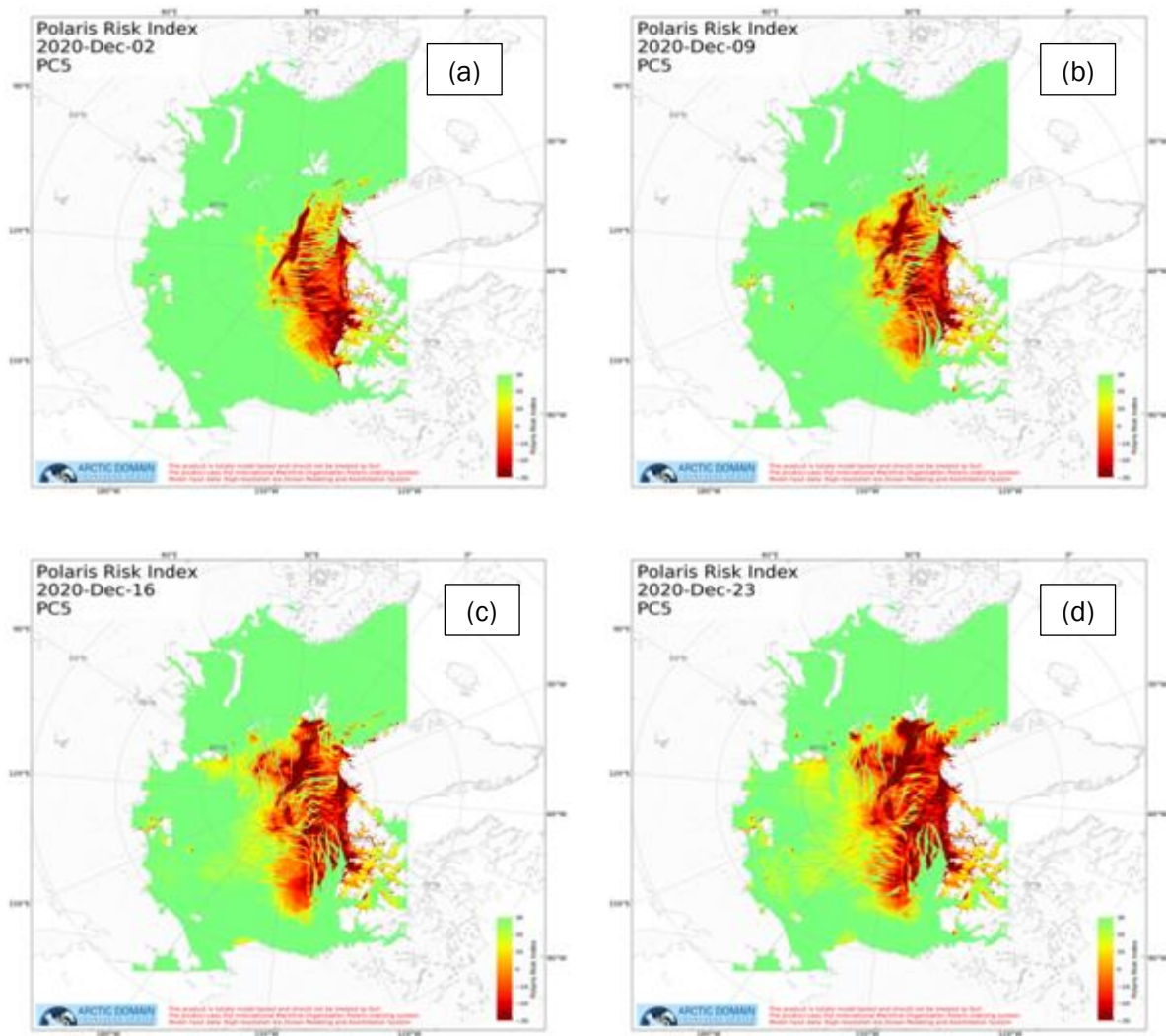


Figure 27: ARCTICE RIO charts

ARCTICE produced RIO charts. Charts were produced by the algorithm on December 2, 2020, for a Polar Class (PC) 5 vessel. (a) nowcast or current sea ice conditions; (b) forecast conditions 1 week out; (c) forecast conditions 2 weeks out; (d) forecast conditions 3 weeks out. Not shown forecast conditions 1 month/4 weeks out.

Accomplishment 2.1: The project team created ARCTICE visualizations. While the initial test of ARCTICE visualizations was accomplished in year 6, the research team completed this task in year 7 in the second quarter. This included expanding the output to provide plots for 12 separate ice classes (Polar Class: PC1, PC2, PC3, PC4, PC5, PC6, PC7; Baltic Class: 1a super, 1a, 1b, 1c, and no class).

Accomplishment 2.2: RIO plots are available for 1 month in advance. Once the project team integrated the index into a visualization framework, the team then ensured the output RIO plots would be available in both a now and forecast format. Frequency of these plots are currently available for: current day, 1-14 days, 21 days, and 28 days in advance. Examples of

these now and forecast plots for a PC5 class vessel are shown below, and all other RIO plots for vessel classes are available upon request.

Conduct validation.

Accomplishment 3.1: Validate ARCTICE output. During the third quarter, the project team worked closely with the Axiom Data Science team to validate the algorithm's output. The team inspected the output for each class to ensure the expected RIO values met the computed RIO values. Charts were updated to more clearly indicate that information provided in the figures is for planning purposes only and not to replace the very necessary observed conditions provided by ships' crews.

Accomplishment 3.2: Prepare and submit manuscript. As part of the research process, the project team collaborated to write an academic-focused research paper on the major accomplishments of the program. That manuscript was completed in the fourth quarter of the project year and was submitted to the Journal of Marine Science and Engineering. Currently the manuscript is under peer-review.

Transition ARCTICE to an operational destination.

Accomplishment 4.1: ARCTICE is currently running on Axiom servers. In partnership with the Axiom Data Science, the project team worked during the second quarter to transition the ARCTICE product to Axiom data servers. With the ongoing HIOMAS updates during the program year, the project team felt an early transition would allow for a longer test period, and a more robust operational algorithm at the end of the project phase. Output from the ARCTICE algorithm can be accessed here: <https://stage-arctice.srv.axds.co/> where the team continuously works to improve access and usability of the charts.

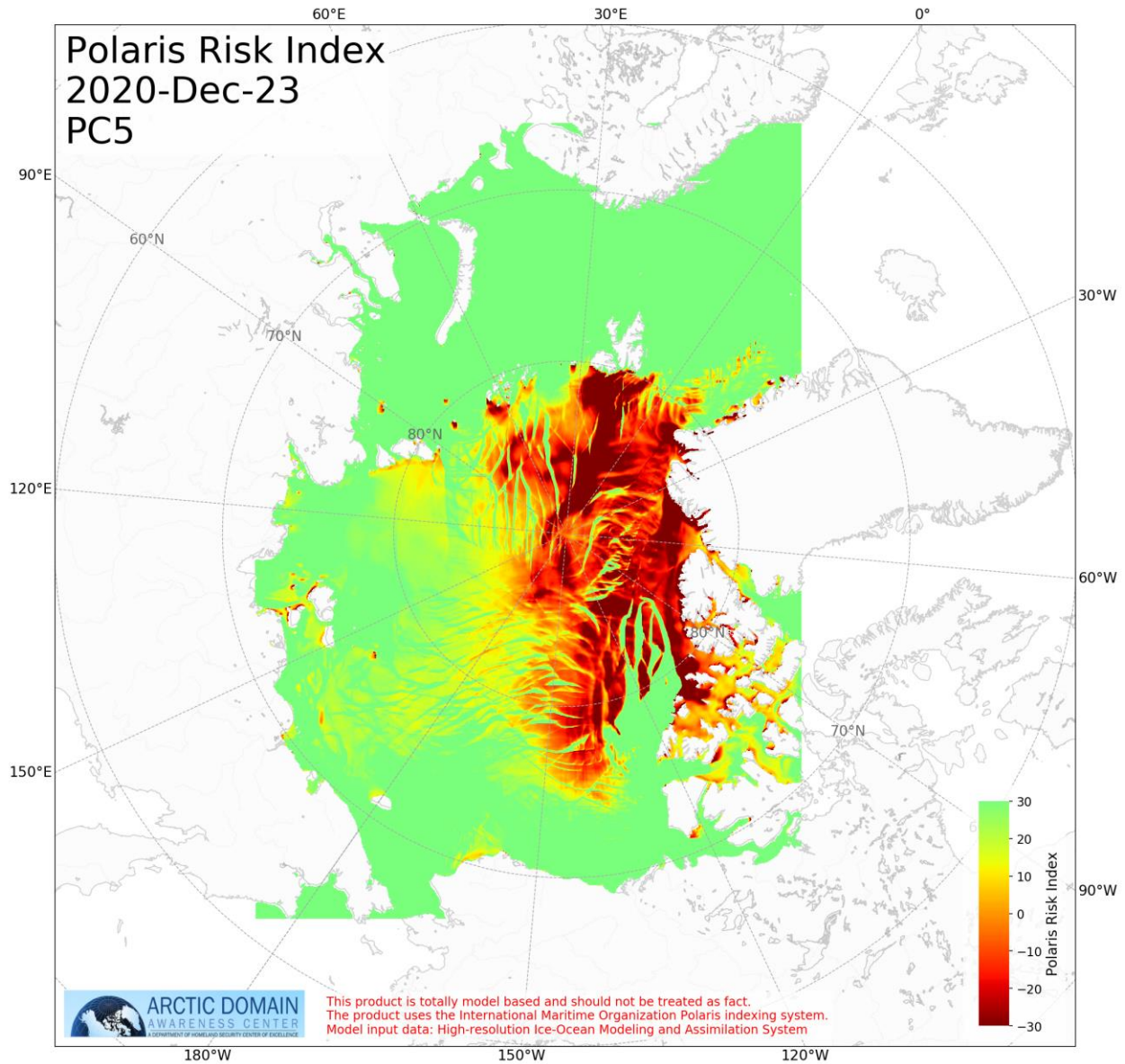


Figure 28: Polaris Risk Index

Great Lake ICECON

The research and development of Great Lake ICECON had been previously completed and its operation (hosted at Axiom Data Science) established in project year 6. The ADAC team Presented the ICECON product to D9 in a teleconference before the past winter season. The ICECON product was sent to a list of users provided by D9 (mostly COs of D9 ice fleet) in daily email from Dec 2020 to April 2021. The ICECON product was also sent to USNIC for their evaluations.

Per evaluation from USNIC's Great Lakes Lead Scientist Jonathan Edwards-Opperman, "overall, ICECON seems to be doing well"; "The regions with higher ice concentration and thicker ice are

getting a higher ICECON value. The most interesting event was the relatively rapid freeze up in mid-February in western Superior and Erie. ICECON did capture that signal a couple days out which was good to see.” On a few occasions pointed out by D9 users, the ICECON model overestimated the ice field condition. However, per analysis by USNIC, “it has been pretty easy to trace the errors back to WCPS (the input data for ICECON). The WCPS model sometimes over-estimated freeze up or did not melt out enough ice as winds pushed the ice offshore toward warmer water. Since the WCPS model had an error, that error just translated over to ICECON.”

Before the past winter season, the ADAC team also delivered an upgraded Android version of ice data collection app to D9. However, due to D9’s transition to iOS devices, the additional requests for encryption of data collected by the app, and the light ice conditions for the season, no data was collected by D9 users. Based on the feedback from USCG D9 on the mobile app, the ADAC team is going to further upgrade the app to add 2-way communications between the ICECON model and ship observations as a year 8 task.

Key Milestones:

Table 19: Project Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Complete coding of the ARCTICE algorithm	Complete	N/A
Update HIOMAS from 8 to 24 ice categories	Complete	N/A
ARCTICE (based on the 24-ice category input) is automatically calculating RIO plots	Complete	N/A
Create ARCTICE visualizations	Complete	N/A
Provide/forecast RIO plots 1 month in advance	Complete	N/A
Validate ARCTICE output	Complete	N/A
Prepare and submit manuscript	Complete	N/A
Transition ARCTICE to an operational destination	Complete	N/A

Performance Metrics:

Researchers will conclude performance measurements in Program Year 8 according to the following metrics:

Table 20: Performance Metrics

Metric	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
ARCTICE algorithms enable accurate Arctic ice condition predictions a minimum of 65% of the time.	Incomplete	Validation underway and will be completed in Program Year 8.
ARCTICE algorithms provide comparable Bering, Chukchi and Beaufort Sea ice-conditions index accuracy to known accuracy of Canadian ice services within Canadian waters	Incomplete	Validation underway and will be completed in Program Year 8.

Unanticipated problems and plans for addressing them:

N/A.

Outcomes/Outputs/TRL:

Outcomes/Output

- A finalized set of ARCTICE algorithms for U.S. waters in the Bering, Chukchi and Beaufort Sea.
- A finalized vessel classification system U.S. waters in the Bering, Chukchi and Beaufort Sea.
- Axiom Data Science hosting POLARIS index from ARCTICE for U.S. waters in the Bering, Chukchi and Beaufort Sea.

Technology Readiness Levels (TRL)

- Final product development anticipated to conclude at TRL 7.

Transition Plan.

Overall, the ARCTICE transition seeks to replicate the transition planning used for Great Lakes ICECON from research to an operationally relevant tool. The ADAC team has worked with Axiom Data

Science to establish the operation for ARCTICE and will pursue an agreement with USNIC to host the generated ARCTICE data. In addition to USNIC, the Alaska Ocean Observing System based in Anchorage potentially serves as an alternate or replication of a USNIC destination. In addition to directions and guidance received from USCG D17 and other Council of Expert members, transition planning will need to account and gain input/product feedback from Alaska- based mariners who comprise the bulk of the maritime traffic in the U.S. Arctic waters.

PROJECT: Arctic Vessel Monitoring Geofencing/Alert Awareness

Project Investigators: Dr. Shawn Butler

Supporting Team:

Mr. Rob Bochenek and associates at Axiom Data Sciences

Lead Institution: University of Alaska Anchorage (UAA)

Project Champion: LT Evan Richter and Mr. James “Dan” Blackman, CG7, HQ USCG.

Project Description:

Abstract:

This project seeks to extend the Arctic Vessel Monitoring Geofencing/Alert Awareness project, initially funded in ADAC Program Year 5, by providing enhanced command and control features that improve on the original goals of monitoring and alert awareness developed for the unclassified Marine Exchange PACTRACS system (which is a commercial mariner application). As CG OneView 3.0, is USCG’s determined common operating picture, which now displays both terrestrial and satellite AIS data, there is a need for a geofencing/alert awareness application that supports Coast Guard planning and command and control decision making tasks which easily integrates into CG OneView.

In addition, new geofencing capabilities could be implemented with the research outcomes developed in the Arctic Domain Awareness Center’s project Arctic All Hazards GIS Platform. The Geofencing/Alert Awareness project oriented to USCG CG OneView in ADAC Program Year 7 focused on the development of requirements and application design.

Objective/Purpose:

The objective of this project is to develop a geofence prototype that meets the needs of operators and planner’s using CG OneView and can be relatively easy to integrate into the U.S. Coast Guard’s command and control application, (again, CG OneView). The prototype will be functional and capable software innovation for integration into CG OneView either by USCG directly, or if/as desired, by the established contract CG OneView vendors to USCG.

USCG watch-standers across Coast Guard command centers, (using CG OneView) are the principal users of geofences. These watch-standers will over time, create a number of geofences in support of various planning and operational needs. Accordingly, these USCG users will need a mechanism to find existing geofences, perhaps modify some of the geofence attributes, and reuse or create altered copies. In addition, they will likely need to cull no longer needed geofences. Further details:

- Some geofences will be created that need to follow the shoreline. Users should be able to create a geofence that can be defined some specific number of meters/kilometers from the shoreline. ArcGIS is known to have tools that can identify the coastline which may be used to identify geofence boundaries. This will give the Coast Guard more accurate information when vessels cross geofences.
 - Identify and implement additional features that may help improve planning tasks and operational response to vessels crossing geofences. For example, detect vessels that are approaching (i.e., likely to cross if the vessel doesn't change heading), but have not yet crossed a geofence. Use color to show when a vessel is approaching (yellow)/crossing a geofence (red) so that operators can instantly see the geofence and vessel that is approaching/crossing. This will allow less clutter on the CG OneView operational picture.
 - Operators and planners need to share geofences within and across commands or change ownership of the geofence.
- It may be necessary to provide a historical record of a geofence violation for law enforcement reasons.

The objective of this project in Year 7 was to extend both CG OneView and develop an initial ADAC geofence/alert notification application that would provide better geofence management and improved alert notification for Coast Guard users. The specific objectives for Year 7 were to:

- Develop an application that would allow Coast Guard users to create new geofences, find existing geofences from a database of geofences, modify one or more of the geofence attributes, and reuse or create altered copies of geofences. Finally, users must be able to delete no longer needed geofences.
- Develop an application that allowed users to create geofences that followed shorelines, and easily define the geofence distance from the shoreline, by specifying the number of nautical miles from the shoreline.
- Implement additional features that help improve planning tasks and operational response to vessels crossing geofences such as:
 - Alert operators when a vessel has crossed a geofence
 - Detect vessels that are approaching (i.e., likely to cross if the vessel doesn't change heading) but have not yet crossed a geofence.
 - Use color to show when a vessel is approaching(yellow)/crossing a geofence(red) so that operators can instantly see the geofence and vessel that is approaching/crossing.
- Develop an application that could easily integrate into the CG OneView Architecture.

Methodology:

Through a select team of experienced computer information systems architects and working with U.S. Coast Guard stakeholders in Alaska and Virginia, the research team will develop a CG One View

prototype following a modified *agile* software engineering development cycle. The two most crucial practices in the agile development cycle are small iterations and close stakeholder involvement. Since the two primary objectives of this project is 1) to produce a working prototype that meets user requirements and 2) can be integrated into CG One View with minimal effort, then the two primary stakeholders are the coast guard users at the Anchorage Sector and the CG One view technical integrators.

The USCG D17 Sector Anchorage has committed to working with the project team in prioritizing and reviewing geofencing functionality as it is developed. Researchers expect to show end users incremental functionality as frequently as every two weeks once the foundation is developed. Based on their feedback, investigators will update the parameters and implement their requested changes. The agile software development process supports the flexibility that a software developer needs to ensure that the final product is very close to what the user needs.

The CG One View technical developers agreed with the investigation team during coordination meetings in Program Year 6 in confirming '*continuous integration*' as the preferred process to ensure minimum integration issues during transition. Continuous integration ensures that the developers frequently integrate new features to minimize the possibility that the two software baselines (CG One View and Geofencing) diverge as software changes. A continuous integration process will result in a product that can become part of CG One View without major modifications, ideally quickly getting the capability into the hands of those that need it most.

Finally, researchers will closely coordinate with the ADAC investigation titled "All Hazards WebGIS project developer and CG One View system architects to ensure that we seamlessly integrate into their software as All Hazards WebGIS transitions into CG One View. The project will rely on the experience of Project Investigator and Axiom Data Science to provide expertise, development, and project continuity.

The agile methodology includes:

- Continued requirements elicitation and refinement from USCG stakeholders regarding geofencing feature priorities and refinement of existing requirements.
- Close coordination with CG One View technical developers to ensure continuous integration of newly developed features.
- Software development that builds upon existing AIS datasets and lessons learned from geofencing technology developed in years 5 and 6 for the Marine Exchange.
- User accepting of testing within the limits of the prototype.
- Peer-reviewed publication/presentation for validation and improvement.

The research objectives include accomplishing the following:

- Design and implement a geofencing prototype based on the Ozone Widget Framework that can be adopted by the CG OneView project.
- Improve situational awareness with regards to geofencing and vessel alerting by using HCI best practices.

Improve geofence management through improved creation, find and re-use, and deletion using enhanced Meta data for geofences.

The ADAC development team from Axiom Data Science developed an application that allowed users to create, modify, and delete geofences for display on the CG OneView operational display. Using an agile software development methodology and following CG OneView development team provided the documentation, the ADAC development team created a geofence application that communicated via the CG OneView messaging infrastructure to 1) create new geofences, 2) modify geofences, and 3) send geofence alerts. Figure 1 shows how the ADAC Geofence application interfaces with the CG One View architecture to display geofences.

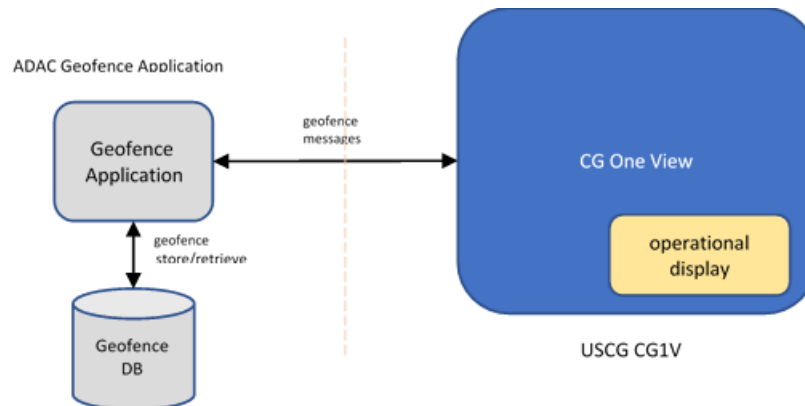


Figure 29: ADAC Geofence Architecture

Student Involvement:

Ms. Rachelle Lewis, an ADAC fellow and senior at the University of Alaska Anchorage, supported the geofencing project by developing user requirements from the discussions held with USCG Anchorage Sector.

Key Stakeholder Engagement:

The Project team continued to engage Project Champion and the primary operational customer for this product at the 17th U.S. Coast Guard District, and the tactical customer is U.S. Coast Guard District 17 Sector Anchorage. Project team participated planned ADAC “Customers and Partners” Roundtables. Deliberate investments in the collection of information continued throughout the year and was used to establish flow diagrams and identify the end-user requirements of the tools. Once Covid-19 restrictions were relaxed, the project team met with Anchorage Sector to demonstrate the application’s capabilities, receive feedback, and solicit additional requirements. This event occurred approximately 45 days prior to the end of the project year. The team felt that more frequent feedback with Anchorage Sector is necessary to ensure the team appropriately identifies and prioritizes the Sector’s requirements as requirements evolve.

Key Publications (peer reviewed):

None

Key Presentations:

Project team presented at ADAC Program Year 7 Annual Meeting. The Annual Meeting was held virtually via ZOOM as COVID-19 prevented an in-person gathering in Washington D.C. as in previous program years.

Key Accomplishments:

1. The project team developed an application that can create geofence polygons that can be shaped to follow geographical land features such as shorelines and bathymetry contours.
 - a. The geofences can be created to follow nautical miles distances from shorelines and include 3 layers of geofence to indicate ships that are: approaching a geofence, ships that are exceptionally close to crossing a geofence, and those that have crossed a geofence.
 - b. Users can copy, modify, or delete an existing geofence.
 - c. The geofence application can communicate with CG OneView so that geofences can be displayed within the CG OneView Operations display
 - d. Users can define geofence alerts and are notified when a vessel crosses a geofence boundary.
2. The project team worked with the CG OneView Developers to implement and fine tune a messaging system between the geofence application and CG OneView. The messaging system allows geofence users to manage geofences and changes are communicated via the messaging system to the CG OneView operational display.
3. The project team met with USCG Anchorage Sector to demonstrate the application's geofencing capabilities and received positive feedback on the application as well as additional requirements that users would like to see added to the application. Although several additional requirements were captured, some of the more urgent requirements were:
 - a. The ability to share geofences within the Coast Guard.
 - b. Fine grained alert management. For example, alert only on vessels with specified attributes such as vessels exceeding a specific tonnage.
 - c. Integrate with the Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database
 - d. The ability to create dynamic geofences
4. The project team worked closely with the CG OneView developers to ensure the application could integrate into the CG OneView suite of applications with minimal modifications.
 - a. The project team followed CG OneView documentation and continuously tested the application interfaces with CG OneView.
 - b. The project team developed an initial set of documentation that will accompany the application when it is transferred to the Coast Guard.

Key Milestones:

Table 21: Project Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Continued requirements elicitation and refinement from USCG stakeholders regarding geofencing feature priorities and refinement of existing requirements	Completed	N/A
Close coordination with CG One View technical developers to ensure continuous integration of newly developed features.	Completed	N/A
Software development that builds upon existing AIS datasets and lessons learned from geofencing technology developed in years 5 and 6 for the Marine Exchange.	Completed	N/A
User accepting of testing within the limits of the prototype.	In-progress	COVID19 significantly delayed interaction with USCG D17 Sector Anchorage. Gaining user acceptance is planned for Program Year 8.
Design and implement a geofencing prototype based on the Ozone Widget Framework that can be adopted by the CG OneView project.	Completed	N/A
Improve situational awareness with regards to geofencing and vessel alerting by using HCI best practices.	In-progress	COVID19 significantly delayed interactions needed to gain feedback to complete this task. This is planned to be completed in Program Year 8.
Improve geofence management through improved creation, find and re-use, and deletion using enhanced Meta data for geofences.	In-progress	COVID19 significantly delayed interactions needed to gain feedback to complete this task. This is planned to be completed in Program Year 8.

Performance Metrics:

The following are the associated metrics for the project:

Table 22: Project Metrics

METRICS	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
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Design and documentation of Geosystem architecture, use cases, and test cases	In Progress	Plan for completion in Program Year 8.
Percentage completion/project velocity of features and use cases	In Progress	Plan for completion in Program Year 8.
Percentage of successful synthetic test cases (simulated vessel movements or other automated tests).	In Progress	Plan for completion in Program Year 8.
Number of successful customer acceptance tests	In Progress	Plan for completion in Program Year 8.
Archival ability of created Geofences to support routine use-cases	In Progress	Plan for completion in Program Year 8.
Number and impact of peer-reviewed publications/presentations	In Progress	Plan for completion in Program Year 8.

Changes from initially approved Workplan:

1. The project development team has not yet implemented dynamic geofences; however, the team anticipated this requirement will be implemented in Year 8.
2. Integration with the All Hazards Web GIS application was postponed until the project finds a sponsor.
3. The project development team has not yet implemented dynamic geofences; however, the team anticipated this requirement will be implemented in Year 8.
4. Integration with the All Hazards Web GIS application was postponed until the project finds a sponsor.

Outcomes/Outputs/TRLs:

Outcomes/Outputs:

The project planned outcomes/outputs are:

- Enhanced geofencing\vessel alerting prototype based on the Ozone Widget Framework.
- Application architecture documentation.
- Geofence management tools developed using the Ozone Widget Framework that allows users to create, find, delete, and share existing geofences based on geofence and alert Meta information.
- Documented user feedback from the USCG 17th District, Sector Anchorage.

Technology Readiness Level (TRL)

- Following investigations and development activities planned for Program Year 8, the application will represent a Technical Readiness Level of 7 – system prototype demonstration in a realistic environment.

Unanticipated Problems and Plans to Address:

Much of the project's success in Year 7 was due to our ability to work closely with the lead software developer for CG OneView. Unfortunately, he was re-assigned towards the end of Year 7, so we must work with the Project Champion to find a replacement.

Transition Activities:

Transition plans and progress made:

As the geofencing application was being developed, the project team worked closely with the CG OneView lead developer to ensure that the project team developed a messaging system that could communicate within the CG OneView Architecture. This was tested frequently and demonstrated to Anchorage Sector on 12 May 2021. The Lead Software developer anticipated that the application would be able to integrate with CG OneView within 30 days, or sooner, after final delivery. The ADAC application team documented the application as they progressed working with the lead CG OneView developer.

PROJECT: Remote Unmanned Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region

Project Investigator (PI): Jessica Garron, International Arctic Research Center (IARC), University of Alaska Fairbanks (UAF)

Lead Institution: University of Alaska Fairbanks

Project Supporting Researchers: Mr. John P. Henry (Native Village of Unalakleet (NVU)) Alaska and Ms. Margaret Hall (Model Forest Policy Program (MFPP), Priest Lake, Idaho).

Project Collaborators: U.S. Coast Guard District 17, Sector Anchorage and Pacific Northwest National Laboratories, to be confirmed.

Project Champion: CDR Chad Thompson, CG-711.

Project Description:

Abstract:

Conducting required rural area key infrastructure testing for safety compliance across Alaska (in particular, Western Alaska) is a time and resource challenge for the U.S. Coast Guard (USCG). Normal USCG processes require USCG inspectors to physically fly from home station to remote regions to conduct hands and eyes on tests. Integrating remote sensing tools, such as unmanned aircraft systems (UAS), into the operational environment of remote, sparsely populated, western

Alaska has the potential to increase the efficiency of USCG infrastructure inspection missions, while supporting the expansion of community Science, Technology, Engineering and Math (STEM) capacity. To demonstrate this integration concept, project investigators designed a program to train a set of UAS pilots, (equipped with U.S. manufactured UAS platforms) in the Bering Strait hub community of Unalakleet, Alaska, to conduct infrastructure inspections, specifically oil-containing infrastructure, and emergency response (ER) actions in support of local and/or regional crisis. The major components of the investigations are to train approximately eight pilots within Unalakleet to safely operate UAS and become certified under the FAA Part 107 rule: to co-produce infrastructure inspection protocols (IIP) and emergency response (ER) flight protocols with members of the Native Village of Unalakleet, the USCG (specifically, USCG District 17, Sector Anchorage and the core project team). Planned investigations will determine the feasibility of the expansion of the program, statewide, potentially (and ultimately), nationwide; and to disseminate lessons learned to a broad audience of non-technical and technical stakeholders. This work will be conducted over the course of an 18-month period and employ a combination of remote delivery and face-to-face methods of execution. The critical outcome of this program will be a research knowledge product of the investigations for USCG consideration as well as a set of trained pilots and flyable UAS staged in the Bering Strait region, prepared to efficiently support community and USCG maintenance inspection and emergency response needs if/as desired by USCG or facility.

Objective/Purpose.

The primary objectives of this project are to 1) create a knowledge product providing analysis of experiments using multispectral sensor capacity to support infrastructure monitoring, and to 2) co-produce a UAS-based monitoring program, (using non-Chinese UAS platforms) focused on USCG regulated (33 CFR 154) bulk fuel facility inspections and emergency response, with the Alaska Native Village of Unalakleet. The secondary objectives are to 3) understand the feasibility of expanding the developed monitoring program to communities throughout the Norton Sound region to effectively support CG facility inspections and the response efforts in remote western Alaska, and 4) determine if this project can be used as a roadmap for that expansion. This program will develop a trained pilot team (planned at five individuals) within the community of Unalakleet, versed in the operation of off-the-shelf U.S. made UAS technologies that can be used to regularly monitor bulk fuel storage facility infrastructure, as well as be available to fly for situational awareness pre and post regional disasters. Discussions of current spill response strategies in the region and the roles communities can fulfill during an emergency response will be explored, as detection and reporting strategies are defined. The following addresses the major components of the planned investigations:

Pilot Training - Key to a successful program will be to determine the efficacy of visible spectrum and infrared sensors to support community inspection flights, and to provide high quality UAS flight training, including the use of sensors for inspections, to seven motivated residents of the Unalakleet community. The pilots will be chosen from a pool of applicants that perform emergency operations and environmental compliance tasks as part of their everyday duties. Developing an experienced

UAS team that can be deployed locally and regionally will advance operational response capacity in the region as well as promote technology integration in rural Alaska.

Co-Production of Infrastructure Assessment Operational Protocols – This work is to pair current inspection techniques mandated in 33 CFR 154 with UAS capacity to support inspections of fuel storage and delivery infrastructure in accordance with USCG inspection protocols. The research goal is to investigate and co-produce an operational UAS-based inspection protocol that can be utilized on a regular basis, to affirm storage tank and infrastructure integrity in rural regions, to reduce and potentially reduce the need of USCG inspectors from traveling to these regions to conduct such routine inspections.

Co-Production of Emergency Assessment Protocols - The goal of this work is to co-produce emergency flight protocols, that will define image/video collection techniques for gaining situational awareness during all stages of an emergency response. The protocols will include methodology to efficiently deliver collected information to the response Incident Command center for any given response in the Norton Sound region. Baseline data sets collected using the co-produced emergency response flight protocol will be produced as part of this research.

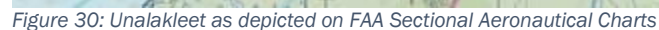
Regional Expansion Feasibility Study – The goal of the feasibility study is to identify benefits, shortcomings and challenges of implementing the designed community-based pilot program in Unalakleet for the long-term, and in other communities in the Norton Sound and Bering Strait region.

Information sharing – The resulting program outcomes will be presented to a broad audience of DHS stakeholders as a principal focus. Research outcomes will be shared with other rural Alaskan communities through face-to-face and on-line engagement efforts, non-technical bulletins and a technical journal publication. Researchers see the long-term viability of training pilots and developing protocols will be achieved by adopting project outcomes operationally in Unalakleet, by informing the community of emergency responders outside of Unalakleet of the response capacity available there, and by promoting the expansion of the project outcomes to other communities in the Bering Strait region. The research team working in concert with ADAC leadership will provide several options, operating in parallel with USCG Project Champion and USCG Project stakeholders. This includes sharing information via Arctic ERMA and the associated ADAC webpage (see <https://arcticdomainawarenesscenter.org/Projects>) as well as standard mailing of hard drive materials via secure addresses.

Methodology:

Project research methods were designed to answer the question, ***what opportunities exist to train local observers to provide quality information to support local infrastructure inspections and emergency response actions?*** To address this question, the project research methodology is a sequenced set of coordinated and collaborative activities that incorporate USCG inspection requirements, provide rural regional UAS pilot training, coproduce routine inspection and emergency response protocols for UAS operations, and conduct UAS data collections by vetted and approved local citizens in rural Western Alaska. Key to this methodology is information dissemination about

In ADAC Program Year 7, this project was approved and subsequently launched on November 1, 2020. The following tasks were initiated and conducted in accordance with the projected project timeline between November 1, 2020, and June 30, 2021. All work to date has been accomplished remotely due to the on-going COVID-19 pandemic.



Key Accomplishments:

The following section outlines the work identified to be completed during the project, that which has been completed-to-date.

Task 0 – Project Coordination:

The project was established among all institutions and sponsors during November and December of 2020 following the overarching coordination methodology of all ADAC projects. Throughout this time, the tools and methods of communication for the lifecycle of the project were identified and agreed upon by the project core team during preliminary coordination meetings. Included in this program establishment phase was the development and execution of a remote kick-off meeting with sponsors and HQ USCG Project Champion, CDR Chad Thompson, and the establishment of reporting protocols for the project team. The establishment of this project follows the overarching methodology of all ADAC projects, with additional communication requirements imposed by the current Coronavirus 2019 (COVID-19) pandemic.

Task 0.1 Program Establishment. This work included the iteration, coordination and associated implementation of the project workplan, and the establishment of contractual and reporting mechanisms for all members of the research team.

Task 0.2 Kick-off meeting with HQ USCG Project Champion. This meeting introduced the Project Champion (CDR Chad Thompson) to the Project Team and provided a forum for detailed discussion of the project vision, the objectives, and the anticipated outcomes. This meeting provided the opportunity to gather post workplan approval project directions from HQ USCG, and to describe methodological nuances, while thoroughly examining program risk and outlining associated risk mitigation strategies.

Task 0.3 Identify Webinar and Synchronous Instructional Tools. The societal constraints imposed by COVID-19 requires that a significant portion of this project be delivered remotely. To accomplish this task, an investigation into available synchronous and asynchronous content delivery tools was conducted. The tools identified through this investigation needed to be flexible enough to support the needs of all project stakeholders (UAF, MFPP, NVU, USCG), and be able to work effectively with bandwidth constraints. The primary tools used for communication among the project team and partners include **Zoom** for webinars, weekly meetings, and reporting to sponsors; **Google Drive** for archiving and sharing documents, presentations and other project content; **YouTube** for editing, archiving and distribution of project videos to pilots in training; **Facebook** for distribution of project videos to pilots, and informal information sharing; text messaging and personal **phone** calls among team members is also utilized.

Task 0.4 Conduct team coordination meetings. Regular, remote, and weekly team meetings are held among core team members, with additional ad hoc meetings as needed for iterating on the program and completing deliverables. Monthly meetings with project stakeholders occur on the first Tuesday of every month, and are used to report monthly progress, gather feedback and share successes.

Task 0.5 Prepare and participate in ADAC Quarterly reviews, Customers and Partners Roundtables, Annual meetings and write Semi-Annual, and Annual Reports. In accordance with ADAC's management processes, the project team prepares and participates in ADAC Quarterly reviews, Customers and Partners Roundtables, and Annual meetings as well as authors the UAS project Semi-Annual and Annual Reports. These actions will continue to take place throughout the lifecycle of the project.

Task 1 – UAS Pilot Training and Certification: In order to develop the community-based Unmanned Aircraft System (UAS) response team, a set of potential UAS pilots needed to be identified and engaged in the community of Unalakleet. The steps to identify potential UAS pilots for program participation centered on a recruitment webinar, an application for participation, and an on-line 8-week training program held synchronously over Zoom. A set of operational aircraft outfitted with EO sensors was purchased to begin general protocol development and in preparation of delivery to Unalakleet once the pilots have achieved their Part 107 certification from the FAA. UAS instructors are teaching all aspects of the operational aircraft to the pilots as part of the hands-on portion of the UAS training program. All participants in the project train on the same aircraft to allow for additional data collection, regional support of community pilots, and aircraft specific data processing protocol development. Hands-on pilot training includes general practice flights, and test flights for protocol development.

Task 1.1 Develop and Deliver Kick-Off/Recruitment Webinar. A two-hour recruitment webinar was developed by the project core team of Garron (PI), Henry (Co-I) and Hall (Co-I) and held over Zoom on February 25, 2020, to introduce the project to the community, stakeholders from across the state, and potential pilots in Unalakleet, Alaska. To engage key community members and entice participation from a broad swath of the community, a set of formal invitation letters were sent to select members of the Unalakleet community specifically recruited for the program based upon current employment duties or expressed interest in UAS. In addition, webinar invitation letters were also sent to community planners and managers, as well as the local State of Alaska Troopers, the Village Public Safety Officer (VPSO), members of the Kawerak regional tribal consortium, the Norton Sound Economic Development Corporation, the Alaska Department of Transportation (Aviation Division), and instructors of the Career and Technical Education program in the Bering Strait School District. The overarching objectives of the project as well as the methodology and roadmap for participation were shared with participants, recorded, and provided to all invitees and attendees and invitees at its conclusion. The entire project team was on-line to present and answer questions, as were project sponsors from the ADAC leadership team.

Task 1.2 Acquire and train pilots in use of UAVs, Sensors and Software. A set of EO outfitted operational UAS have been purchased for delivery to the NVU. These small drones bridge the gap between the simulated flights and the operational aircraft, exposing the new pilot teams to the three-dimensional (3D) aspects of UAS flight. The operational unmanned aircraft and sensor packages are currently being tested by the UAF instructional and data processing teams in advance of instructional periods in NVU to understand and document aircraft and sensor nuances.

Task 1.3 Develop General Protocol for UAS Flights and Data Processing. Operational hardware and software are being tested and leveraged at UAF to streamline protocol coproduction and data processing nuances. This work includes flight testing the aircraft in sub-Arctic conditions to identify the operational range of the aircraft in rural Alaska and performing simulated test flights for infrastructure inspection and emergency response situational awareness. Data gathered by the sensors during these test flights is being processed using three post-processing software solutions to determine which software provides the highest quality data product for decision-making, while also being reasonably user friendly to support the success of data product creation by the NVU UAS pilots.

Performing data delivery of test data sets to USCG Stakeholders and advisors is being coordinated as part of this testing, to identify requirements and limitations to operational data delivery from the NVU. Efforts are underway to have the test data catalogued in NOAA's Arctic Environmental Response Management Application (Arctic ERMA) a repository for data accessible to USCG maritime environmental response at tactical and operational levels.



Figure 31: Left: UAS pilot Mike DeLue performs the role of aerial observer during a test flight of 3D scan capacity. Right: Output of 3D scan test flight. Imagery courtesy of Jessica Garron.

Task 1.4 Identify/Notify Pilot Teams. A UAS pilot application for program participation that also doubled as the employment application for the UAS pilots with the Native Village of Unalakleet was developed while the recruitment webinar was under development. This application highlighted the minimum requirements for both employment with NVU, for the Part 107 certification, and also included the general requirements and preferences for all aspects of the program, such as familiarity with maps, and comfort using computers and radios. The application period lasted for three weeks and resulted in three, pilot/co-pilot UAS teams (plus one back-up/coordinator) were identified in Unalakleet. The project core team (Garron, Henry, Hall) reviewed and selected applicants based upon motivation, pilot skills competency and references.

Task 1.5 Deliver Remote UAS Pilot Training. Remote pilot instruction included synchronous and asynchronous content delivery to the NVU using Zoom, Google Drive and email as the primary modes of project communication. Fundamental UAS flight training for pilots and observers was provided by the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) of the University of Alaska Fairbanks over the course of 8-weeks via Zoom. Community pilots were trained on the safe operation of UAS in Alaska's airspace, UAS policy and best practices for the

safe use of UAS in Alaska, with specific orientation suitable to the Norton Sound region. This instruction was designed to provide a foundation to community pilots, and preparation for the FAA Part 107 exam. The content reflected all laws and safety components of UAS flight in addition to lessons learned, and fundamental components of UAS flight in US airspace. Additional instruction on lessons-learned during prior operations and specific instruction based upon the airspace and general conditions of the Norton Sound region were included.

An introduction to data processing was included in this remote instruction. Remote data processing instruction will be based upon the experience of, and bandwidth available to the trained pilots, and will utilize the test data sets acquired at UAF, by the operational aircraft and software.

Task 1.6 FAA Certify UAS Pilots. Trained program pilots are required to take and pass the FAA Part 107 certification exam for UAS operators. Pilot teams have been trained on all aspects of the certification test through remotely delivered instruction and have participated in six hours of collaborative review sessions but are still required to learn and reflect the laws and requirements for UAS flight in US airspace to pass the FAA certification exam independently. One of the seven NVU UAS pilots has already successfully passed their Part 107 certification exam. However, the remaining six pilots still need to sit for the exam at a FAA testing center in Anchorage, AK.

Numerous logistical challenges are being overcome to have the remaining NVU UAS pilots Part 107 certified during the on-going COVID-19 pandemic, some of which are a direct consequence of the pandemic. Quarantine requirements for unvaccinated individuals traveling to Unalakleet from Anchorage will impact the primary jobs of the NVU pilots by absenteeism and has been a hurdle to the identification of dates when these pilots are willing to take off work from their primary job to accommodate the testing trip as well as the quarantine

requirements upon their return. Another challenge is due to the delay in project establishment. This delay shifted the project timeline into the commercial fishing season, for which half of our NVU UAS pilots are currently participating. The project leads are still in communication with these pilots on the fishing boats and anticipate their Part 107 certification trips to Anchorage to be conducted in late August or early September of 2021. The final logistical challenge is the coordination of all of the travel plans for the NVU UAS pilot trainees by UAF. This requires a number of steps including registration within the UA travel system, identification of preferred dates of travel, establishing a test date and time within the preferred window of travel, and



Figure 32: Hard copy FAA Part 107 study materials provided to each pilot trainee. Photo courtesy of Margy Hall.

executing that travel. Though these are not consequential steps for UAF employees who regularly travel for work, it is an entirely new system and mode of developing travel itineraries for the NVU UAS pilot trainees and has not been a smooth process. Work around techniques and proxy efforts on behalf of the PI and UA travel team are being utilized to overcome this challenge, but do not remove it all together. The UAF project team that will be supporting the pilots in the long run have successfully passed their Part 107 exams, and the MFPP supporting pilot will be Part 107 certified by the end of the September 2021.

A final challenge to the certification of these pilots is actually passing the exam when in Anchorage to take the test. If an individual attempts the Part 107 certification exam and does not meet the minimum requirements to pass, they are not allowed to attempt the certification exam for an additional two weeks. Due to the timeline and budgetary constraints of this project, we are only able to provide the NVU UAS pilot trainees one opportunity to travel to Anchorage for this exam. If this circumstance is encountered, alternative pilots or travel modes will be identified to support a Part 107 certified NVU UAS pilot team.

Task 2 - Coproduction of Infrastructure Inspection Operational Protocols: This work pairs 33 CFR 154 regulated bulk fuel facility integrity inspection requirements and State of Alaska (18 AAC 75) guidelines for reservoir/tank farm infrastructure inspections, with UAS operations, via the co-production of an operational, infrastructure inspection protocol. Data collection, processing and delivery requirements for providing UAS-captured data for infrastructure assessment is being co-produced among the pilots and the project team, using information gathered during testing in Fairbanks and training in Unalakleet. This effort is underway, on schedule and scheduled for completion in the early months of ADAC Program Year 8.

Task 2.1 Determine Current Infrastructure Inspection Requirements. Project investigators have been working with the Environmental Protection Agency, USCG, and the State of Alaska to gain and understand documented requirements for the inspection and integrity of fuel carrying and fuel storage facilities in remote Alaska. Examining and summarizing these requirements is underway, an effort key to the development of a viable UAS inspection solution in support of the observational requirements and local ordinances of Unalakleet. In addition, the needs of USCG inspectors that are not defined in codified requirements have been ascertained via teleconferences between project investigators and USCG Sector Anchorage inspection teams for subsequent flight protocol codification.

Task 2.2 Coproduce UAS Infrastructure Inspection Protocol. Project investigators are leveraging knowledge gained during general protocol development and flight testing in Fairbanks to identify the different methodologies afforded from the operational aircraft to develop Unalakleet specific infrastructure inspection protocols. Knowing that infrastructure inspection flights will include linear, gridded, and 3D scanning flight plans, coproduced protocols are being drafted for each mode of operation based upon the location and accessibility of the key infrastructure targets. For example, linear flights are needed to monitor the fuel pipeline header along the Unalakleet River where fuel is offloaded from the barge into the pipeline leading to the bulk fuel storage facility. However, once at the facility, 3D scanning flights of the tanks and their secondary containment are used to identify integrity of the specific tanks and the facility overall. Due to the 3D scan

requirement, bulk fuel facility inspection protocols will be developed when the entire project team is on-site and iterated against in real-time during test flights.

Task 3 - Coproduction of Emergency Response (ER) Assessment Protocols: The NVU is a remote, subsistence-based community, off the road system in Western Alaska. As such, environmental compartments and community support mechanisms, like the airport, power plant and school, are key assets for the survival of the community. Being able to monitor these assets and report on their condition is key for ER activities, as are search and rescue missions and other dynamic ER scenarios. Partner building discussions with all stakeholders about the required components of ER assessments is increasing trust among the pilots and program researchers, while integrating expectation management for UAS applications. Through these discussions, specific emergency scenarios that the pilots have identified for their community. These specific scenarios are search and rescue actions over land, search and rescue support over water, flood delineation and oil spill detection and monitoring.



The coproduction of ER protocols may end up being the most critical and long-lived outcome of this project. Coproduction of ER UAS flight protocols was initiated during ADAC Program Year 7.

Figure 33: City of Unalakleet's water tanks and GCI earth station dish. Photo courtesy of John P. Henry, Jr.

Task 3.1 Determine Key Community Assets. This work is to determine what the key assets are in the NVU through community engagement, document review and scenario analysis. The resulting information will inform the flight patterns and data products created as a result of the coproduced ER UAS protocol, whether the emergency is a marine-based oil spill, flooding event or other large-scale, environmental disaster, impacting the community.

Utilizing the weekly two-hour work sessions between the project leads and the UAS pilots of NVU, identification of local key resources of concern that could be impacted by marine spills in the Bering Sea region are being identified. This information, inclusive of geographic areas of concern for these subsistence resources (i.e., marine mammal haul-outs), will be integrated into the operational protocols for subsequent analyses during scenario assessment.

Task 4 – Regional Expansion Feasibility Assessment: To determine if the experimental UAS program can be implemented for the long-term in other Bering Sea region communities, the project

team is undertaking a feasibility study. The feasibility assessment is intended to serve as a suitable roadmap for other rural Alaskan communities should they want to independently establish inspection programs based on the findings of this project, and as a prototype of implementation considerations for other communities and USCG Sectors across the nation.

Task 4.1 Summarize Regional Critical Infrastructure and ER Information. This work is in its infancy and includes summarizing current Norton Sound communities' critical infrastructure, critical and vulnerable (subsistence) assets, ER capacity and protocols as part of the determination of how UAS-based Infrastructure Inspection and ER protocols could be applied in other Norton Sound communities, beginning with Unalakleet. Project investigators have begun to review key (individual community) documents (e.g., Local Economic Development Plan, Hazard Mitigation Plans, and Small Community Emergency Plans) for information regarding critical infrastructure and ER plans, the first steps in the development of this assessment.

Task 5 - Information Dissemination: Key to the long-term viability of the information and results of this project is effective information dissemination about the work to various audiences, both formally and informally. The project team disseminates results through planned face-to-face engagement events and continuously executed asynchronous publications and reporting mechanisms. The key subtask that is being leveraged throughout the lifecycle of the project is the engagement with non-technical audiences.

Task 5.2 Engage Non-Technical Stakeholders. Engagement of non-technical stakeholders and other interested parties is critical in order to increase understanding of the project by a broader group of individuals including local and regional decision makers. To engage these broader communities, development and dissemination of project updates are executed via our project newsletter. The newsletter is a bimonthly publication of project highlights that is broadly distributed via email lists of partners and stakeholders, and through the cooperative support and distribution mechanisms of such entities as the Institute for Tribal Environmental Professionals (<http://www7.nau.edu/itep/main/Home/>), the Alaska Native Tribal Health Consortium Center for Environmentally Threatened Communities (<https://anthc.org/center-for-environmentally-threatened-communities/>).

A press release developed by UAF was released to all Alaska media outlets in June of 2021. This press release caused a flurry of inquiries about the project and resulted in interviews given to an Alaska statewide television news outlet (KTVF), a Norton Sound regional radio news outlet (KNOM), and direct communications with other Alaskan communities interested in learning more about the program for potential implementation in their communities, one of the primary objectives of the project. The value of these informal communications has become increasingly evident throughout this project.

Student Involvement:

N/A

Key Stakeholder Engagement:

- **UAS in Bering Strait Monthly Update Meeting** held the first Tuesday of each month - This virtually-held monthly gathering is used by PI Garron as a forum to present recent project updates to the project team, internal project stakeholders, and ADAC leadership.
- **USCG Sector Anchorage Update Meetings** - These ad hoc meetings occur approximately once a month with CDR Altendorf and team to allow for updates and alignment of the project with local USCG mission needs.
- **ADAC Weekly All Hands Meetings** - PI Garron and Co-I Hall regularly attend and report out at the ADAC weekly meetings to provide specific and direct updates to the ADAC team on the status of the project.
- **ADAC Quarterly Reviews** / January 8, 2021, and May 3, 2021 - PI Garron and Co-I Hall developed, recorded and presented project updates for both quarterly reviews that have occurred since project kick-off. The aim of the ADAC quarterly review is to comprehensively review each project, including the appropriate fiscal details, in order to assess progress of each project as we finalize the planned year of research.
- **ADAC Quarterly Customers and Partners' Roundtable** / January 29, 2021 - PI Garron and Co-I Hall developed, recorded and presented project updates on the project and its status at these quarterly venues. The aim of the quarterly Customers and Partners' Roundtable is to facilitate interaction with the following entities: U.S. Coast Guard Project Champions, U.S. Coast Guard Stakeholders and advocates, Other DHS maritime mission communities, U.S. Federal and Canadian government officials, State of Alaska and local officials, academic/research and industry professionals from across the U.S. and Canada.
- **Arctic Challenges, Innovations, and Commerce Expo (Arctic CICE)** / March 15-16, 2021 - This hybrid in-person/ virtual event aimed to explore the networks, resources, and infrastructure needed to enable the commercial entrance of Arctic-related products and technologies into the Arctic domain using an interdisciplinary and collaborative approach. PI Garron, Co-I Hall and Co-I Henry developed, recorded and presented about this project at this Expo.
- **ADAC Annual Meeting** / June 2-3, 2021 - PI Garron and Co-I Hall developed, recorded and presented project updates for this virtually-held meeting. The aim of this meeting was as a summary review of the ADAC's current research endeavors and conducting discussions to foster USCG and the ADAC partner community's thinking in better leveraging ADAC in upcoming Program Year 8 and beyond.

Key Publications (peer reviewed):

N/A.

Key Presentations:

- **Remote Unmanned Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region Recruitment Webinar** / February 25, 2020 - This two-hour recruitment webinar developed by the project core team of PI Garron, Co-I Henry and Co-I Hall was held over Zoom to introduce the project to the community, stakeholders from across the state, and potential pilots in Unalakleet, Alaska. The webinar was recorded and delivered to all participants as well as project stakeholders throughout the State of Alaska.
- **9th Biennial OSPR/Chevron Technology Workshop for Oil Spill Response** / February 22-26, 2021 - This virtually-held international symposium has been recognized as an outstanding opportunity to learn about emerging and innovative technologies and strategies for oil spill response. PI Garron presented about the project in the session, “Remote Sensing, Sampling, and Data Management”.
- **Arctic Science Summit Week** / March 22-26, 2021 - This virtually-held international conference aims to provide opportunities for coordination, cooperation and collaboration between the different scientific organizations involved in research in the Arctic, so as to discuss the scientific advances regarding the region. This annual event is hosted by the International Arctic Science Committee in conjunction with the Arctic Council ministerial meeting. PI Garron presented on the project in the session, “Use and Usability of Data and Information within Arctic Community-Driven Research”.
- **Western Alaska Interdisciplinary Science Conference** / May 13-14, 2021 - This virtually-held regional conference aims to bring together local and indigenous knowledge of subsistence-based communities and other scientific research relevant to Western Alaska, including economic, ecological, social, and health issues important to rural communities. This year’s conference focused on the future threats and opportunities in the face of a changing climate. PI Garron presented on the project in the session, “Sustaining Community”.

Changes from Initially Approved Workplan:

Period of Performance: Processing this workplan from submission through full approval took a number of months that were not accounted for in the timeline included in the approved workplan. As a result, the period of performance was approved for adjustment to account for this four month delay to begin in November 2020 and complete by April 2022. The Tasks and Milestones identified in the approved workplan were also shifted to reflect this unanticipated four month delay in project establishment and kick-off. The Key Accomplishments, Project Progress Against Each Milestone and Project Progress against Each Metric, that are reported on here have been adjusted to reflect this shift in the timeline.

Technological Solutions: Critical to the success of this program is the integration of commercial off the shelf solutions (COTS) that are usable and master able by our novice pilot team. Once the pilots were accepted into the program for participation, a reevaluation of identified technologies to meet project objectives was performed. This evaluation included the required level of mastery required to operate the operational aircraft, its payload, and the post-processing software and methodology for data visualization locally and by USCG Sector Anchorage. The conclusion resulting from this reevaluation was an adjustment in the USA-made aircraft, payload and post-processing solutions.

The multispectral payload had driven the choice of aircraft to a vertical take-off and landing (VTOL) UAS capable of carrying the multispectral sensor payload, and which also offered some robust characteristics for protection against minimal precipitation. Once the UAS pilot recruits were identified, it became clear that the required post-processing of the multispectral data and the software that could support these actions were not going to be effectively mastered within the short timeline of the project. As such, a longwave infrared (IR) sensor was identified as an alternative second payload in addition to the EO payload already identified for integration. By changing the payload, many USA-made UAS alternatives for carrying these payloads became available for consideration for this project. Of these alternatives, a USA-made, multirotor vehicle with integrated EO and IR payload capacity from Skydio, Inc. was identified for training and operational purposes. Additionally, the commercially available software packages available for processing the collected EO and IR data are more mature and are more easily mastered by non-academic users.

ER protocol expansion: Coproduction of the ER assessment protocols has expanded in scope from oil spill detection to include additional emergency scenarios that the pilots have identified as critical for their community. These specific scenarios are search and rescue actions over land, search and rescue support over water, flood delineation and oil spill detection and monitoring. This scope expansion is not anticipated to increase any component of the timeline but will include additional test flights in the community to leverage the coproduced ER protocols specific to these scenarios.

Project progress against each milestone:

The following summary table of key milestones were scheduled in accordance with the tasks of ADAC Program Year 7 in accordance with the adjusted timeline.

Table 23: UAS in Bering Strait Year 7 Milestones

<i>MILESTONE</i>	<i>PROGRESS</i>	<i>WHY NOT REACHED? (IF APPLICABLE)</i>
Milestone 1.1: Develop and deliver kick-off/recruitment webinar.	Completed	N/A
Milestone 1.2: Acquire operational UAVs, sensors and software.	Completed	N/A
Milestone 1.3: Develop general protocol for UAS flights and data processing.	Completed	N/A
Milestone 1.4: Identify/notify UAS pilot teams.	Completed	N/A

Milestone 1.5: Deliver remote UAS pilot training.	Completed	N/A
Milestone 1.6: FAA certify UAS pilots.	Incomplete	One NVU UAS pilot has successfully passed their Part 107 certification exam. Three of the pilots recruited for UAS training are commercial fishermen resulting in these pilots rescheduling their FAA Part 107 testing for early fall due to their fishing commitments. UAF is supporting the remaining three pilots in preparing their travel arrangements to sit for the Part 107 certification exam in Anchorage in August 2021.
Milestone 2.1: Determine current tank and fuel delivery infrastructure inspection requirements.	Completed	N/A
Milestone 2.2: Coproduce a UAS-based tank and fuel delivery infrastructure inspection protocol.	Incomplete	This work has been initiated via localized UAS test flights to determine the basic flight parameters needed for the UAS infrastructure inspection protocols. Compilation of all protocol components and iteration against the basic flight protocol will take place during weekly work sessions and in person once additional NVU UAS pilots successfully pass their Part 107 certification exam. This work is on schedule for on-time completion.
Milestone 3.1: Determine key community assets for monitoring pre/post emergency response.	Incomplete	This work has been initiated by utilizing the weekly two-hour work sessions to identify local key resources of concern that could be impacted by marine spills in the Bering Sea region. Additional discussions and their documentation among regional partners will complete this task. This work is on schedule for on-time completion.

Milestone 4.1: Summarize key (local and regional) documents for critical infrastructure and emergency response information.	Incomplete	This work has been initiated by identifying the primary planning, risk and response plans used locally and regionally, and how UAS support can bolster their efficacy. Additional discussions and their documentation among regional partners will complete this task. This work is on schedule for on-time completion.
Milestone 5.2: Engage non-technical stakeholders.	Completed	This Milestone is on-going throughout the lifecycle of the project and has been met to date.

Project progress against each metric:

Below are the overall performance metrics planned for the entire research project, encompassing both ADAC Program year 7 and Year 8. Project progress toward each metric is summarized in the table below.

Table 24: UAS in Bering Strait Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
T1: Acquire operational UAVs, sensors and software suitable to operate in an Arctic environment.	Completed	Operational UAVs, sensors and software have been acquired for training pilots and developing protocols. Operational UAVs outfitted with infrared sensors are planned for purchase in accordance with the approved workplan to expand the capacity of emergency response and infrastructure inspection.
T1: Develop general protocol for UAS flights and data processing satisfactory to HQ USCG Project Champion and supporting USCG teams (in particular, Sector Anchorage).	Completed	N/A
T1: Recruiting and training 7 UAS pilots to FAA standards.	Incomplete	Seven pilots were successfully recruited and trained remotely. The final step in obtaining this metric is for the pilots to pass the FAA Part 107 certification exam which is required to fly commercially.

T2: Determine current tank and fuel delivery infrastructure inspection requirements, coproduce a UAS-based tank and fuel delivery infrastructure inspection protocol, and perform infrastructure inspection flights and product delivery tests processing in accordance with FAA, State of Alaska and Local Ordinances to the satisfaction of HQ USCG Project Champion and supporting USCG teams (in particular, Sector Anchorage).	Incomplete	Tank and fuel delivery infrastructure requirements have been determined and the coproduction of infrastructure inspection flight protocols are in process of development. Delays in the certification of pilots and delivery of UAS by the vendor delayed completing the coproduction portion of this metric. Conducting inspection flights and data processing for delivery to USCG Sector Anchorage remains on schedule. This work is on schedule for on-time completion.
T3: Determine key community assets for monitoring pre/post emergency response, coproduce emergency response UAS protocol based upon surveys of key community assets and perform emergency response baseline flights and product delivery tests processing in accordance with FAA, State of Alaska and Local Ordinances to the satisfaction of HQ USCG Project Champion and supporting USCG teams (in particular, Sector Anchorage).	Incomplete	This work has been initiated by utilizing the weekly two-hour work sessions to identify local key resources of concern that could be impacted by marine spills in the Bering Sea region. Additional discussions and their documentation among regional partners will complete this task. Test flights by the UAF team include search and rescue specific flight plans, as well as flood delineation and gridded terrestrial flight plans. This work is on schedule for on-time completion.
T4: Summarize key (local and regional) documents for critical infrastructure and emergency response information, develop regional contact list and conduct regional UAS survey, and aggregate survey results in a regional expansion feasibility report in accordance with FAA, State of Alaska and Local Ordinances to the satisfaction of HQ USCG Project Champion and supporting USCG teams (in particular, Sector Anchorage). Feasibility assessment will be suitable to serve a roadmap for other rural Alaskan communities should they want to independently establish inspection programs based on the findings of this project.	Incomplete	This work has been initiated by identifying the primary planning, risk and response plans used locally and regionally, and how UAS support can bolster their efficacy. The overarching feasibility study has been outlined, and survey recipients preliminarily identified. This work is on schedule for on-time completion.
T5: Create USCG-focused Knowledge Project, engage non-technical stakeholders, develop and hold community engagement events in Unalakleet ("Project Fair"), develop and deliver two webinars and develop and submit publication about	Incomplete	This work has been initiated by coordinating project work to achieve valued USCG Knowledge Products within the project lifecycle. Knowledge products identified in the workplan were directly requested by Project. Champion CDR Thompson and partner CDR Altendorf

sensor capacity testing and general inspection methodology to technical journal, to the satisfaction of HQ USCG Project Champion and supporting USCG teams (in particular, Sector Anchorage).		and will also include costs and lessons learned for future application. This work is on schedule for on-time completion.
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Outcomes/output and TRLs:

Outcomes:

- *Training UAS pilot teams in the Bering Strait region.* The official training of UAS pilots in Unalakleet, Alaska for the FAA Part 107 certification exam was completed this year.
- *Broad stakeholder engagement.* Due to the priority of this project to disseminate information to a broad audience of stakeholders, regular information delivery about this project to non-technical audiences was conducted via public presentations, news coverage and project newsletter. These efforts have resulted in numerous inquiries about the project from a diverse and broad audience including USCG HQ, NOAA, communities from all parts of Alaska, the Alaska Native Tribal Health Consortium and academia.

Outputs:

- *Development of UAS Pilot job description.* To identify the best candidates for participating in this program, the project core team of Garron, Henry and Hall with the input of our ACUASI Part 107 instructor (A. Wentworth), developed a job description for the NVU UAS pilot team. This application identified the minimum qualifications to enter the training program, preferred skills and abilities, was vetted by the NVU leadership, and was used by the NVU to hire the UAS pilot trainees that are taking part in the program. This job description can be transferred to other communities with minimal required revisions in support of UAS team establishment outside of Unalakleet.
- *Recruitment webinar.* A two-hour recruitment webinar was developed by the project core team to introduce the project to the community, stakeholders from across the state, and potential pilots in Unalakleet, Alaska. The webinar addressed the overarching objectives of the project as well as the methodology and roadmap for participation. The archived webinar is available for distribution and can be used as a guiding presentation when developing recruitment webinars for UAS pilot teams in other communities.
- *FAA Part 107 training program.* To conduct the remote training of the UAS pilots, the training materials needed to be identified, developed, polished and delivered. This effort incorporated reference materials, lessons learned and expertise from multiple UAS pilots that have been working in the industry for close to twenty years. This included the creation of a syllabus to outline the 8-week training program, the identification of hard copy and on-line resources for FAA Part 107 operations and exam certification preparation, a series of instructional PowerPoint Presentations, and the recordings of the training sessions which include personal lessons learned as well as multiple Q & A sessions that took place in an ad hoc fashion during training.

- *Newsletter.* The project team develops and distributes a project newsletter every quarter, starting late this spring; one has been distributed and the second is currently under development. The newsletter supports our project goals of disseminating knowledge of the project work to a broad audience, but also serves as an easily consumable summary of the work to date (public archive), and an opportunity to highlight components of the project that otherwise do not have a venue for reveal.

See Key Presentations section for additional outputs

Technology Readiness Levels:

N/A

Unanticipated problems and plans for addressing them:

Working in rural Alaskan communities provides unique challenges to program execution even in times when a global pandemic is not persisting. The project team has extensive experience working with these communities to achieve common goals but are exposed to new challenges at each step of project execution. Though there have been few unanticipated problems as part of this program, the encountered problems described below and plans for addressing them include flexibility and patience.

Pilots as commercial fishermen. Many residents of Unalakleet perform numerous roles, and often have multiple modes of employment depending on the time of year. Due to the delay in project establishment, project components that were intended to take place during winter months were shifted into the commercial fishing season, for which half of our NVU UAS pilots are currently participating in. This has impacted team cohesion as well as the timeline for pilot certification by the FAA. The impacts of this unanticipated delay are not fully realized at this time but are being actively minimized by all means possible by the project core team of Garron, Hall and Henry.

Vaccination status influencing project required travel. COVID-19 vaccination status among members of this project is variable. For unvaccinated team members living in Unalakleet needing to travel to Anchorage to sit for their Part 107 certification exam, there is a 10-day quarantine requirement upon their return to their community. This quarantine requirement impacts the primary jobs of the NVU pilots by absenteeism and has been a hurdle to the identification of dates when these pilots are willing to take off work from their primary job to accommodate the Part 107 certification trip as well as the quarantine requirements upon their return. There is little the project core team can do to mitigate this impact.

Delays in UAS receipt from vendor. The requirement for USA-made and supported UAS as part of this project restricts the number of UAS vendors that were considered as part of this project. Within the group of Blue sUAS (UAS approved for use by the Department of Defense and Federal government partners), the UAS solution that was determined most appropriate for novice fliers, and which met

the objectives of this project was the Skydio platform. Due to high demand for these particular vehicles, our initial shipment of UAS was delayed, which in turn delayed the test flights for general protocol development, and data processing methodology development. This impact to the overarching project because of this delay is relatively small.

Transition Activities:

Transition plans and progress made. The transition plan for this project is focused on a comprehensive dissemination of knowledge products and research findings for journals, and other practical measures to help communities and other agencies assess the utility of this approach for remote area use of UAS for inspection purposes.

The project team is currently disseminating the results of the program through monthly presentations or publications about the project to academic, operational and non-technical audiences, and through ADAC/DHS reporting mechanisms. The project team is also in the process of creating a model or “road map” for succinct UAS program creation for remote communities in partnership with USCG Sectors. The model is comprehensive and inclusive of lessons learned from ground zero to an up and running program with challenges of working remotely and in different cultures. This Knowledge Product contains the tangible components of UAS pilot job description, standard operating procedures for an overarching program, flight-specific checklists, and data management solutions. These transition efforts will continue throughout the lifecycle of the project and be concluded holistically at the project’s cessation at the end of ADAC Program Year 8.

PROJECT: Alaska and Arctic Maritime Communications and Connectivity Analysis (AAMC&CA)

Project Investigator: Dr. Doug Causey, Principal Investigator, Mr. Jason Roe, Petty Officer, USCG (Ret), ADAC Associate Director and Senior Research Professional, University of Alaska Anchorage (UAA), Anchorage, AK. Dr. Mark Ivey Sandia National Laboratories, Albuquerque NM.

Lead Institution: University of Alaska, Anchorage (UAA)

Supporting Team: CG-761, USCG 5PW [MOU18], CG-926, D17 [JR19]; Sandia National Labs, Arctic Slope Regional Corporation (ASRC) Federal Mission Solutions, Alaska Chadux Corporation, Marine Exchange of Alaska, Ukpeaġvik Iñupiat Corporation.

Program Year 7 Project Champion: CDR Sam Nassar, HQ USCG CG761, Washington D.C.

Project Description:

Abstract:

This project provides a comprehensive review of mariner communications and connectivity mission needs for the Alaska and the U.S. Arctic Extended Economic Zone (EEZ), with a particular focus on the Arctic (based on near, mid-term, and long-term time horizons). The investigation will take a sequenced and iterative approach, beginning with a comprehensive literature review, the establishment of a Core Advisory Team, and the development of detailed working groups. These

phases will inform and drive the development of a detailed qualitative market survey, which will serve as the primary data-gathering stage in which key stakeholders will identify gaps and shortfalls related to maritime connectivity needs in their respective regions, industries, and communities. The culmination of the latter phases will inform an expert assessment, leading to the creation of a draft knowledge product, which will be assessed and finalized through a final capstone workshop. The principal focus of this planned series of investigations is to review current-to-long term mission connectivity needs, and to assess current and emerging technologies in order to derive an expert-driven comprehensive knowledge product.

Objective/Purpose:

The goal of this project is to create and publish a knowledge product (a comprehensive report) that will contain:

1. Comprehensive review of mariner communications and connectivity mission needs for the Alaska and the U.S. Arctic Extended Economic Zone (EEZ).
2. An updated and expanded market survey and literature review of current and baseline communications technology solutions corresponding to Alaska and the U.S. Arctic EEZ, which include voice and digital mediums.
3. A geographic review of the Alaskan and U.S. Arctic regions in terms of communications/connectivity shortfalls. Currently, there are a number of variances in connectivity in the high latitudes; the proposed study would assess these variances in forming a baseline of connectivity challenges and gaps.
4. A technology-focused review of known/understood existing communications and connectivity capabilities, assessed against researched gaps for the high latitudes.
5. An expert-derived set of options and recommendations via a framework oriented to a Doctrine, Organization, Training, Material, Leadership and Education, Personnel and Facilities (DOTMLPF) framework that addresses methods and means to close communications and connectivity gaps as related to near, mid, and long-term planning and technologies.
 - a. Additionally, recommendations will consider and address solutions in the context of buying services vs. organically deriving and developing technologies.
 - b. The final knowledge product will include prioritized options (while considering options such as commonality of usability/application of high latitude solutions to lower latitudes).

Methodology:

Guided by an expert coordination team to organize and conduct investigations, as well as to effectively solicit expert and community opinion, the research method is a sequential and iterative process of review, query, and knowledge product development, which will ultimately be refined and finalized via multi-functional expert assessments. The objective of this project is to identify the potential current state-of-the-art maritime communications suitable for remote Alaskan and Arctic

waters, based on a comprehensive literature review, a qualitative market survey, community and stakeholder engagement, and solicitation of expert professional opinion via focused working groups.

The primary focus of the project is to understand and assess the communication and connectivity challenges unique to Alaskan and the U.S. Arctic maritime regions (e.g., ice, adverse weather, high latitudes, sparse population densities, lack of infrastructure, and other logistical challenges) that make communications particularly challenging. The scope of investigations seeks to further identify the needs, shortfalls, and outline parameters of the potential corresponding solutions most appropriate to a variety of Arctic mariners.

This project is focused on mariner communications and connectivity in U.S. waters outside that of the military services. As suitable and in accordance with ADAC's established ability to coordinate with Canadian colleagues in government and research communities, including Canadian aspects in these assessments (in particular with the shared challenges of the Beaufort Sea) will be pursued in the investigations.

This project will further engage communities to research these characteristics as they are unique or shared across six major geographic regions of Alaska and the U.S. Arctic region: Southeast, Southcentral, Southwest, West (Bering Sea), and Northern (Chukchi and Beaufort Seas).

Key Accomplishments:

The following Phases were completed in Program Year 7:

- *Phase 0: Conducted a virtual conference with HQ USCG Project Champion, USCG Stakeholders and USCG technology developers.* At the onset of the project, the project team conducted a virtual conference with the HQ USCG Project Champion, USCG Project Stakeholders and USCG technology developers to discuss project scope and confirm supporting details as well as the ultimate consumers of the end state knowledge product such that the vision and needs are as clearly defined as possible as the vector/pathway for the research.
- *Phase 1: Conducted a Comprehensive literature review (to continue through Phase 5).* Note, the literature review includes information and insights from previously accomplished USCG research products.
- *Phase 2: Forming of project Core Advisory Team.* The AAMCCA "Core team" includes ADAC leadership, Proposed Principal Investigators, Technical Researchers, Community Engagement Coordinator and Project Advisors.
- *Phase 3: "Engaging the Community": conducted virtual Meetings across the communities of interest.* The Core Team with key project stakeholders sought to clearly establish Alaskan and Arctic maritime communication and connectivity needs, and to define the scope of project for stakeholders. These meetings defined goals and boundaries for the virtual assessment in Phase 5.

Note: The following Phases were initiated in Program Year 7 and are currently in-progress:

- Phase 4: Establishing virtual Working Groups. These groups investigate specific maritime communications and connectivity components/criteria, principally focused on Alaska and U.S. Arctic EEZ.
- Phase 5: Conducting a virtual assessment. Planning and conducting a three-segment invitational virtual (or hybrid) assessment focused on Alaskan and Arctic maritime communications and connectivity topics

Associated discussion

Completed Phase 0: Conducted a virtual conference with HQ USCG Project Champion, USCG Stakeholders and USCG technology developers.

Alaska and Arctic Maritime Communications and Connectivity Analysis Project Investigators held the project virtual conference and project kickoff meeting on 2 February 2021. The meeting was attended by the Project Champion and included representatives from DHS S&T OUP, USCG 5PW, CG-761, CG-926, D17; Sandia National Labs, Arctic Slope Regional Corporation (ASRC) Federal Mission Solutions, Alaska Chadux Corporation, Marine Exchange of Alaska, Ukpeaġvik Iñupiat Corporation, Alaska Ocean Cluster, National Oceanic and Atmospheric Administration, and Alaska Ocean Observing System.

Completed Phase 1: Conducted a Comprehensive literature review.

ADAC Student Fellows Rachel Lewis and Tristan Goers completed the first draft of the literature review. AAMC&CA Project Investigators edited the document and sent onward to Sandia National Labs and Arctic Slope Regional Corporation (ASRC) Federal Mission Solutions for further content additions. The AAMC&CA literature review can be found at:

https://arcticdomainawarenesscenter.org/P30_AAMCCA Note: The Literature Review is intended as a project working document designed to be periodically updated as needed throughout subsequent phases of the project.

Completed Phase 2: Forming of project Core Advisory Team. Associated with project initiation, the Project Investigator organized a kickoff meeting with HQ USCG designated Project Champion and “Core Team,” which serves to steer the project in subsequent phases.

The Project Core Team was formed, and the first meeting held on 22 February 2021. The Core Team includes representatives from Sandia National Labs, Arctic Slope Regional Corporation (ASRC) Federal Mission Solutions, Alaska Chadux Corporation, Marine Exchange of Alaska, Ukpeaġvik Iñupiat Corporation, Alaska Ocean Cluster, National Oceanic and Atmospheric Administration, and Alaska Ocean Observing System. The Core Team has held 6 subsequent meetings (as of 12 July) and continues to meet on a monthly basis, providing guidance and direction to the Project Investigators.

Completed Phase 3: Engaging the Community”: conducted virtual Meetings across the communities of interest. The principal effort of this phase is to determine communications and connectivity needs via Virtual Meetings of the Core Team and Key Stakeholders.

The Project Team conducted five “Engaging the Community” virtual meetings in each region beginning 29 March ending on 25 June 2021, completing a total of 30 meetings. Meetings were planned for 90 mins and were supported by AAMC&CA Project partners including Sandia National Labs, Arctic Slope Regional Corporation (ASRC) Federal Mission Solutions, Alaska Chadux

Corporation, Marine Exchange of Alaska, Ukpeaġvik Iñupiat Corporation, Alaska Ocean Cluster, National Oceanic and Atmospheric Administration, and the National Weather Service.

The following are associated details:

Region 1: Southeast Alaska.

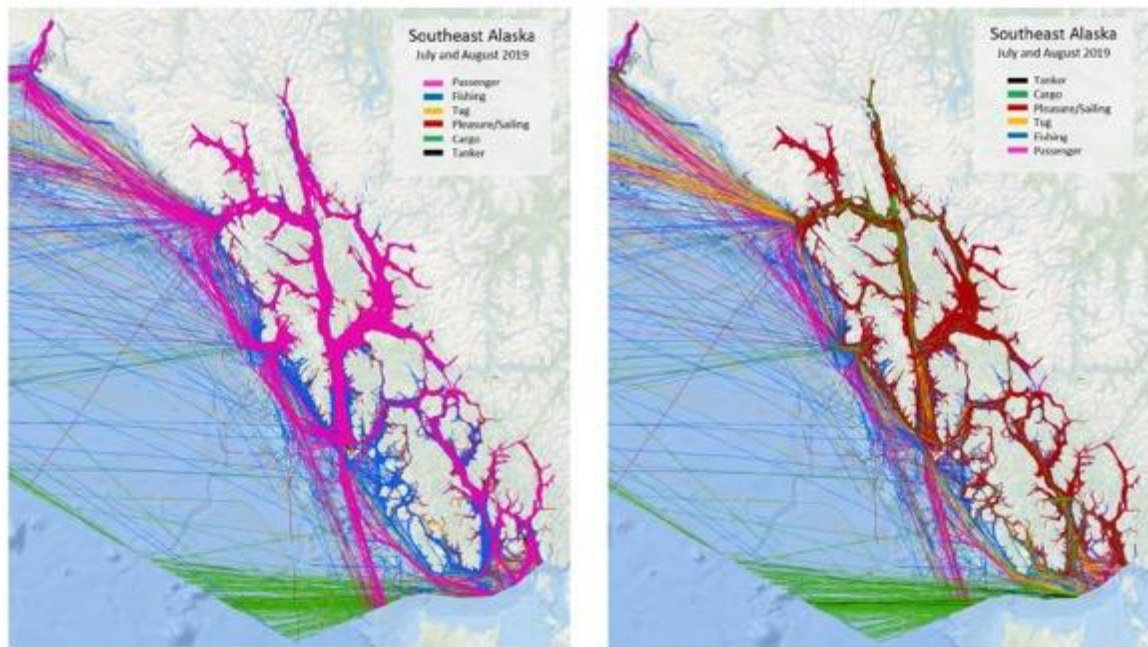


Figure 34: Southeast Region vessel traffic, courtesy Marine Exchange of Alaska

Southeast Alaska Region vessel traffic is characterized by:

- Frequent Large passenger vessel and Cruise Ship traffic during summer months
- A large amount of small fishing vessels
- Regular tug and barge traffic
- A large amount of recreational vessel traffic

Southeast Alaska Region communications challenges are characterized by:

- Small fishing vessels and recreational vessels that frequently transit VHF dead zones
- VHF RFF/Site outages
- VHF is most widely used communications method followed by cell phones
- Satellites/Satellite communications blocked/disrupted by mountainous terrain
- Unreliable Satellite speed of service
- Sat phones and HF used only on larger vessels

Region 2: Southcentral Alaska (extending from Cordova to Kodiak, including Prince William Sound and Cook Inlet).

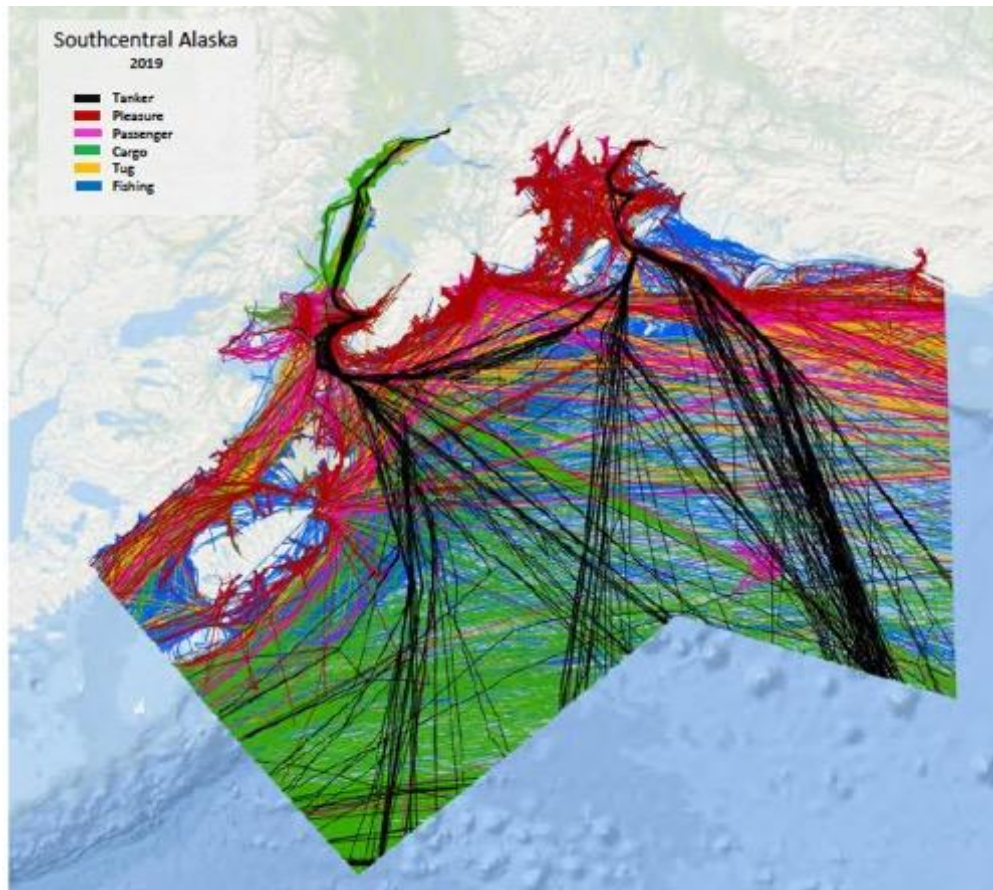


Figure 35: Southcentral Alaska Region vessel traffic, courtesy Marine Exchange of Alaska

Southcentral Alaska Region vessel traffic is characterized by:

- Some Large passenger vessel and Cruise Ship traffic during summer months
- A large amount of small fishing vessels
- Regular tug and barge traffic
- A large amount of recreational vessel traffic
- Tanker traffic into Valdez and Cook Inlet

Southcentral Alaska Region communications challenges are characterized by:

- Small fishing vessels and recreational vessels that frequently transit VHF dead zones
- VHF outages
- VHF is most widely used communications method followed by cell phones
- Satellites/Satellite communications blocked/disrupted by mountainous terrain
- Unreliable Satellite speed of service
- Sat phones and HF used only on larger vessels
- Several large weather forecast regions with differing conditions, i.e., PWS and Shelikof Strait
- Glacial Fog and narrow waterways

Region 3: Alaska Peninsula and Aleutian Islands.

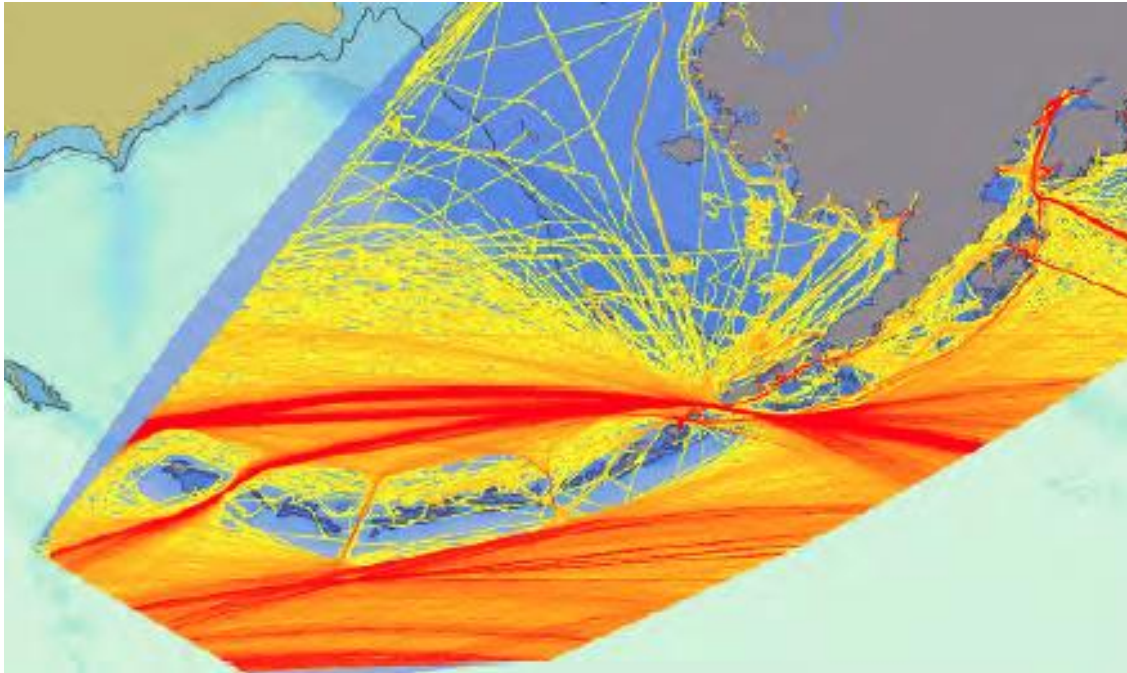


Figure 36: Alaska Peninsula and Aleutian Islands vessel traffic, courtesy Marine Exchange of Alaska

Alaska Peninsula and Aleutian Islands Region vessel traffic is characterized by:

- High volume of foreign deep-draft vessel traffic
- Large Fishing vessels
- Very few passenger vessels and recreational vessels

Alaska Peninsula and Aleutian Islands Region communications challenges are characterized by:

- Almost no VHF infrastructure
- Very remote region with great distances
- Most vessels utilize HF, Satellite Communications, and AIS
- Vessel contact difficult via Sat phone
- AIS monitoring of foreign vessel traffic labor-intensive
- Frequent severe weather
- Need for greater fidelity with air temperature in marine broadcasts to assist with mitigating icing

Region 4: Bering Sea (extending from Bristol Bay Northward to Bering Straits, to include Norton Sound).

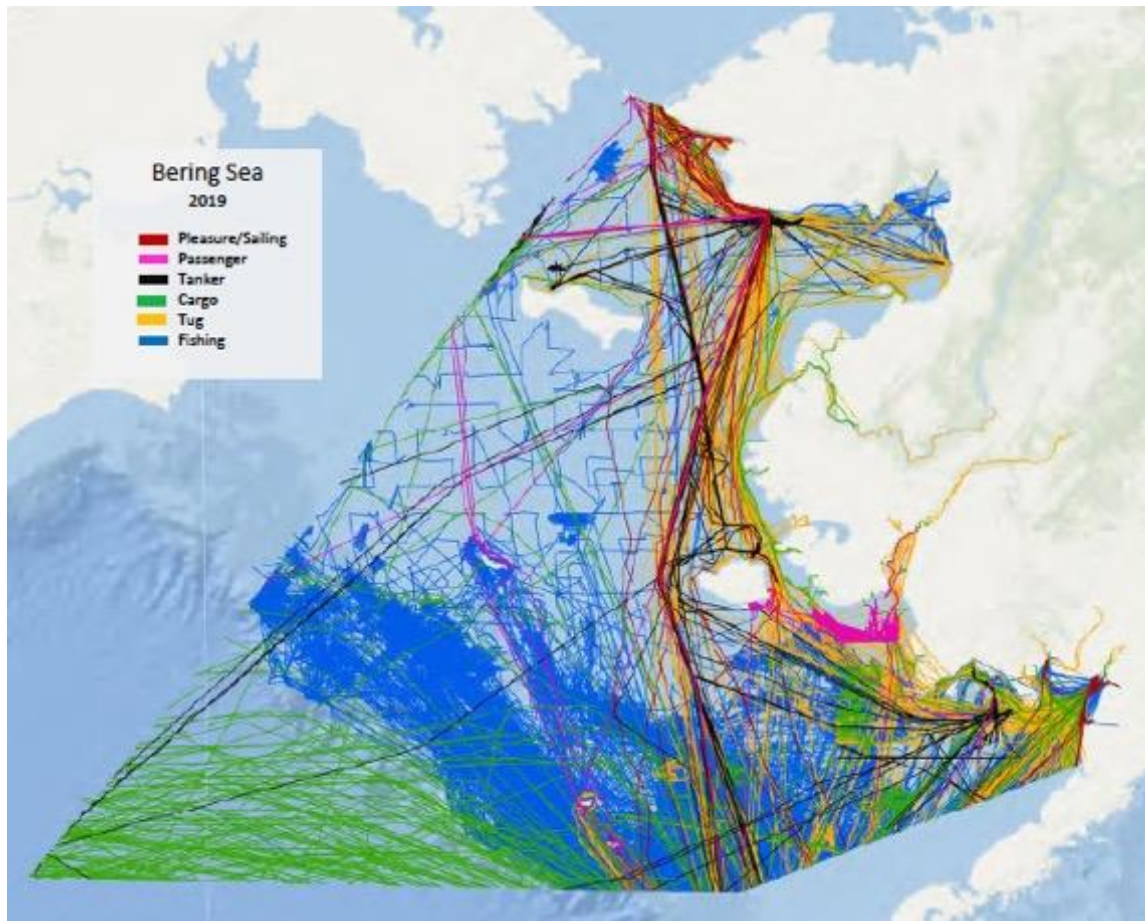


Figure 37: Bering Sea Region vessel traffic, courtesy Marine Exchange of Alaska

Bering Sea Region vessel traffic characterized by:

- Large volume of large fishing vessels
- Large volume of small fishing vessels near shore
- Moderate amount of tank vessels
- Moderate amount of tugs
- Small recreational vessels traveling great distances offshore

Bering Sea Region communications challenges are characterized by:

- Only one USCG VHF site (Tuklung Mountain)
- Congested waterways in southern and northern parts of the region
- Bering strait is a narrow international waterway with safety concerns
- No VHF weather broadcasts in northern Bering Sea
- Need for greater fidelity with air temperature in marine broadcasts to assist with mitigating icing
- Mariners with satellite service now use WhatsApp

Region 5: Chukchi Sea.

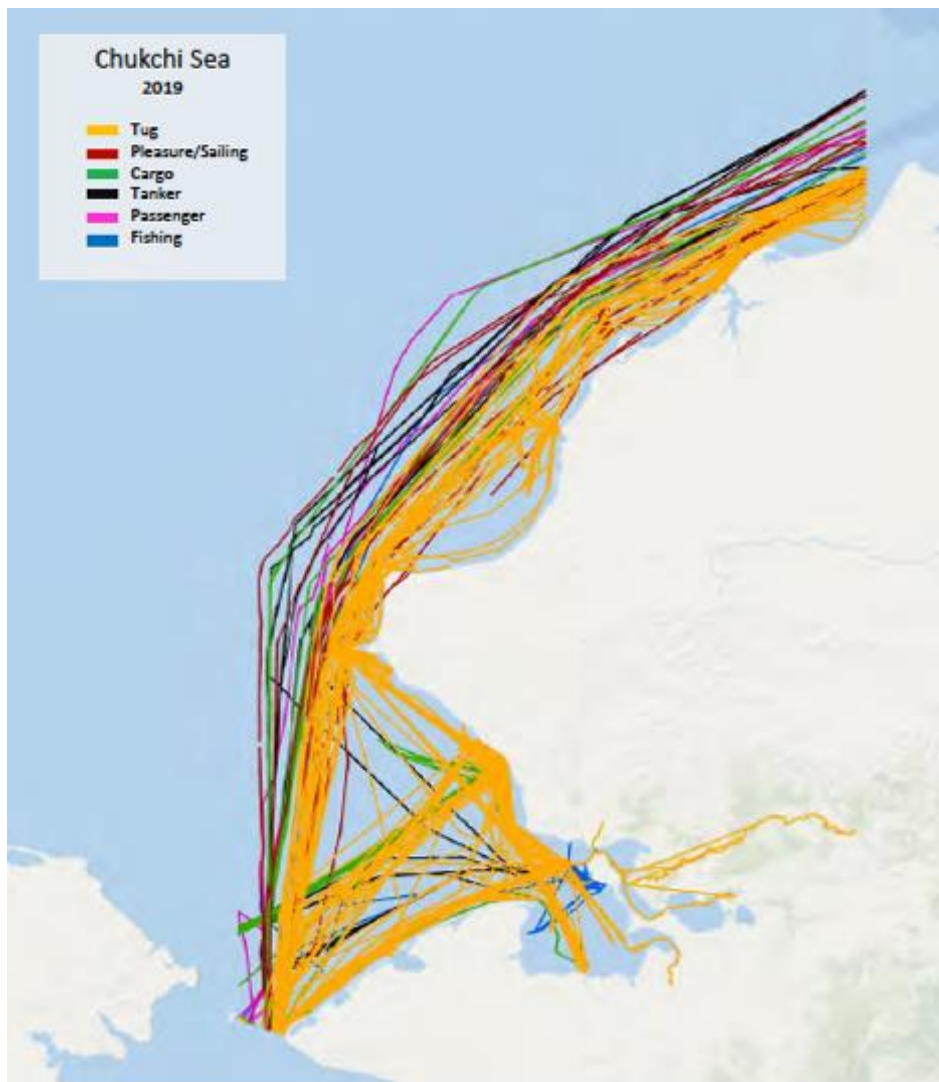


Figure 38: Chukchi Sea Region vessel traffic, courtesy Marine Exchange of Alaska

Chukchi Sea Region vessel traffic is characterized by:

- Most vessels transit near to shore
- Moderate amount of Tug traffic
- Small subsistence and recreational vessels travel great distances from shore

Chukchi Sea Region communications challenges are characterized by:

- No USCG VHF site
- Congested waterways in southern part of the region
- No VHF weather broadcasts
- VHF becomes a ‘party line’ during subsistence activities
- NWS has need for weather observations

Region 6: Beaufort Sea.

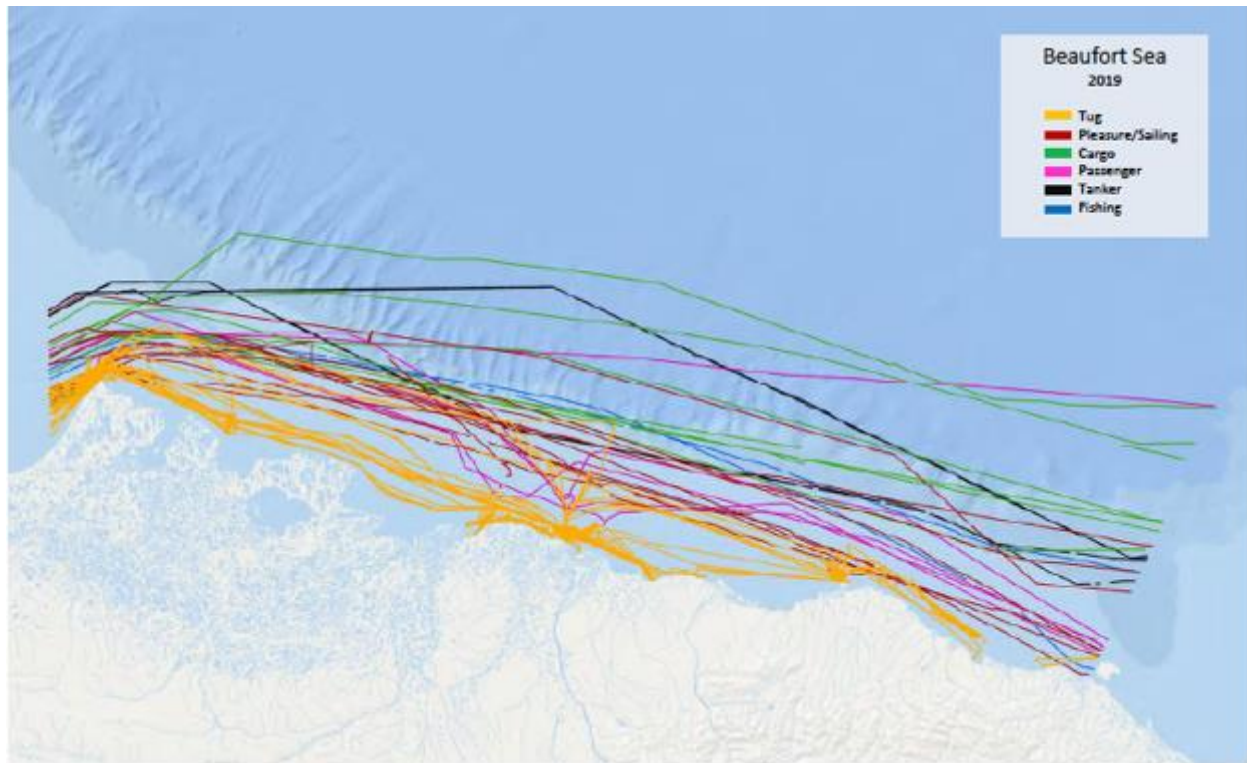


Figure 39: Beaufort Sea Region vessel traffic, courtesy Marine Exchange of Alaska

Beaufort Sea Region vessel traffic is characterized by:

- Moderate amount of Tug traffic
- Small subsistence and recreational vessels travel great distances from shore

Beaufort Sea Region communications challenges are characterized by:

- No USCG VHF site
- No VHF weather broadcasts
- VHF becomes a 'party line' during subsistence activities
- NWS has need for weather observations

Initiated Phase 4: Established virtual Working Groups. The principal task in this phase is forming and providing onward investigations via Alaskan and Arctic Maritime Connectivity Virtual Working Groups.

Working Groups include the following topics:

- Arctic Working Group
- Non-Arctic Working Group

Initiated Phase 5: Conducting a virtual (or hybrid) assessment. The principal task in this phase is planning and conducting an Alaskan and Arctic Maritime Communications and Connectivity Analysis Three-Part Virtual (or hybrid) Assessment.

Student Involvement:

Two ADAC Fellows worked on this project: They completed the following activities in Program Year 7:

- ADAC Fellows Rachel Lewis and Tristan Goers, University of Alaska Anchorage, UAA. They developed the first draft of the literature review.

Key Stakeholder Engagement:

The Project team engaged with the designated Project Champion as determined by Project Champion feedback, but as a minimum the team sought to conduct monthly teleconferences. Critical coordination continued with all team members, the Investigator, and project champion. Key project stakeholders include rural Alaska mariners, subsistence mariners, commercial and private industry mariners, HQ USCG CG-5PW, CG-926, CG-7 offices, USCG PACAREA and LANTAREA, and USCG D17, D17 Sector Anchorage and the USCG R&D Center.

Project Investigators represented our team at the following ADAC events:

1. Meetings with Project Champion.
2. Weekly All Hands meeting (Normally Thursdays, 1130-1230 Alaska Time via teleconference).
3. Quarterly Reviews and Quarterly Customer's and Partner's Roundtable.
4. Annual meeting with HQ USCG, Washington D.C. (Program Year 7 held virtually)

Key Publications (peer reviewed):

N/A.

Key Presentations:

Project team presented at ADAC Program Year 7 Annual Meeting. The Annual Meeting was held virtually via Zoom as COVID-19 prevented an in-person gathering in Washington D.C. as in previous program years. The meeting was well attended drawing a total of 204 registrations for the 2-day virtual event. DHS S&T Leadership, USCG HQ Leadership, NWS Leadership, DHS S&T OUP, HQ USCG ADAC Project Champions, ADAC Executive Counselors, and many other customers and partners participated ADAC's Year 7 Annual Meeting.

Changes from initially approved Workplan:

N/A

Project progress against each milestone:

Table 25: AAMC&CA Project Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
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<u>Phase 0</u> : Conduct a virtual conference and kickoff meeting with HQ USCG Project Champion and USCG Project Stakeholders	Completed	N/A
<u>Phase 1</u> : <u>Conducting a Comprehensive literature review</u>	Completed	N/A
<u>Phase 2</u> : Forming the Core Advisory Team	Completed	N/A
Continue monthly Core Team meetings throughout project.	Incomplete	Core Team meetings ongoing, monthly meetings have continued as scheduled.

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
<u>Phase 3</u> : Engaging the Community” conducting virtual meetings across the communities of interest	Completed	N/A
Phase 4: Establishing virtual Working Groups	Incomplete	Working Groups have been established and the date of the first meetings have been set. *Working groups delayed due to additional Phase 3 meetings.
Continue Working group meetings	Incomplete	Working Group meetings to continue throughout all project phases.
<u>Phase 5</u> : Conducting a virtual assessment	Incomplete	Planning for virtual assessment in progress. Project Team will offer select stakeholders the option to attend a hybrid in-person / virtual event. *Virtual assessment delayed due to additional Phase 3 meetings.

Project progress against each metric:

Table 26: AAMC&CA Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Is the project on time, based on the schedule set forth in the detailed work plan established between ADAC, the Core Team, and the Project PI?	Completed (for Phases 1, 2, and 3.)	N/A
Is the project at, or under, cost based on the budget established by ADAC and Project PI?	Completed (for Phases 1, 2, and 3.)	N/A
Are resources (e.g., references, workshop/working group participants) being gathered/recruited in sufficient numbers for the project tasks?	Incomplete	Project team will continue to build a comprehensive assessment of communications and connectivity gaps and shortfalls through continued engagements with Alaskan and Arctic maritime professionals.
Is the scope of the project adequate or does it need to change to meet unforeseen components oriented on current and emerging maritime communications suitable for Alaskan and U.S. Arctic maritime regions?	Completed	Completed during reporting period. However, this will need to be continuously evaluated during the project.
Is the quality of the project products acceptable to the Project Champion/Core Team/ADAC? Are the products useful to USCG maritime operators?	Completed	Will be continuously evaluated by Core Team and Project Champion.

Outcomes/output and TRLs:

Outcomes.

Project outcomes from a culmination of engaging the community meetings, Core Team discussions, and Project Champion input include summarizing vessel traffic throughout the six regions identified in the project workplan, identifying the two regions with the greatest disparity between communications and connectivity infrastructure (Arctic and Non-Arctic), and understanding many of the innovative methods mariners use to address their communications and connectivity needs more accurately.

Output:

Completed project outputs include the AAMC&CA literature review and the AAMC&CA regionally focused vessels traffic breakdown (provided courtesy of the Marine Exchange of Alaska). Project outputs-in-progress include a communications and connectivity technology and maritime requirements matrix and an Alaskan and Arctic communications and connectivity user story chart series.

Technology Readiness Level (TRL):

N/A.

Unanticipated problems and plans for addressing them:

Phase 3 Engaging the community meetings received less-than-anticipated participation from various segments of the maritime community leading to a less-than-comprehensive reporting of regionally oriented communications and connectivity gaps and shortfalls. The Project team addressed the participation gaps by adding two additional engaging the community meetings to the schedule, coordinating with stakeholders to conduct one-on-one interviews with maritime professionals scheduled directly through Calendly, and to continue interviews and meetings throughout the first and second quarters of Program Year 8.

Transition Activities:

Transition plans and progress made: None undertaken in Program Year 7. Not applicable to reports during Project Year 7 because the project will not conclude until Year 8. Principal transition plan is to create a research knowledge product to support USCG led communications and connectivity modernization efforts.

THEME 3: Maritime Technology Research:

1. Propeller Driven Long Range Autonomous Underwater Vehicle (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards (Continuation Project).
2. Arctic-related Incidents of National Significance (Arctic IoNS) Workshop.
3. Arctic Medium and Long Term Environment (Arctic MaLTE) Workshop.

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

Project Investigators: Ms. Amy Kukulya, Dr. Jim Bellingham (WHOI), Mr. Brett Hobson (MBARI)

Lead Institutions: Woods Hole Oceanographic Institution (WHOI) and Monterey Bay Aquarium Research Institution (MBARI)

Supporting Team: Brian Kieft, Ben Raanan (MBARI), Daniel Gomez-Ibanez, Noa Yoder, Amanda Besaw, Ryan Govostes, Steven Seeberger, (WHOI),

Project Champion: CAPT Kirsten Trego, HQ USCG MER



Figure 40: Polaris flying through the air from a USCG Jayhawk Helicopter in Cape Cod. Figure 2. Polaris being readied for a Helicopter pick and launch into Buzzard's Bay, Cape Cod on 15 April 2021.

Project Description:

Abstract:

The Propeller Driven LRAUV System is a proven helicopter-portable platform, with corresponding communications buoys which functions as a multi-mission capable system in open ocean or under-ice. Through designing, fabricating and testing two platforms, two sets of sensing capabilities and three communication and navigation buoys, the LRAUV project team is providing a suitable deployment package to support USCG-led Arctic oil spill response and associated incidents of national significance (IONS). In sum, the ADAC LRAUV project, led by WHOI and MBARI, creates a rapid response solution to incidents occurring in the maritime environment, and increases situational awareness by characterizing the undersea and under-ice conditions of ocean surroundings, autonomously, and capable at great distances from first responders in an Arctic maritime crisis.

Increasing level of commercial marine activity in high latitudes creates an ever-growing risk of oil spills in ice laden waters. Characterizing oil spills in remote and austere Arctic locations is a daunting challenge to the U.S. Coast Guard. Through 7 years of focused research and engineering, the LRAUV team at WHOI and MBARI have taken the original baseline Tethys Autonomous Underwater Vehicle (AUV), created by a team at MBARI ten years ago, through a significant re-design effort, and have developed and fabricated a specialized portable long-range Arctic-capable Tethys platform equipped with oil sensors, new software and navigation systems.

Through seven years of investigations, in addition to creating (1) an under-ice capable LRAUV, the project team has (2) provided demonstrations of the LRAUV survey capability, (3) created a simulator

for establishing Standard Operating Procedures (SOP) related to AUV oil spill deployments, (4) designed and created three communications and navigation agnostic Arctic buoys, (5) designed and fabricated exchangeable nose sections with communications and homing capabilities and a mechanical retrieval and docking capability for ease of shipborne handling and recovery as well as docking for extended periods of time to extend mission duration, (6) completed a review of a reduced cost design for USCG leveraging additive manufacturing; (7) demonstrated LRAUV system in extensive open water tests in real world oil seeps in Santa Barbara Channel California (8) tested LRAUV in fresh water under ice in northern New England (9) demonstrated helicopter portability through a USCG Jayhawk helicopter demonstration (10) Exercised over-the-horizon missions out to the continental shelf (11) Ran 11+ day science mission testing new anomaly detection and front tracking capabilities (12) filed a provisional patent on the technology and capability (13) developed a backseat CPU capability for sensor and behavior development at WHOI and beyond (open-architecture) (14) developed drivers for inertial navigation and Norbit multibeam integration on a newly implemented ROS backseat (15) Completed redesign and testing of a new, more rugged antenna for open ocean and under-ice and (16) 65% through building a the second LRAUV platform, Stella.

Objective/Purpose:

Complete a seventh year of investigations in research and engineering on the LRAUV System to provide DHS S&T and USCG a world class system for high latitude spill response and marine environment characterization. Accordingly, project team advance LRAUV capability for DHS S&T OUP and USCG through additional research and technical development program to (1) advance HQ USCG Project Champion designated USCG technical abilities in operating and testing the platform, (2) seek to further reduced cost fabrication by constructing an additional LRAUV (spanned over Program Year 6 and 7), (3) conduct Arctic tests (4) design and fabricate an additional sensor capability to LRAUV in order to create a multi-mission capable LRAUV, and (5) create a knowledge product outlining various scenarios and approaches to conduct an LRAUV deployment, and (6) further mature software capabilities including autonomy and simulation devices. In parallel to technical development to deliver the LRAUV System to support USCG, ADAC and research team will conduct investigations for commercialization of the System with industry. The research team's principal objective was to develop a Long Range Autonomous Underwater Vehicle (AUV) system, which included adapting, testing and orienting USCG mission operators and stakeholders to a Tethys AUV platform specifically modified for long range under ice operations capabilities to observe and sample dynamic processes in the Arctic Ocean. In addition to the platform, researchers have designed and developed a deployable communication buoy system that supports near real time transmission of oil spills via data such as heat maps and other environmental hazards under ice as characterized by LRAUV. Further, in order to support additional capability for Arctic maritime environmental response, investigators advanced developmental activities that create greater precision in characterizing environmental responses via integration of multi-beam sonar and INS and a backseat processor for rapid integration and development of new sensors and algorithms.

Methodology:

The research team employed a task-oriented team of expert oceanographic mechanical, software and electrical engineers and operators to advance further capability in the creation of a readily deployable, easily handled, variable speed, and long range AUV capable of detecting and mapping oil spills under ice and in open water. The team leverages prior investments in AUV research and oil sensor technology, and under-ice operations. The research method used in Program Year 7 included four pillars of coordinated activities. 1) Technical development, 2) advanced testing, 3) completion of low-cost manufacturing studies) 4) documentation of engineering designs and tests. A fifth task for Year 7, Systems familiarization for the HQ USCG Program Champion designated USCG POCs was delayed due to COVID19.

A critical component of ADAC Program Year 7 LRAUV System research method was to leverage mechanical and electrical engineering advances made over the previous 6 years to complete technical development of the second LRAUV platform, synchronize development specifications in platform hardware and software, incorporating testing data from open water and under ice to finalize the development of two platforms and three Arctic communication buoys. In addition to these advances of engineering and technical development, LRAUV System team prepared for advanced tests under ice and at high latitudes to evaluate and validate LRAUV System capabilities in sensors, navigation, and chemical mapping, while advancing reduced cost manufacture.

In Program Year 7, the ADAC LRAUV project entered into a critical push to Arctic demonstration of the full suite of capabilities required for oil spill response. Since this project has a series of ‘Arctic firsts,’ the effort is structured in a “test-evaluate-address” (a modification of the “spiral development” approach conducted in the Department of Defense) cycle. Field programs conducted in Year 7 pushed the envelope of discrete capabilities (logistics, homing, docking, navigation, sensing, software etc.) necessary to identify strategies for improving system performance and reliability. In parallel with this evolution, the hand-off of LRAUV operations from MBARI to WHOI provided the groundwork for the goal in providing USCG an available technical support entity capable to provide USCG on-call support as USCG determines suitable for LRAUV as an operational system. Accordingly, in program Year 7, LRAUV investigators advanced competency in AUV oil response and mission capabilities for long range AUV platforms. The LRAUV team has accordingly completed successful testing and training of LRAUV during four expeditions in addition to advancing improvements to platform #1, *Polaris*, and conducted significant fabrication for Platform #2 (Stella). Transition of LRAUV to WHOI, with project funding from ADAC, allowed the project team to build the technical competency of the platform for under-ice capabilities, while enabling the team to lead operations and prepare to train USCG operators and first responders/scientists to access cutting edge technology in a time of crisis, as well as for multi-mission environmental response capabilities by completing the following: building a second platform; developing new behaviors and sensor capabilities for oil research and mapping objectives; develop an efficient manufacturing workflow for follow-on platforms; conduct open ocean and under-ice testing for mission development, reliability, training and transition.

This report details the in-water testing conducted on *Polaris* and the Arctic buoy system as well as the development of a second platform and its new capabilities.

Key Accomplishments:

In ADAC Program Year 7, the LRAUV System team's research agenda was focused on fabrication tasks associated with completing the second platform, development of additional software for improved operator-system interface and backseat development, conducting investigations of detailed testing to ensure the platform and communication systems perform in accordance with technical specifications, and expanded under-ice tests to evaluate LRAUV System's performance in cold air/water environments similar to the Arctic. The research agenda also included advancing manufacturing of LRAUV, producing testing documentation and familiarization of USCG personnel and furthering WHOI operators to expand the project into a Center of Expertise for USCG in LRAUV System operations in accordance Project Champion direction.

The research team have completed ten local *Polaris*'s deployments between Woods Hole and the New England shelf break since 1 July 2020. An emphasis has been placed on operator training, with virtual support from the MBARI based operator/engineering team to assist us with upgrades, development and implementation of under-ice docking/undocking behaviors, underwater communication using the hybrid Arctic buoy system, long-baseline navigation testing, backseat autonomy integration with ROS (Robot Operating System) for more rapid development of new sensors and behaviors including oil plume tracking, multibeam and inertial navigation capabilities for mapping the seafloor and under-ice features as well as testing of newly updated front tracking capabilities.

Additionally, the second platform, *Stella*, is 65% complete with the second phase of its completion starting with the electrical systems still underway. Several missions were conducted for *Polaris* to exercise its over-the-horizon utility to scientists and stakeholders by launching the vehicle from Woods Hole and commanding it to swim to the shelf break to conduct environmental sampling missions typically done from a ship on station. With these efforts, the team strengthened its ability to transition the capability for rapid response of environmental hazards to the USCG and other stakeholders. Additionally, the team engaged in outreach and collaboration with local USCG in New England. This partnership can enable a fast track to transition as well as help meet our goals of helicopter launch and recovery and USCG operator training anticipated for this project. The team successfully completed a helicopter demonstration showing the ease of picking up LRAUV from land and deploying it as sea where it was dropped and continued on a mission without incident.

Several more local tests were conducted to advance our navigation and communication systems including two buoys for the beginning of LBL testing and a long-range acoustic test. A series of multi-day missions were run over program year 7 to test and evaluate docking/undocking as well as many of the new (~20) missions that have been developed under the ADAC project. All missions further our transition efforts to make the LRAUV platform and its systems ready for rapid deployment to assist in incidents of national significance in open water or under-ice.

Specifically, the team worked extensively on system testing of the base platform with a focus on developing user-friendly capabilities for planning, testing, mission development, and furthering navigation capabilities for mapping (LBL) and docking/homing (USBL) in local Cape Cod waters. Additionally, the team procured and is integrating a Norbit multibeam for acoustic detection of oil and gas droplets in an open water and under-ice environment as well as mapping applications. The team worked to develop user friendly software interfaces as well as a 'backseat' capability for

autonomy software development needed for new mission behaviors and sensor integration. The team is developing a software simulator in order to be able to ‘simulate’ missions of LRAUV using the entirety of the system payload as well as real world environmental models (introducing ice models, wind, currents, etc.). This software simulation is also supported by outside funding led by MBARI in order to advance its implementation more rapidly across the LRAUV fleet.

In follow-up to the successful design and engineering accomplishments of the project, in project year 7, ADAC and LRAUV project team continued an additional research and engineering program to (1) advanced collaboration and partnering with the HQ USCG Project Champion designated USCG designated POCs in operating and testing the platform as well as in local districts in New England, (2) work to further and simplify fabrication of an additional LRAUV (spanned over Program Year 6-8), (3) conduct Arctic-readiness tests in local Cape Cod waters, (4) designed and fabricated an additional sensor capability to LRAUV in order to create a multi-mission capable LRAUV including a multibeam and inertial navigation system.

As of 30 June 2021, The LRAUV project team has provided the USCG the foundation for a state-of-the-art capability in long-range Arctic oil spill detection and characterization via an easy deployable package (land, air or sea deployable), advanced Project Champion designated USCG POC AUV competency, created additional LRAUV mission capability to add multiple facets of marine environmental characterization, and conducted platform testing in cold weather New England conditions to ensure USCG is provided a suitably evaluated LRAUV System. ADAC and the Project team were not able to test the system under extensive ice or in high latitude conditions due to limitations in travel related to COVID-19 [KF20]. [MOU21]

In parallel to technical development to deliver the LRAUV System to support USCG, ADAC and the research team is conducting investigations for commercialization of the System with industry.

Specific project advances (in summary) for Program Year 7”

- Tested and demonstrated the LRAUV System’s ability to navigate relative to a three- buoy/transponder gateway system using USBL. The vehicle can dock and undock itself with improved gains and newly intergraded reverse thrust
- Integrated a more advanced docking algorithm that increased our docking rate. Next steps are to run docking/undocking sequences for several days to obtain successful percentage of docking.
- Integrated more advanced scientific sensors (Seabird CTD with integrated DO).
- Polaris’s navigation and communications system testing are complete.
- Data from all missions has been evaluated and data is archived with operator notes.
- Ran freezer tests on whisker box to complete Arctic readiness tests with the docking nose.
- Technical competency of the base LRAUV vehicle at WHOI is complete. New capabilities and sensors are being developed and outreach of its capabilities is underway with USCG and the oil spill response community. [MOU22]

- Picked and launched Polaris from a USCG Jayhawk helicopter in Woods Hole (April 2021).
- WHOI is fabricating a second platform, Stella with multi-mission capability and can operate and develop and manufacture LRAUV in house at WHOI which is 65% complete.
- Added a new bulkhead (9th) connector for an additional sensor (multibeam).
- Added backseat CPU for easier software and sensor development.
- Redesigned the antenna. Tall for open ocean and stubby for under-ice and fully tested.
- Completed a successful mission from shore to the shelf and back home (without a ship). We completed a 265 km mission with 8 days of battery left in the tank.
- Provisional Patent filed, Title: Device and system for performing measurements under ice-covered water.
- Completed mechanic and electrical design of new mapping payload. System is currently being assembled for testing.
- Developed plume tracking algorithm (to be tested in Program Year 8).
- Developed onboard simulation mission for plume tracking testing.
- Built second docking nose module with upgraded cold weather gear box.
- Developed modular nose configurations (Docking, Mapping, Short-Science).
- Developed new, lighter helicopter lifting bails.



Figure 41: a two pick, lighter lifting bail system was developed for the helicopter demonstration.

- Developed >20 new software behaviors for docking, undocking, no surfacing, new sensor configurations, etc.

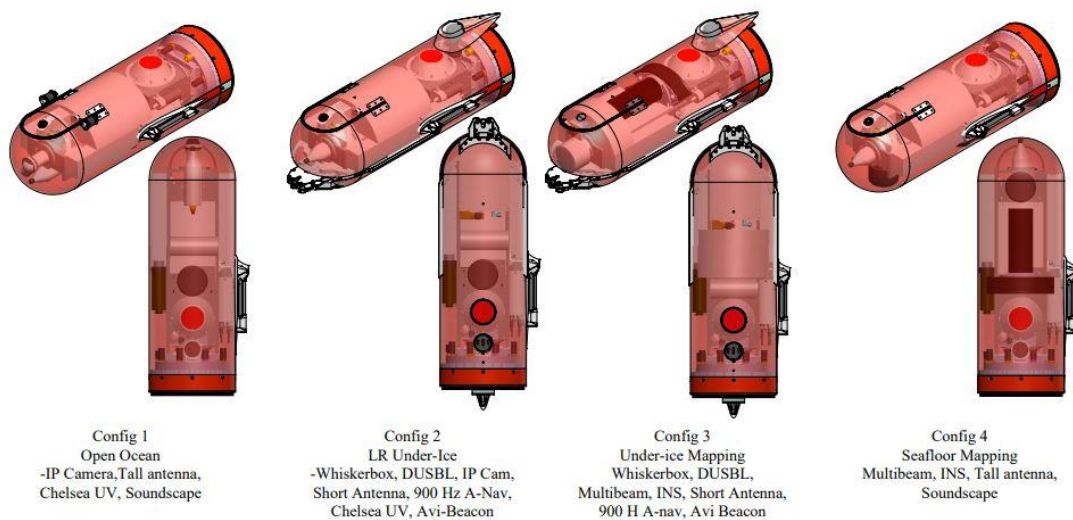


Figure 42: shows four nose configurations for the Polaris and Stella vehicles

1. Open water science standard sensors, tall antenna, Chelsea UV, Soundscape
2. LR under-ice with Whisker box, DUSBL, short antenna, Chelsea UV, Avi-beacon with room for camera, 900 Hz A-Nav
3. Under-ice mapping, Whisker box, DUSBL, Multibeam, INS, short antenna, 900 Hz A-Nav, Avi Beacon
4. Seafloor mapping, Multibeam, INS, tall antenna, soundscape

Details on System Evaluation and Fabrication: Creating LRAUV Platform #2: “Stella.” The WHOI/MBARI team conducted a full system evaluation, inclusive of auxiliary gear and buoys, in order to review low cost manufacturing and design improvements for Build-2 and future builds in YR6 and implemented changes in YR7 to the platforms. The team has continued to use PDM tools consisting of Autodesk Vault, Basecamp, Slack and WHOI Roundabout for tracking current and future inventory and allowing time and cost savings for Build-2 ordering and manufacturing. Autodesk Vault enables revision control on drawings and documentation related to the build. With these tools in place, WHOI has all mechanical drawings as well as ordering information for the entire LRAUV platform in a secure and controlled environment as well as a BoM template for tracking current and future builds. Build instructions were drafted in year 6 and that effort continued through Y7 to make manufacturing of LRAUV a more efficient and economical endeavor.

All vehicle parts [MOU23] for the Stella platform were ordered and organized in the WHOI Scibotics lab in bins labeled per assembly. Through Year 7, the team worked diligently documenting how to build up [MOU24] the platform with photos, diagrams, drawings and notes/instructions all captured and secured in Basecamp.

The team at WHOI worked on updating the electrical drawing package and is an ongoing effort that will continue into program Y8. This effort is a slow and methodical hands-on evaluation of the current vehicle [MOU25] [MOU26], Polaris, with applications for Stella, and a learn as you go effort in order to update

[KF27] project materials provided by MBARI. We are also working to make the vehicle more modular (inside and out) so we can move around payloads such as the sonar more efficiently.

Low Cost Vehicle Evaluation: Low cost evaluation has been an ongoing part of the LRAUV build to identify what items can be 3D printed versus machined. In theory, 3D printing provides quicker and less expensive fabrication. In Program YR6, parts were identified that are currently machined, but could possibly be 3D printed without redesign, based on the following criteria:

- Currently made in plastic
- No sealing features
- Not strength-limited

If printed, these parts may cost as little as a quarter of their current cost, which would represent a roughly 3% reduction of the core vehicle cost (not inclusive of auxiliary equipment, sensors, etc. costs).

For example [MOU28], there is a single machined part that was designed to protect the ends of the pressure hull when not installed on the vehicle, designated as [MOU29] “Tube Protectors.” Just eliminating this part and taping a cardboard or rubber mat over the end of the tube would save \$1000 per vehicle. In Y7, the WHOI team used 3D printing to make up the majority of new bracketry associated with the inertial navigation system and multibeam integration.

Additional Accomplishments:

- The team achieved successful underwater docking and undocking to a transponder during testing in Woods Hole.
- The team conducted a shipless operation ‘over-the-horizon’ mission from Woods Hole to the shelf break and back. The vehicle was able to navigate back using a cookie crumb waypoint driven mission in order to avoid small islands, shoals and rock piles.
- Added a new bulkhead (9th) connector for another sensor add-on (multibeam sonar).
- Ran a 440 km mission with new front tracking software tracking salt intrusions up the shelf break. Showed reliability of LRAUV as an autonomous adaptive sampling vehicle.
- We modified one of three buoys for optimal docking and have a kit to change buoys frequencies between high and low depending on mission objectives
- Team built relationships with New England USCG and performed a successful Jayhawk pick and launch demonstration. Polaris was dropped from 5 feet and ran a successful mission.
- Stella, platform 2 is 65% complete
- Developed drivers and backseat capability for inertial navigation and multibeam sensors
- Further developed PDM tools and procedures for LRAUV Build-2 using Vault, Basecamp and WHOI Roundabout. Released all mechanical drawings

- Began created models of the vehicles and systems to make future designs easier to modify
- Continued to evaluate end of life parts and LRAUV system for improvements and manufacturing.
- Internal battery charger system was redesigned to be more efficient and also increases battery capacity. A new, more robust antenna design was completed, and five new antennas were built and tested.
- Backseat computer for more versatile control of sensor integration/new behaviors was implemented. Integration on Polaris and Stella is complete. ROS development underway and continues into YR8
- CTD and DO sensors were updated on Polaris and Stella with new bracketry and less power draw.
- Multibeam was integrated on the backseat. Next steps are water testing.[MOU30]
- Created operator/mission documentation and checklists available through the Dash
- Filed a patent, Title: Device and system for performing measurements under ice-covered water.[MOU31]
- Built a vehicle in a box (Proxima) for rapid software and system/sensor testing
- Updated Plume tracking algorithm
- Developed onboard simulation mission for oil spill testing
- Developed four different nose configurations (mapping, docking, under-ice and slow science)
- Further developed WHOI operational DASH for operating LRAUV from inside WHOI
<https://lrauv.whoi.edu/#/>



Figure 43: A USCG Jayhawk lands in Woods Hole to pick up the Polaris LRAUV and conduct a demonstration to allow for launch and recovery from a helicopter, April 15, 2021

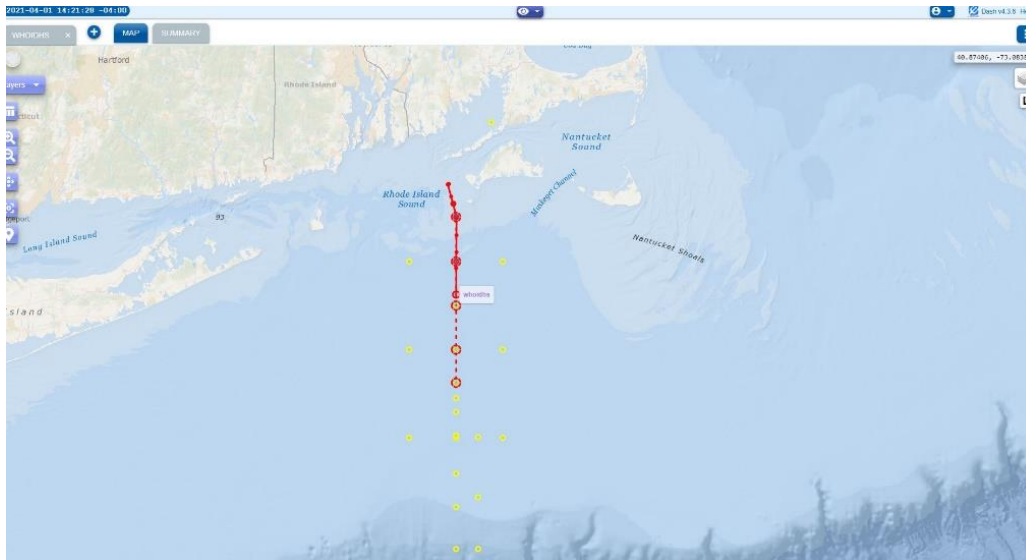


Figure 44: cookie crumb trail of waypoints that Polaris traveled from Woods Hole out to the long-term ecological research area that crosses the shelf break.

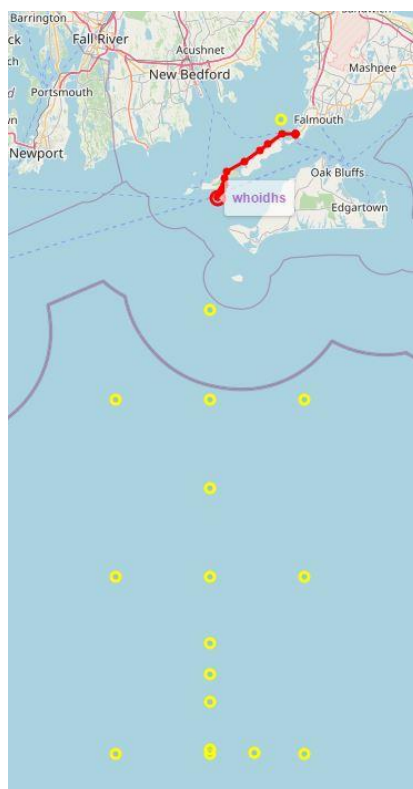


Figure 45: cookie crumb trail of waypoints that Polaris traveled from Woods Hole out to the long-term ecological research area that crosses the shelf break, offshore area.

Typically, this area is surveyed using large, expensive ships and LRAUV's ability to swim from shore and conduct slow science over a 1-2-week period provided a compelling proof of concept over the pandemic when ships were not in service. It also provided training to WHOI operators and engineers as troubleshooting also occurred via Iridium communications (troubleshooting a ground fault over-the-horizon)

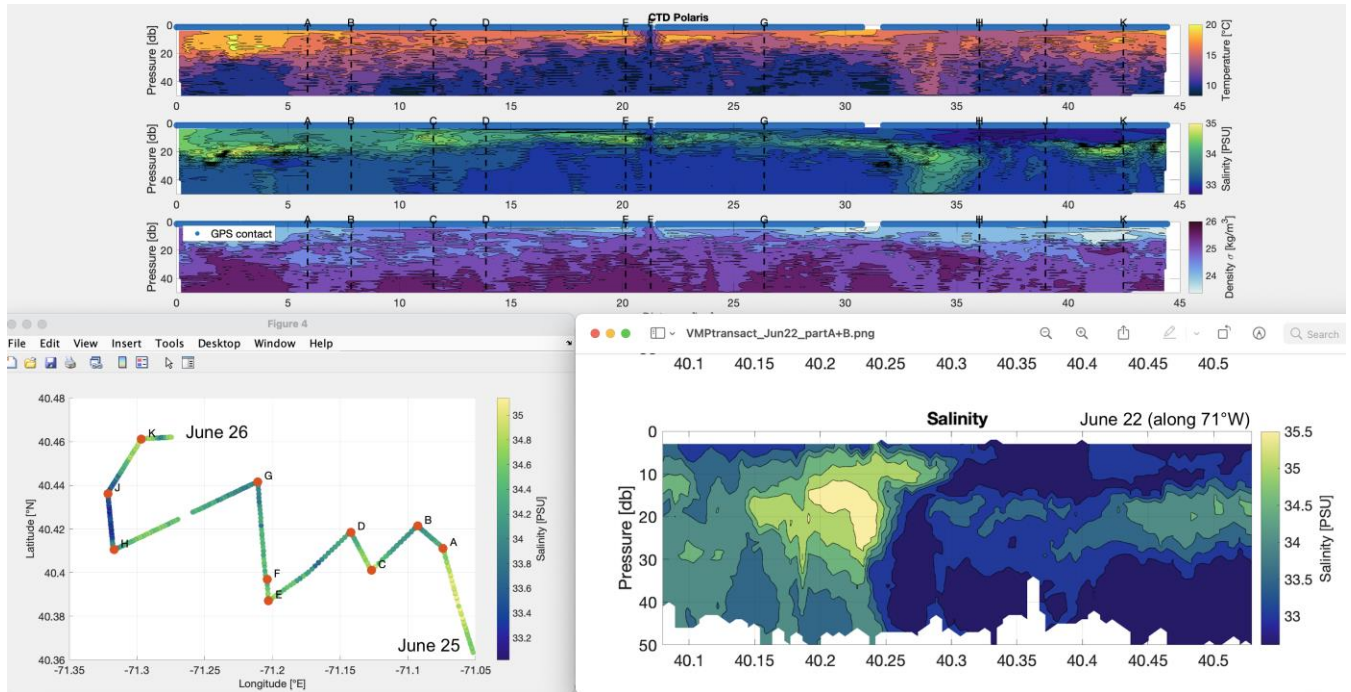


Figure 46: shows LRAUV (Polaris) processed data acquired from its 440 km mission using its adaptive mission capability (2D front tracking) to identify and map out salinity and temperature hotspots flying a yo-yo mission.

This data will help identify prolific fishing grounds and inform NOAA policy on catch recommendations for long-fin squid. This mission allowed the WHOI team to independently operate and over-the-horizon mission using new behaviors (developed by MBARI). Many different proxies can be used to 'sniff' out hotspots such as chlorophyll, temperature, salinity and dissolved hydrocarbons and data can be quickly visualized to inform scientists and first responders.

Student Involvement:

N/A

Key Stakeholder Engagement:

Project team participated in four ADAC Customers and Partners Roundtables. During the Customers and Partners Roundtable, the project team provided a brief technical summary of their project and answered questions from federal customers and interested parties including representatives from the US Coast Guard and National Oceanic and Atmospheric Administration. The team also participated in transition meetings and patent meetings for ADAC.

Key Publications (peer reviewed):

Project investigators have under-ice and oil spill technology manuscripts underway (leveraging field reports from summer 2019 and winter 2020). The team has one peer reviewed paper published in the IOSC proceedings.

Conmy, R.N., L. DiPinto, A. Kukulya, O. Garcia, D. Tulis, D. Sundaravadivelu, M. Gloekler, A. Hall, E. Fischell, D. Gomez-Ibanez (2021) Advances in underwater oil plume detection capabilities. International Oil Spill Conference Proceedings: Vol. 2021, No. 1.

Key Presentations/Documentation:

- Participation in ADAC Quarterly Reviews, Kukulya (Remote)
- Presentation, ADAC Annual meeting 2021, Kukulya (Remote)
- Talk- (NASA) Destination Space 2021, April 29, 2021, Kukulya
- Virtual Training-(USCG), Sector Southeastern New England Waterways, Inspections, response, 11/24/20 (Kukulya)
- In-person collaboration- (USCG), Joint Base Cape Cod (helicopter Conops development) and Woods Hole, fall 2020-ongoing (WHOI)
- Talk – (NOAA), <https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/orr-lecture-series-you-dont-know-what-you-dont-know>, What can underwater robots do in a crisis? Everything but the kitchen sink, with Amy Kukulya, Research Engineer, Woods Hole Oceanographic Institution (WHOI), 12/17/20
- US Senator Markey’s Office, meeting on USCG and Arctic experts discuss state of security; hope for the future, Kukulya, 12/14/20
- Talk, AFE, USFWS Alaska Region, Alaska Marine Science Symposium, “Responding from Afar: New Oil Spill Response Technologies” is scheduled for February 11, 11:00-12:00, Kukulya
- UN DESA, Global Policy Dialogue Series, Strengthening Sustainable Forest and Ocean Management to Mitigate Climate Change, 26 May 2021, Panelist, Kukulya

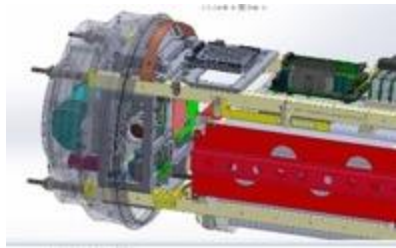
Changes from initially approved Workplan:

No under-ice or high latitude testing was conducted due to limitations from Covid-19. Instead, local testing and demonstrations took place.

Project progress against each milestone

Table 27: LRAUV Project Milestones

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Test and demonstrate the LRAUV System ‘s ability to navigate relative to a three-buoy/transponder gateway system using both USBL The vehicle will be able to reliably dock and undock itself.	Completed	N/A

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Operate under-ice and in high latitudes	Incomplete	All field work was canceled due to Covid, and Arctic readiness tests took place locally in and around Cape Cod [MOU32]
Completed navigation performance evaluation with compass and USBL	Completed	LBL evaluation to take place in Program Year 8
Finish fabrication and test of the second platform.	Incomplete	Platform Stella is ~65% complete and expected to be finished by 30 Aug 2021
Project team will advance the technical competency of USCG RDC in operating and testing the platform. Project team, led by WHOI investigators at Woods Hole, MA, will conduct up to two training sessions. Project team will complete this task via two sessions, the first by 1 Feb 2020 and the second by 30 June 2020.	Incomplete	COVID19 prevented suitable meetings to conduct follow-up meetings to advance technical competency. ADAC and LRAUV Systems leadership at WHOI and MBARI created a comprehensive LRAUV Systems Concept of Applications to advance technical competency and conducted one Video teleconferences in May 2021 with USCG Project Champion
Initiate fabrication of an additional sensor capability to LRAUV (focused on multi-beam sonar)	Completed	
Build second capture/USBL docking nose system.	Completed	N/A
Develop backseat ROS infrastructure	Completed	N/A

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Develop new rugged antenna	Completed	

Associated discussion.

The WHOI team invested ample time in reviewing vehicle build details including bill of materials and drawings that were provided by MBARI. The impacts of COVID-19 slowed electrical work with wiring and testing components due to both long-lead times with connectors and a shortage of staff (long-quarantines and social distancing, space limitations). The sonar was integrated on the backseat, but full testing and mechanical integration was moved to YR8. Completion of the second LRAUV platform, *Stella*, will occur in the first quarter of program YR8.

Progress on local testing of *Polaris* was steady and focused on the core system and new behaviors associated with docking, USBL and under-ice behaviors. Each iteration of testing took two weeks which included bench testing, 4-5 days of around the clock missions and then data and system evaluation.

All in all, the LRAUV team is on schedule to complete *Stella* in early program YR8 and have both platforms fully configured for full system testing in early 2022.

Project progress against each metric

Table 28: LRAUV Project Metrics

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Navigation performance: Conduct design improvements for Tethys platform to achieve the following drift rate: percentage of distance traveled. Target: < 1.0% with LBL aided navigation. Conduct design improvements for Tethys platform to achieve the following error bounding of navigation drift by ranging from a fixed beacon.	Incomplete	Testing delays in Program Year 6 & 7 due to COVID 19 delayed measurements to confirm navigation performance. LBL continues into YR8 due to Covid delays
Modification of Tethys platform in mechanical and electrical engineering to integrate separate oil sensor package to accomplish detection level of oil: measured in terms of minimum sensitivity. Target: < 80 ppb.	Completed	N/A
Modification and design improvements for Tethys platform to meet specified AUV range and endurance. Target: 300 km on secondary batteries, twice that on primary	Completed	Polaris completed a 440 km mission in June 2021 along the continental shelf
Modification and design improvements for Tethys platform to integrate mapping algorithm for adaptive sampling performance-mapping of spill extent. Target: Area coverage 1000 km² per vehicle deployment.	Incomplete	Evaluations will be accomplished once 2 nd platform is fabricated.
Each Arctic buoy will be able to communicate position data via acoustics up <= 5 Km distance per buoy to undersea vehicle	Incomplete	One buoy was tested to exceed 5 Km. A long range three buoy test has not yet been completed.

provide a commercially available off-the-shelf sensor package that is AUV ready, and turnkey for Arctic seafloor and under-ice mapping. Predicting and monitoring environmental hazards in the Arctic remains an outstanding challenge for under-ice surveys. Our approach builds on proven AUV technology and expands its capability by adding the latest COTS sensor technology for creating 3D maps. Although the current workplan does not include a camera system to augment the acoustic measurements for imaging ice, oil contrast or seafloor features, we strongly recommend adding a visible measurement system in follow-on project years/funding. The power of this technology for investigation of oil spills in open water or under ice remains largely unexplored, but sample data shows strong potential for oil mapping and detection capabilities in the future (Wilkinson, 2007, 2015, Maksym, 2014). The team is also tracking newer, smaller, more effective oil detection sensors and is looking for follow on funding to test and implement on the ADAC platforms in order to keep up with cutting edge COTS capabilities in a time of crisis.

Outputs:

The team achieved several successful underwater docking and undocking missions to a transponder during testing in Woods Hole as well as successful docking under-ice by LRAUV using the Arctic buoy and micromodem system with implementation of reverse thrust and undocking. The team developed and tested firmware for buoys for subsurface capabilities, conducted further evaluation of COTS sensor packages, developed tools and procedures for LRAUV Build-2, and evaluated end of life parts and LRAUV system for improvements and manufacturing. The team successfully conducted cold weather testing of the entire system and made necessary changes to improve reliability and ruggedness (gear box, antenna, software and designed and integrated a lifting bail system for launch and recovery from a helicopter. The team completed ordering of all year six funded build-2 mechanicals and sensors. Researchers also were able to receive all outstanding parts despite major shutdowns and delays of shops and services affected by COVID19. The team also integrated a multibeam system for seafloor mapping, in water detection of particles and potentially oil submerged under-ice. A concept of operations was developed by the research team for a USCG helicopter demonstration. The team also built a LRAUV in a box, Proxima, for rapid software development.

The ultimate goal is a fly away capability with rapid response for oil spills, sunken ships (etc.), pipe leaks, seafloor mapping, habitat monitoring, measuring soundscapes (weather, whales, etc.), long-range shipless surveys, open ocean, fresh water and under-ice capabilities over-the-horizon data relay, 24/7 operator response

Technology Readiness Levels (TRLs):

As of close of the year 7 program, the system is at TRL 5. [MOU33] While Stella is not yet built, the design has a base platform like Polaris. Planned for the current program year are successful T&E in a simulated operational environment with the end user fully briefed. Following the LRAUV's testing plan, and completion of data relay devices, the overall system will be TRL 7/8 and ready for production.

Transition Activities: [MOU34]

Transition plans and progress made: During program year 7, the LRAUV Team, in collaboration with ADAC and the USCG Research and Development Center, coordinated several transition-related meetings, events, documents, and activities.

ADAC and LRAUV project team continue to seek an integrated approach as desired by HQ USCG Project Champion to acquire and develop additional LRAUVs commensurate with USCG mission needs. In accordance with DHS S&T UP-ADAC Grant Terms and Conditions, LRAUV Intellectual Property (IP) rights developed under this project remain jointly held between ADAC, WHOI and MBARI. According to the DHS S&T Terms and Conditions, DHS and USCG may leverage this IP royalty free to acquire and construct additional LRAUVs to USCG and other DHS maritime mission needs.

ADAC, WHOI and MBARI remain ready to support HQ USCG Project Champion planned transition pathway.

LRAUV System likely represents the most commercially marketable investigation conducted under the ADAC cooperative agreement. In parallel to technical development to deliver the LRAUV System to support USCG, ADAC and research team advanced investigations for commercialization of the System with industry as the Center's flagship development to commercial engagements over the course of Program Year 7 as outlined in the management section of this report. Accordingly, Center management and Project investigation team continued to showcase LRAUV system, which included ADAC's Arctic Challenges, Innovations and Commerce Expo (C-ICE) "C-ICE" event (as described in this report, with additional details at: https://arcticdomainawarenesscenter.org/EventHub_C-ICE, and look to expand methods for showcasing this technology at significant oil spill conferences. | [KF35] Collectively, ADAC sought to increase visibility of a variety of Arctic Domain Awareness technologies, to include ADAC research endeavors, seeking to strengthen connections, collaboration and partnering between these communities, and to explore or initiate commercial transition pathways for ADAC completed/completing research.

Depending on DHS S&T and USCG acquisition desires, project team relays WHOI and MBARI have around-the clock technical expertise available if any such need arises. This technical support covers hardware, software, design, fabrication, specialty application, and operations expertise. WHOI has a history transitioning technology to operational use, especially with the U.S. Navy. WHOI uses a variety of transition methods 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.

PROJECT: Arctic Response-related Technologies: Strengthening Partners in Arctic Industry (SPAI)

Project Investigator: ADAC ED, Randy Kee, Maj Gen, USAF (Ret)

Project Support:

- ADAC AD/SRP, Jason Roe, Petty Officer, USCG (Ret).
- ADAC EAM, Elizabeth Mathews.

- ADAC Communications and Research Associate, Connor Keesecker.
- ADAC Research Associate, Kelsey Frazier

Lead Institution: University of Alaska Anchorage

Project Description:

Abstract:

In support of commercializing ADAC and other participating mature and completing research, ADAC central management planned, organized, and facilitated a Strengthening Partners in Arctic Industry (SPAI) Symposium in order to promote Awareness Center Technologies, foster academic and commercial research collaboration and partnering and generate new Transition Pathways that support the Arctic response community. While the SPAI Symposium is structured to support a collaborative approach to connect and network the community of science and technology research with industry, it serves as a useful venue to connect completed and completed research with maritime oriented industry for possible commercialization.

Objective/Purpose:

ADAC hosted Alaskan and Arctic maritime industry leaders, response organizations, Oil Spill Response Organizations (OSROs), maritime shippers, Arctic cruise industries, first responders, Arctic oriented non-profit groups, State of Alaska and U.S. Federal departments and agencies and National Laboratories in a two day Symposium designed to increase visibility of a variety of Arctic Domain Awareness technologies, to include ADAC research endeavors, seeking to strengthen connections, collaboration and partnering between these communities, and to explore or initiate commercial transition pathways for ADAC completed/completing research.

Methodology:

In support of commercializing ADAC and other participating mature and completing research, ADAC central management planned, organized, and facilitated Arctic Challenges, Innovations and Commerce Expo (C-ICE) on 16-17 March 2021 as virtual event. Originally proposed as Strengthening Partners in Arctic Industry (SPAI) Symposium in ADAC Workplans, the event to what was conducted in Program Year 7 in order to promote Awareness Center Technologies, foster academic and commercial research collaboration and partnering and generate new Transition Pathways that support the Arctic response community. While the SPAI Symposium is structured to support a collaborative approach to connect and network the community of science and technology research with industry, it serves as a useful venue to connect completed and completed research with maritime oriented industry for possible commercialization. Similar to Program Year 7, a uniquely titled name for the workshop will be developed and promulgated in Program Year 8. The workshop is planned as a virtual activity.

As the Arctic changes, a current gap lies in the connections between commercial and industry interests, innovative and entrepreneurial minds, and existing opportunities in the region. As a result, existing opportunities often fail to be recognized, or are too difficult to find. In response to this gap, the Arctic Domain Awareness Center's (ADAC) Arctic Challenges, Innovations, and Commerce Expo (Arctic CICE) seeks to explore the networks, resources, and infrastructure needed to enable the commercial entrance of Arctic related products and technologies into the Arctic domain. Drawing

from ADAC's vast experience in federally funded operational research and design (R&D), this expo utilizes an interdisciplinary and collaborative approach to foster conversations around Arctic-centered business pressure points, state-of-the-Arctic focused R&D, gap analysis of investment and innovation, and the future of business in the region. Participants were exposed to the latest hardware, software, and people-ware emerging to advance domain awareness, risk mitigation, exploration, Arctic operations, and overall, Arctic security.

Student Involvement:

ADAC Fellows participated in preparation and administrative support as part of professional development and opportunity for networking.

Key Accomplishments:

ADAC's Arctic C-ICE took place virtually over a two-day timeframe, March 16-17, 2021. Day one of the conference consisted of both live and prerecorded panel presentations that were accessible via online streaming services, as well as interactive platforms. The topics of the first day provided participants with a foundational understanding of the existing challenges associated with commercializing innovative technologies in the Arctic region, while also highlighting the emerging technologies being developed to tackle such challenges. In particular, the first day of the conference focused on the topics of scientific exploration, risk mitigation, domain awareness, and the current known barriers to business in the Arctic region. Lastly, the first day of the conference concluded with a "Solutions Showcase," in which a variety of existing Arctic technologies (both in development and already finalized) were displayed in a virtual booth format. Day two of the Arctic C-ICE delved deeper into the challenges discussed on the first day of conference by exploring the ways in which such challenges can be transformed into opportunities. The second day began with plenary discussions regarding the ways in which R&D and entrepreneurship play a role in tackling the challenges of the harsh Arctic domain. These discussions followed with a group tabletop exercise in which all workshop participants had the opportunity to participate in a "Strategic Doing" exercise, which teaches people how to form collaborations quickly, direct them towards measurable outcomes, and to adjust along the way.

Key Stakeholder Engagement:

ADAC recruited key stakeholders to facilitate the development of the expo. Specifically, ADAC recruited partners from the University of Alaska with experience in commercialization and business development. Partners participated in planning meetings via conferencing calls and supported key activities including a "Strategic Doing" exercise held at the end of the Expo. The event was widely advertised via ADAC's communication networks, which include the U.S. Arctic Research Commission Daily Update, the Arctic Research Consortium of the U.S., the Interagency Arctic Research Policy Committee, University of Alaska sources and DHS S&T OUP communications. The event was recorded and is now available for viewing on the ADAC Website and YouTube Channel.

Key Publications (peer reviewed):

N/A

Key Presentations:

N/A

Changes from initially approved Workplan:

N/A

Project progress against each Performance metric:

The event was completed in fulfillment of the performance metrics.

Performance Metrics:

1. Planned and conducted event that showcase ADAC and participating research to a variety of Alaska and Arctic maritime commercial and government officials.
2. Use of “Poll Me” technology to solicit participant feedback will be conducted. Key performance measure will be participant satisfaction with the event.
3. ADAC research project investigators connecting with one or more interested commercial enterprises.

Outcomes/output and TRL:

The principal output of the Arctic Strengthening Partners in Arctic Industry symposium is to increase industry interest in completed/completing research of the Center and other participating research and technology presenters.

Unanticipated problems and plans for addressing them:

N/A

Transition Activities:

Transition plans and progress made: ADAC's goal of the Program Year 7 Strengthening Industry Partnerships Symposium is to ultimately transition and commercialize ADAC research for improved Arctic Domain Awareness and Response efficiency and to promote the public good. Due to the success of ADAC's Arctic C-ICE in 2021, the Center plans to repeat this event in the Winter 2022.

PROJECT: Arctic Medium and Long Term Environment (Arctic MaLTE) Workshop

Project Investigator: ADAC Executive Director Randy Kee

Lead Institution: University of Alaska Anchorage

Supporting Team: ADAC Fellows

Project Champion: HQ USCG 5PW (Senior Arctic Policy Advisor...SAPA).

Project Description:**Abstract:**

ADAC planned to conduct one Arctic focused Medium and Long Term Environment (MaLTE) workshop to understand and address the medium and long-term strategy, policy and planning needs specific to the USCG Arctic mission. The Arctic MaLTE format is planned as a structured workshop

involving select academics, industry researchers, and government officials, who explore longer, range challenges comprehensively, from policy, governance, and science & technology vantages. The outcome of the MaLTE workshop is a comprehensive knowledge product which includes workshop analysis and recommendations.

Objective/Purpose:

Conduct focused workshops to meet medium and long-term strategy, planning and policy problems as determined by HQ USCG (specifically, HQ USCG Senior Arctic Policy Advisor to the Commandant.

Methodology:

As a strategy, planning and policy oriented workshop, Arctic MaLTE events convene subject matter experts, Government Officials in both the U.S. and Canada, academic researchers, and respected leaders of the Arctic, to include Arctic residents from indigenous communities and organizations. The workshop structure is framed as a series of focused briefings, highlighting issues, concerns and recommendations, followed by roundtable discussions and breakout sessions using Delphi prioritized solutions that if taken for action through policy decisions, provide pathways to improved governance, safety and security for U.S. interests in the Arctic. ADAC conducted a comprehensive literature review through Center Fellows to establish a baseline of published experts to support the workshop. In creating the workshop, ADAC solicited and assembled an appropriate panel of select researchers from the baseline to present to invited operators and government officials in Canada and the U.S. (at Federal, State, Local, and Tribal) to form cross-section expertise resulting in comprehensive discussions. After the plenary, ADAC divides participants across facilitated breakout workshops to discover pathways towards improved unified action.

While focused on strategy, policy and planning, through this structured plenary and breakout workshop, participants also gain understanding of knowledge gaps and shortfalls in science and technology. In order to capture the discussions in plenary, roundtables and breakout groups, ADAC created a Rapporteurs report, with prioritized recommendations and conclusions.

ADAC planned and convened one Arctic MaLTE workshop in Program Year 7. This workshop was tentatively scheduled for September 2019 and eventually held convened in May 2021 as “*Arctic Maritime Horizons*,” hosted in Anchorage at UAA. Arctic Maritime Horizon’s Exercise 2021 (AMH 21) held from 4-6 May as a hybrid virtual/in-person event. AMH 21 was organized to address policy, plans and initiatives to support HQ USCG and the Coast Guard Enterprise in addressing the 2019 USCG Arctic Strategic Outlook (ArcSO) task to “Advance and Modernize the Arctic Marine Transportation System.”

The Arctic MaLTE workshop established areas of concern in accomplishing strategy, high level goals, policy and planning. ADAC extended invitations to a team of researchers, operators and government officials assemble to analyze the preparatory materials to investigate scenarios and plenary discussions to determine needed policy, governance, and science & technology to realize DHS and USCG strategic goals and objectives, corresponding to Arctic Maritime shipping within the U.S. Extended Economic Zone.

Arctic Maritime Horizons Exercise provided an orienting and deliberative plenary forum to set the foundation for participants followed by a 3-move exercise. These activities were constructed to challenge assumptions, gain insights and organize follow-on items of consideration to guide USCG Arctic and Maritime Commerce Strategic Outlook implementation tasks. Scenario based literature

review presented a baseline of understanding 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. ADAC collected the findings of the research into a comprehensive report. Please see:

https://arcticdomainawarenesscenter.org/EventHub_Horizons21

Student Involvement:

ADAC Fellows aided in preparation and administrative support as part of professional development and opportunity for networking. Due to COVID-19 restrictions, student fellows participated remotely via virtual conferencing tools.

Key Accomplishments:

N/A

Key Stakeholder Engagement:

The Project team engaged with the designated Project Champion, Mr. Jenkins on a frequent basis as determined by the Project Champion, but as a minimum the team sought to conduct monthly teleconferences. Critical coordination was planned with all team members, the PI, and project champion. Key project stakeholders include USCG PACAREA and LANTAREA, USCG D17, D17 Sector Anchorage and the U.S. Coast Guard Academy Center of Arctic Study and Policy (CASP). Project team participated and were featured in the ADAC “Customers and Partners” Roundtable, in order to inform and receive feedback on project progress.

ADAC center team informed stakeholder progress about workshop progress at the following events:

1. Quarterly Reviews and Quarterly Customer’s and Partner’s Roundtable.
2. Annual meeting at HQ USCG, Washington D.C.

Key Publications (peer reviewed):

None

Key Presentations:

Exercise report. Following HQ USCG approval, this will be posted at

https://arcticdomainawarenesscenter.org/EventHub_Horizons21

Changes from initially approved Workplan:

N/A

Project progress against each milestone:

N/A

Project progress against each metric:

Project was completed in accordance with the metrics outlined in the Program Year 7 Workplan

Performance Metrics:

Planned and conducted workshops that meets HQ USCG Senior Arctic Policy Advisor to the Commandant.

Unanticipated problems and plans for addressing them:

N/A

Outcomes/output and TRL:

The principal outcome of the project is a knowledge product which provides a comprehensive assessment advancing known baseline of the U.S. Arctic EEZ MTS, which will inform policy concerns of HQ USCG SAPA in developing implementation plans associated with USCG's 2018 MCSO and 2019 ArcSO oriented to the region. Key inputs to the literature reviews include Arctic oriented or applicable Committee Maritime Transportation System documents as well as associated Aleutians, Bering Sea, Chukchi and Beaufort Sea Port Access Route Studies (PARS), along with navigation and waterways management policies and regulatory guidance developed and maintained by HQ USCG be key USCG stakeholder consensus on the approaches to, and solutions for, addressing polar region communications and connectivity shortfalls and gaps. The goal of the assessment is to establish a credible and useable knowledge framework to support USCG decision makers in addressing the implementation plans associated with MCSO and ArcSO, and to inform associated safety and security policies for the region. The final project is anticipated to meet at least TRL-3 threshold requirements.

The final knowledge product will be a comprehensive report containing:

1. Preparatory materials and planning information.
2. Comprehensive review of prepared remarks and presentations.
3. Detailed accounting of breakout discussions.
4. Review of prioritized recommendations and onward actions/implementation approaches.
5. Delphi analysis of recommendations and associated priorities
6. Analysis, overall recommendations and strategic suggestions for onward application consideration.

In addition, with the approval of the Project Champion, Project Champion and ADAC will coordinate a corresponding peer-review journal article, oriented to USCG Proceedings professional journal of the U.S. Coast Guard. ADAC will correspondingly plan to post all information to the ADAC website.

Unanticipated problems and plans for addressing them:

N/A

Transition Activities:

ADAC's goal of Arctic MaLTE is to understand issues and concerns, analyze those concerns to create understandings of shortfalls and gaps to strategy, policy and planning, and develop solutions to address the shortfalls and gaps. Lastly, through employing Delphi techniques, prioritization of

solutions by workshop participants can be well achieved. As a complement to Arctic IoNS, the longer-range focus of Arctic MaLTE advances long lead research, requiring greater community of interest patience in awaiting relevant outcomes.

THEME 4: Integration of Science and Engineering with Maritime Security Governance and Policy Research

THEME 5: End-to-End (E2E)

THEME 6: Integrated Education

1. Education Outreach and Workforce Development Overview.
2. PROJECT: Minority Summer Intern (MSI) Program.
3. PROJECT: Arctic Summer Internship Program (ASIP). ASIP is an integrated project with Minority Summer Intern (MSI) Program.

Education Outreach and Workforce Development Overview

Project Investigator: Elizabeth (“Ellee”) Matthews

Supporting Team: Randy “Church” Kee, Maj Gen (Ret) USAF, MS, Executive Director, UAA
Jason Roe, USCG (Ret), Associate Director and Senior Research Professional, UAA

Lead Institution: The University of Alaska Anchorage (UAA)

Project Champion(s): N/A

Project Description:

Abstract:

ADAC’s Workforce Development (WFD) Fellowship Program aims 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. Participation in the program provides student fellows with both valuable research experience and professional development opportunities, as well as access to DHS and other federal professional forums and networks. Furthermore, the funded fellowship provides students with monthly stipend and tuition support at respective education levels. Fellows are selected to the program based upon a set of criteria established by the DHS S&T OUP Award Terms and Conditions, which include U.S. citizenship, a GPA of 3.3 or higher on a scale of 4.0, the ability to pass a background check, a major in a science, technology, engineering, or math discipline (STEM), and a commitment to seek and gain employment

within the HSE or a related discipline for at least one year following graduation⁶. ADAC leadership manages these requirements to ensure compliance and continues to mentor and develop opportunities for each student fellow throughout the duration of their fellowship.

Furthermore, ADAC's WFD Fellowship program's mission seeks to recruit and incorporate minority students, as well as those from underrepresented classifications, in addition to non-minority students.

Objective/Purpose:

The objectives of this project were to provide scholarship and professional development opportunities to both undergraduate and graduate students in order to facilitate fulfilling future careers in the Homeland Security Enterprise, or related disciplines. These activities are not only aimed to contribute to the growth of a highly skilled federal workforce, but also to contribute to the capability of the U.S. Coast Guard operator in support of USCG missions in the Arctic. The specifications and expectations for the project are included in the DHS - ADAC Terms and Conditions for Workforce Development Plan.

Methodology:

Students were recruited to the ADAC WFD Fellowship program using ADAC's Fellowship webpage, as well as through ADAC's project principal investigators upon recognition of outstanding performance in an academic setting. In order to apply, students first completed the application on ADAC's website. Applications were then screened and evaluated by ADAC's leadership team using the same criteria required for ADAC's fellowship program (as discussed in the "Abstract" section). Upon acceptance into the program, students were placed either with a project principal investigator, or incorporated as a primary ADAC team member to assist with Center-related activities, such as event and workshop planning, technical report writing, feasibility analyses, literatures reviews, etc.

In order to track and evaluate the progress of each student, a fellowship "Work Plan" was developed, and/or modified at the start of each semester (Spring/Summer/Fall). The progress of each student was then evaluated with each student's respective PI (if applicable), as well as ADAC's Education and Administrative Manager. Each fellow also provided a monthly progress report to the Education and Administrative Manager throughout the academic year. In addition, student fellows attended monthly gatherings with ADAC leadership at the ADAC office, as well as virtually (due to COVID-19). These meetings included regular Center-related updates, mentoring opportunities, and occasional guest presentations.

Throughout their fellowship, students were provided continuous mentoring, coaching, and professional development. This came in the form of participating in research, attending and assisting with the education of ADAC's workshops and events, as well as assistance with placement into a 10-week summer internship program, such as ASIP (discussed in the following section).

Upon completion of the fellowship program, career assistance and guidance were provided to each student as they either sought employment within the HSE or related discipline. In addition, in many cases, assistance with placement into graduate school programs is also offered⁶.

⁶ Students may defer their employment commitment in order to pursue higher education. In addition, students with veteran status do not need to fulfill the HSE employment commitment.

ADAC's WFD Fellowship program is entirely focused on student involvement. Below is a table illustrating the number of students that participated in ADAC's Fellowship Program during Program Year 7:

Arctic Domain Awareness Center Fellows – Program Year 7

University	Undergraduates	Graduates	Total	Total Overall Fellows
University of Alaska Anchorage (UAA)	3	3	6	11
University of Texas at El Paso (UTEP)	2	0	2	
University of New Hampshire (UNH)	1	1	2	
University of New Orleans (UNO)	0	1	1	

ADAC's Program Year 7 WFD Fellowship Program achieved key accomplishments as categorized by the following subjects: outreach and exchange activities, research participation, summer internship placement, and post-graduation employment. The key accomplishments are listed for each category below:

- Outreach & Exchange Activities
 - September 2020 – ADAC graduate fellow, Tristan Goers, participated in the collaborative ADAC/NAADS ACCUSARS I Workshop as a breakout group member amongst industry, academic, and operator leadership.

- October 2020 – Four ADAC Fellows, Katherine Humpal (graduate), Megan Verfaillie (graduate), Jessica Manning (undergraduate), and Jack McCaslin (undergraduate), participated in the virtual poster symposium at the 2020 Maritime Risk Symposium hosted by the Critical Infrastructure Resilience Institute (CIRI).
- January 2021 – Three of ADAC’s graduate fellows, Katherine Humpal, Kevin Fitzpatrick, and Stacey Hanson, participated in the 2021 virtual Alaska Marine Science Symposium poster competition based on their work on ADAC’s Arctic Mussels Project. Ms. Humpal’s poster received a top 3 finish in the competition amongst graduate students.
- July 2020 – May 2021 – ADAC Graduate Fellow, Tristan Goers, continued his work with the USCG Sector Anchorage where he used his background and education in data science to assist with the advancement of materials used by the Western & Alaska Area Committee. Mr. Goers worked directly with officers and staff members of USCG Sector Anchorage to work on these tasks.
- January 2021 – April 2021 – ADAC Undergraduate Fellow, Rachel Lewis, and Graduate Fellow, Tristan Goers, worked together to develop the initial draft of the literature review for the Arctic and Alaska Communications and Connectivity Analysis Project, which served as a foundational document to the project.
- May 2021 – Five of ADAC’s Fellows, including undergraduates Rachel Lewis (UAA) and Jessica Manning (UNH), along with graduate students Tristan Goers (UAA), Kevin Fitzpatrick (UAA), and Megan Verfaillie (UNH), participated in the 2021 virtual COE Summit. The undergraduate students participated in the Grand Challenge Tabletop Exercise, while the graduate students participated in the poster competition.
- May 2021 – Five of ADAC’s Fellows, including graduate students Tristan Goers (UAA), Megan Verfaillie (UNH), Kevin Fitzpatrick (UAA), and undergraduates, Rachel Lewis (UAA) and Brenda Almanza (UTEP), pre-recorded research presentations that were posted on the Event Hub for ADAC’s Program Year 7 Annual Meeting.
- All ADAC fellows participated in virtual monthly meetings with ADAC leadership throughout the academic year.
- Research Participation
 - Throughout the academic year, the majority of ADAC fellows participated in Center-supported research projects. The following table illustrates which students were involved in which research related activities through the Center and provides a brief summary of the students’ accomplishments and activities achieved throughout their participation in the respective ADAC project.

Table 30: ADAC Fellows support to Year 7 research projects.

Fellow(s) on Project	Description of Activities/Accomplishments	University
Arctic Vessel Monitoring/Geofencing:		
Raul Reutov (undergraduate)	Mr. Reutov's activities on the Geofencing Project included utilizing the Ozone Widget Framework to assist with app development for the USCG's CG One View platform. Mr. Reutov virtually presented his specific work tasks on the Geofencing Project at ADAC's final semester Fellow's meeting in December 2020, which was also Mr. Reutov's final meeting before graduating from the ADAC Fellows Program, as well as from his academic degree. Mr. Reutov also participated in communication and networking activities with the project's main customer, the USCG, as well as with Axiom Data Science, during project team meetings.	UAA
Rachel Lewis (undergraduate)	Ms. Lewis's activities on the Geofencing project included familiarizing herself with ArcGIS and the Ozone Widget Framework and assisting with the design and implementation of the project into CG One View. Ms. Lewis virtually presented her specific work tasks on the Geofencing Project at ADAC's final semester Fellow's meeting in December 2020. Ms. Lewis also participated in communication and networking activities with the project's main customer, the USCG, as well as with Axiom Data Science during project team meetings. In the spring of 2021, Ms. Lewis also assisted with the literature review for the Arctic and Alaska Communications Connectivity Analysis Project.	UAA
Jack McCaslin (undergraduate)	Mr. McCaslin's accomplishments on the Geofencing project included learning how to use ArcGIS, particularly ArcGIS Online, to analyze and display visual data for the Geofencing project. Mr. McCaslin also assisted with furthering the relationship with Axiom Data Science and the USCG in order to gain skills in networking and communication, as well as how to apply these skills to research project development. Mr. McCaslin virtually presented his specific work tasks on the Geofencing Project at ADAC's final semester Fellow's meeting in December 2020. Mr. McCaslin also participated in communication and networking activities with the project's main customer, the USCG, as well as with Axiom Data Science during project team meetings.	UAA

Arctic Oil Spill Modeling Strategies		
Jessica Manning (undergraduate)	Ms. Manning's activities on the AMSM project included attending and acting as recorder for the Core Team, Workshop OC, and AMSM Working Group meetings, assisting with the consolidation of notes for the AMSM workshops, creating a comprehensive spreadsheet that included key information from the AMSM workshop in December 2019 that she incorporated into an independent research project during ASIP 2020, and virtually presenting at ADAC's final fellows meeting in December 2020. Ms. Manning also actively networked and communicated in numerous research-related and professional settings at AMSM Working Group Meetings and conferences, including ADAC's weekly All-Hands Meetings as well multiple Customer and Partner Roundtable events.	UNH
Megan Verfaillie (graduate)	Ms. Verfaillie's activities on the AMSM project included participation in Project Core Team and Workshop Organizing Committee (OC) Member phone calls as a recorder, participation in AMSM Working Group phone calls as a recorder, continuous communication with the Core Team and Workshop OC via email, assisting with drafting and organizing documents for the Core team and the Workshop OC, and writing a knowledge product for the project that served as Ms. Verfaillie's graduate thesis. Ms. Verfaillie also actively networked and communicated in numerous research-related and professional settings at AMSM Working Group Meetings and conferences, as well as through presentations at ADAC review meetings, including ADAC's weekly All-Hands Meetings, and multiple Customer and Partner Roundtable events.	UNH
Arctic Mussels		
Anastasia Hanson (graduate)	Ms. Hanson's activities and accomplishments on the Arctic Mussels project were specifically related to the biological side of the project, including the extraction of mussel metabolites, running NMR analysis, and the profiling of mussel metabolites. Ms. Hanson presented her specific research activities on the Arctic Mussels project at the Alaska Marine Science Symposium in January 2021.	UAA

Kevin Fitzpatrick (graduate)	Mr. Fitzpatrick's activities and accomplishments on the Arctic Mussels project were specifically related to the biochemical side of the project, including the extraction and analysis of mussel stress biomarkers, running LC-MS / NMR for biomarker qualification, and performing statistical analysis of the results. Mr. Fitzpatrick virtually presented his specific work tasks on the Arctic Mussels project at ADAC's final semester Fellow's meeting in December 2020, as well as participated in the Alaska Marine Science Symposium in January 2021.	UAA
Katherine Humpal (graduate)	Ms. Humpal's activities and accomplishments on the Arctic Mussels project were specifically related to the biochemical analysis side of the project, with particular focus on the work that was being conducted for the project at the University of New Orleans with Dr. Phoebe Zito. Katherine's work on the project is also directly tied to her doctoral work, which is focused on expanding the analytical window of optical sensors to remotely detect petrogenic dissolved organic matter in the Arctic. Ms. Humpal virtually presented her specific work tasks on the Arctic Mussels project at Maritime Risk Symposium in October 2020, as well as at the Alaska Marine Science Symposium in January 2021.	UNO
Assisting USCG Sector Anchorage with the Arctic and Western Alaska Area Committee		
Kelly Ireland (graduate)	Ms. Ireland's activities at the USCG Sector Anchorage utilized her knowledge of the biological sciences in order to assist with the development of sections of the Arctic and Western Alaska Area Contingency Plan as it related largely to bioremediation and oil spill response. As a result, Ms. Ireland had the chance to network closely with ADAC's main customer, the USCG, as well as with constituents at NOAA, the Alaska Department of Environmental Conservation (ADEC), and the U.S. Environmental Protection Agency (EPA).	UAA
Tristan Goers (graduate)	Mr. Goers' activities at USCG Sector Anchorage utilized his background in data science and GIS to incorporate mapping images into sections of the Arctic and Western Alaska Area Contingency Plan. In doing so, Mr. Goers had the chance to network closely with ADAC's main customer, the USCG, as well as with constituents at NOAA, the Alaska Department of Environmental Conservation (ADEC), and the U.S. Environmental Protection Agency (EPA).	UAA

UTEP Vegetation Spectrometer Project		
Brenda Almanza	Ms. Almanza's work at the University of Texas El Paso focused specifically on using hyperspectral reflectance of Arctic vegetation in order to assess potential oil contamination. Vegetation has been shown to uptake petroleum hydrocarbons through its root system – Brenda's project specifically examines this phenomenon using data collected in Utqiagvik, Alaska, during the summers of 2017 and 2019. Ms. Almanza's research specifically tests the capacity of near remote sensing methods to distinguish between contaminated and undisturbed vegetation, which could have significant impact in the realm of oil spill remediation, as well as to studies examining the impact of oil spills on the food web.	UTEP

- Summer Internship Placements: As a requirement of the DHS S&T OUP Workforce Development Terms & Conditions, each ADAC Fellow is required to obtain two ten-week summer internships throughout their duration as ADAC Fellows.
- The following are a list of the summer internship placements obtained by ADAC's 2020/2021 student fellows:
 - 2020 Internship Placements
 - 11 ADAC Fellows – Virtual Integrated MSI/ASIP Internship (this program is further explained in the following education project section).
 - 1 ADAC Fellow – Virtual Internship with Bigelow Laboratories for Ocean Sciences.
 - 1 ADAC Fellow – Virtual Woods Hole Partnership Educational Program.
 - 1 ADAC Fellow – Virtual Internship at UAA on Dr. Caixia Wang's Machine Learning Project.
 - 1 ADAC Fellow – Virtual Internship at UAA on Dr. Kathryn Milligan-Myhre Crude Oil Bioremediation Project.
 - 1 ADAC Fellow – Continued virtual work on ADAC's Arctic Oils Spill Modeling Project with Dr. Nancy Kinner.
 - 2021 Internship Placements
 - 1 ADAC Fellow – Continued work on a project focused on the hyperspectral reflectance of Arctic vegetation with Dr. Craig Tweedie at the University of Texas El Paso

- 1 ADAC Fellow – Continued work on the biochemical side of the Arctic Mussels Project with Dr. Phoebe Zito at the University of New Orleans.

Key Stakeholder Engagement:

ADAC fellows participated in numerous events and workshops during Program Year 7 that involved stakeholder engagement. Please see the section on “Key Accomplishments” for a full list of engagement opportunities that took place during Program Year 7.

Key Publications (peer reviewed):

N/A

Key Presentations:

ADAC Fellows presented their specific research tasks, principally their specific contributions to the associated/assigned work they had with respective ADAC’s funded research projects at the following virtual events during Program Year 7:

- October 2020 Maritime Risk Symposium
- January 2021 Alaska Marine Science Symposium
- May 2021 COE Summit
- May 2021 ADAC Annual Meeting
- May 2021 ADAC’s final fellowship meeting with center leadership

Changes from initially approved Workplan:

There were no programmatic changes to ADAC’s Workforce Development Program during Program Year 7. However, in an effort to streamline and improve clarity in the Program Year 7 Annual Report, all summer internship activities are reported in their own project section for the Arctic Summer Internship Program. As such, only the milestones and metrics applicable to the ADAC Fellowship program have been included in the corresponding tables below.

Project progress against each milestone:

Table 31: ADAC Fellows Year 7 Milestones.

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Fellows will conduct tailored research work during the academic year with schedules mutually determined by the Fellow and assigned mentor with appropriate Center leadership oversight (normally conducted by	Completed	N/A

Education and Administration Manager).		
ADAC Fellows will participate in two, ten-week summer internships with ADAC or industry hosted research (one per summer).	Completed	N/A
ADAC Fellows will join ADAC Customers and Partners Roundtables in order to gain insights to operator driven research requirements.	Completed	N/A
ADAC Fellows will participate in coaching and mentoring sessions hosted by ADAC Education and Administration Manager.	Completed	N/A
ADAC Fellows will participate in planning, execution and follow-up administration of ADAC sponsored research Arctic IoNS and MaLTE workshops.	Incomplete	Due to COVID-19, ADAC's Program Year 7 Arctic IoNS and MaLTE workshops were postponed, which did not allow for student participating in Program Year 7.
Two ADAC Fellows, who have not previously participated, will join the ADAC Annual meeting in Washington, D.C.	Completed	Due to COVID-19, the ADAC Annual Meeting in Washington D.C. was transitioned to a virtual event. Five ADAC Fellows participated in the virtual Annual Meeting in May 2021.
ADAC Fellows will participate in ADAC planned outreach activities.	Completed	N/A
ADAC Fellows will participate in end of academic year recognition event.	Completed	N/A

Project progress against each metric:

Table 32: ADAC Fellows Year 7 Metrics.

METRIC	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Comparing student's grade point average (GPA) with DHS required minimum (3.3 on a 4.0 scale). Program is considered a "Success" when 100% of students are above the required 3.3 GPA. "Caution" is noted for the program when two students are performing below expectation. The program will receive a "Failure" mark if three or more students are not being able to maintain the required GPA;	Completed – success	N/A
Comparing ADAC Fellows completion of required 10-week summer internships with DHS required minimum of two summer internships prior to graduation. Program is considered a "Success" when 100% of students complete two internships prior to graduation. "Caution" is noted for the program when two students are completing only one internship before graduation. The program will receive a "Failure" mark if three students complete only one internship or if two students fail to complete at least one summer internship prior to graduation.	Completed – success	N/A
Comparing graduated ADAC Fellows accredited to DHS enterprise careers with program graduates who are unable to gain employment in HSE. Program is considered a "Success" when all graduated fellows are able to gain employment for 1 (or more) year(s) within the HSE. "Caution" is noted for the program when two ADAC graduates are unable to	Incomplete (in work)	Of the nine ADAC Fellows who graduated in Program Year 7, one fellow is working with the Federal Government at NASA, one fellow is working directly on government contracts with the U.S. Army Corps of Engineers, one fellow is still pursuing positions in the fields of GIS or Machine Learning, and the remaining 6 fellows are continuing their education either through

complete a minimum of one year of HSE service. The program will receive a “Failure” mark if three or more ADAC graduates are unable to obtain employment for a minimum of one year of in the HSE.		their current respective degrees or continuing on to advanced degrees.
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Outcomes/Output and TRLs:

During ADAC’s Program Year 7, a total of nine students graduated from the fellowship program, as well as from their respective degrees. Below is a list of each graduated fellow, their respective university, and their current status as of the writing of this report in the summer of 2021:

- Summer 2020 Graduates
 - Cameron Carlson – Mr. Carlson graduated from UAA at the end of summer 2020 with dual undergraduate degrees in both biology and chemistry. Mr. Carlson is currently serving as a Chemical and Microbial Analyst at a research center in Anchorage, AK, while he explores graduate school prospects.
- Fall 2020 Graduates
 - Jessica Manning – Ms. Manning graduated from UNH in December 2020 with her undergraduate degree in Environmental Engineering. She is now working on her master’s in environmental and Civil Engineering at UNH.
 - Raul Reutov – Mr. Reutov graduated from UAA in December 2020 with his bachelor’s degree in Computer Science. Mr. Reutov is now working as a Software Engineer for the National Aeronautics and Space Administration (NASA) “All Points” program.
 - Jack McCaslin – Mr. McCaslin graduated from the ADAC Fellowship program in December 2020. Mr. McCaslin is finishing his undergraduate degree in Mechanical Engineering at UAA, and currently serving as an intern for the Alaska Center for Energy and Power Utility.
- Spring 2021 Graduates
 - Rachel Lewis – Ms. Lewis graduated from UAA with her bachelor’s in computer science in May 2021. Ms. Lewis is currently pursuing employment options in the field of computer science while applying to graduate schools.
 - Stacey Hanson – Ms. Hanson graduated from the ADAC Fellowship Program in May of 2020 and is currently completing her master’s degree in Biology at UAA while pursuing post-graduation employment options in the field of marine sciences.

- Kevin Fitzpatrick – Mr. Fitzpatrick graduated from the ADAC Fellowship Program in May 2020 and is working towards completing his master’s degree in Biochemistry at UAA in the summer of 2021. Mr. Fitzpatrick also accepted a position as a Research and Field Technician with the Applied Environmental Research Center where he is working on contracts with the U.S. Army Corps of Engineers.
- Tristan Goers – Mr. Goers graduated with his master’s degree in Data Science from UAA in May 2020. Mr. Goers is pursuing employment positions in the field of GIS and Machine Learning.
- Megan Verfaillie – Ms. Verfaillie completed her master’s degree in Environmental Engineering at UNH in May of 2021 and is now pursuing a PhD at UNH that focuses on the intersections between remote sensing and environmental engineering.

Unanticipated problems and plans for addressing them:

N/A

Due to the threats of COVID-19, all ADAC Fellowship activities were transitioned to a virtual platform in March of 2020, which continued throughout all of Program Year 7. While this limited student participation in several events that were correspondingly postponed, the transition to virtual learning continued smooth overall.

Transition Activities:

Transition plans and progress made:

As students prepare to graduate, ADAC Education and Administrative Manager supports Student career placement into the positions aligned to HSE. Transition plans continue past lifecycle of grant for tracking and job initiatives.

PROJECT: ADAC Arctic Summer Intern Program (ASIP). ASIP is an ADAC Fellow & Minority Student Integrated Summer Intern Program.

Project Investigators: ADAC Education and Administration Manager, Elizabeth (“Ellee”) Matthews

Lead Institution: University of Alaska Anchorage (UAA)

Supporting Team: Dr. Craig Tweedie, University of Texas El Paso (UTEP), Primary Instructor; Randy Kee, ADAC Executive Director, PI Support and Program Instructor; Jason Roe, ADAC Associate Director and Senior Research Professional, PI Support and Program Instructor; University of Texas El Paso, MSI, (Hispanic); University of Alaska Anchorage, SME, (Native American Indian)

Project Champion: N/A

Project Description:

Abstract:

Given that the duration of the ASIP program spans the transition of ADAC's program years, the following section will discuss the successes against the milestones and metrics determined for the 2020 ASIP Program and will briefly discuss the 2021 ASIP program at the end of the section.

At the end of Program Year 6, and into the beginning of Program Year 7, ADAC conducted its third Arctic Summer Intern Program (ASIP). ADAC's ASIP mission included the integration of both minority and non-minority students into a comprehensive Arctic-focused education experience. The 2020 ASIP was planned to follow the template set forth by prior years, which included an orientation week in Anchorage, Alaska, followed by two weeks of Arctic field-work experience in Utqiagvik, Alaska. Each location included planned visits to U.S. federal agencies specifically concerned with Arctic issues, focused time with ADAC researchers, and individual research concept development to generate new approaches to addressing Science and Technology solutions to USCG Arctic mission needs. However, due to the risks associated with COVID-19, the in-person program was cancelled, and replaced with a comprehensive 10-week virtual internship. In line with the overall mission of the program, the virtual ASIP utilized an interdisciplinary and holistic approach to teach students of the interconnected nature of the Arctic domain, covering topics ranging from the Arctic biophysical environment to international geopolitics. The program included a comprehensive and esteemed series of guest presenters, Arctic-specific lectures by the program's primary instructor, Dr. Craig Tweedie (UTEP), independent research projects, group projects, and weekly mentorship round table discussions.

Objective/Purpose:

To provide an Arctic focused summer internship program as part of the ADAC's overall workforce development initiatives. In particular, the ASIP program is oriented for Minority Serving Institutions, under-represented classification students, and other ADAC fellows in preparation for entry into the Homeland Security Enterprise. The specifications in expectations for the project are included in the DHS - ADAC Terms and Conditions for Workforce Development Plan.

Methodology:

The ASIP/MSI program is oriented towards students majoring in science, technology, engineering, and mathematics (STEM) fields, as these disciplines are inextricably connected with ADAC's mission and vision. As such, participating students gained exposure to science and technology research oriented towards future careers associated with the Homeland Security Enterprise and similar disciplines.

Students for the 2020 virtual ASIP program were recruited to the program through ADAC's fellowship program, ADAC's project principal investigators housed at a variety of institutions nationwide, as well as ADAC's ASIP application website. Once students were recruited, they applied to the program using ADAC's online application, and were screened and evaluated by ADAC's leadership team using the same criteria required for ADAC's fellowship program (discussed in the previous project section). These criteria include U.S. citizenship, the ability to pass a background check, a major in a STEM discipline, a GPA of 3.3 on a scale of 4.0, and the commitment to fulfill one year of employment within the HSE or related disciplines for at least one year following graduation.

Virtual program topics were selected based on the academic expertise of the program's supporting leadership, with substantial collaboration amongst Dr. Craig Tweedie (UTEP), Church Kee

(UAA/ADAC), Dr. Douglas Causey (UAA/ADAC), Ellee Matthews (ADAC), and Jason Roe (ADAC). Guest presenters were further solicited from ADAC's comprehensive network of Arctic academics, leaders, and operators.

Similar to ADAC's WFD Fellowship Program, coaching and mentoring of all participating ASIP students was conducted during the program's first orientation week, as well as intermittently throughout the program in order to orient students to careers in government service across the DHS Enterprise.

The University of Alaska Anchorage supported the administration of the overall ADAC Education Program, including the MSI summer internship program, and the overall ADAC Fellowship Program via institutional support resourcing.

Student Involvement in the 2020 ASIP Program:

Spanning nearly all time zones of the United States, ADAC's 2020 ASIP includes 11 students originating from a total of 6 universities, including the University of Alaska Anchorage (UAA), the University of Texas at El Paso (UTEP), the University of New Orleans (UNO), the University of North Carolina Wilmington (UNCW), the United States Naval Academy (USNA), and the University of New Hampshire (UNH). This year's students included:

- Brenda Almanza, Undergraduate, Environmental Science, UTEP
- Cameron Carlson, Undergraduate, Biology and Chemistry, UAA
- Jack McCaslin, Undergraduate, Mechanical Engineering, UAA
- Jessica Manning, Undergraduate, Environmental Engineering, UNH
- Katherine Humpal, Graduate, Biochemistry, UNO
- Kevin Fitzpatrick, Graduate, Interdisciplinary Analytical Chemistry, UAA
- Rachel Lewis, Undergraduate, Computer Science, UAA
- Raul Reutov, Undergraduate, Computer Science, UAA
- Sam McNeely, Undergraduate, Marine Biology, UNCW
- Sara Vianco, Undergraduate, Oceanography, USNA
- Anastasia Hanson, Graduate, Biology, UAA

Key Accomplishments:

As mentioned previously in this project's description, due to the risks associated with the COVID-19 crisis, ADAC had to cancel its traditional in-person Arctic Summer Internship Program. In its place, the ADAC Team transitioned ASIP into an entirely virtual 10-week summer internship. With the leadership of the program's Principal Investigator, Dr. Craig Tweedie from the University of Texas at El Paso (UTEP), and program development coordination by ADAC's Education & Administrative

Manager, Ellee Matthews, ADAC's new online internship program began on June 2nd, 2020, and ended on August 6th, 2020.

In recognition of the dynamic and complex challenges presented by the Arctic region, the 2020 ASIP program took an interdisciplinary approach to teaching students about the Arctic. In particular, the program emphasized that the Arctic's challenges are multidimensional, as they are impacted by the current ever-changing characteristics of the Arctic, while also rooted in the region's vibrant historical, political, and cultural complexities. As such, the ASIP program covered a compilation of critical topics, ranging from Alaska Native studies to biology. Below is a list of the lectures provided throughout the program:

- Introduction to the Arctic Biophysical Environment
- Introduction to Arctic Change
- Introduction to Data Archives
- Introduction to Arctic Security
- Introduction to U.S. Arctic Agencies and Entities
- Diary of an Expedition
- An Arctic Operators Perspective

The program was further comprised of a comprehensive series of guest presenters, including:

- Randy "Church" Kee, ADAC Executive Director
- Jason Roe, ADAC Associate Director & Senior Research Professional
- Kaare Erickson, Ukpeaġvik Iñupiat Corporation (UIC) Science Support
- Dr. Shawn Butler, UAA and ADAC PI
- USCG (Ret.) CAPT. Buddy Custard, President and CEO of the Alaska Maritime Prevention and Response Network
- Dr. Douglas Causey, ADAC's Principal Investigator and Professor of Biology at UAA
- Mr. Gilber Castellanos, the U.S. Representative for the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) Working Group
- Dr. John Farrell, Executive Director of the U.S. Arctic Research Commission
- Mr. Delbert Rexford, President and CEO of Ukpeaġvik Iñupiat Corporation (UIC)
- Dr. Paul Berkman, Director of the Science Diplomacy Center at the Fletcher School of Law and Diplomacy at Tufts University
- Sarah Thomas, Community Organizer, Native Movement
- Justin Mitchak Gatten, North Slope Borough, Risk Department
- Mr. Chris Hall, the Planning and Development Manager of Alaska Clean Seas

- Ms. Kelsey Frazier, Research Associate at ADAC
- Mr. Craig Fleener, the Executive Director of the Alaska Ocean Cluster
- Dr. Nancy Kinner, Professor of Civil and Environmental Engineering at the University of New Hampshire, and the Director of both the Coastal Response Research Center and Center for Spills in the Environment

Throughout the program's 10-week duration, students tackled a wide variety of assignments and activities, such as an independent research project, a group disaster-oriented project, bi-monthly Ignite-style presentations, networking weekly with ADAC's constituent base, and exposure to numerous skills-based lectures oriented towards both academic and professional development.

The major learning objectives of this compilation of activities include:

- To learn and apply knowledge of the Arctic biophysical and sociopolitical environment to regional problem solving.
- To gain public speaking and presentation skills.
- To gain a thorough understanding of the research process, from idea conceptualization to the start of research execution (depending on the level of the student).
- To gain critical thinking and analytical skills.
- To practice and develop networking skills, and to learn how to take advantage of connections.
- To develop innovative and well researched options for incidence of national significance in the Arctic.
- Experience a team-working environment influenced by various stressors in the development of planning contingencies.
- Develop experience and appreciation for how science, engineering, and other approaches can be applied to improve adaptive responses to natural and other disasters in the Arctic.
- To be exposed to the federal, state, local, and non-profit agencies and organization oriented towards the Arctic domain.

Key Stakeholder Engagement:

All internship students participated in guest presentations conducted by members of ADAC's constituent base, including members from the U.S. Arctic Research Commission, the Ukpëagvik Iñupiat Corporation, the U.S. Coast Guard, the Arctic Council, the U.S. Coast Guard, as well as the ADAC team, instructors and professors from multiple universities, and Indigenous leaders. These activities provided both mentoring and professional development opportunities, as well as valuable networking opportunities. ASIP progress was additionally included in ADAC's quarterly reviews of the Center's efforts in Education Outreach and Workforce Development with DHS S&T OUP Education Outreach and Workforce Development program management.

Key Publications (peer reviewed): N/A

Key Presentations: N/A

Changes from initially approved Workplan:

As explained in the preceding sections, due to COVID-19, the in-person program for 2020 was cancelled and transitioned to an entirely online 10-week internship.

Project progress against each milestone:

Table 33: ASIP Year 7 Milestones.

MILESTONE	PROGRESS	WHY NOT REACHED? (IF APPLICABLE)
Recruit five students from under-represented minorities to participate in ADAC's Arctic Summer Intern Program and integrate the MSI students with participating ADAC fellows.	Completed - Five students from under-represented minorities and classifications were recruited to the ASIP 2020 program.	N/A
Outline expectations and opportunities for recruited students by providing advance preparation information and associated materials.	Completed	N/A
Funding permitting, support student travel to Anchorage and participation in ADAC's ASIP.	Completed (Modified from orig. workplan)	Due to the cancellation of the in-person program, all funds originally allocated to fund student travel to Alaska were transitioned to fund student stipends in order to fund more students to join the program virtually.
Orient students in ADAC's overall mission, the internship experience, expectations of the program, safety briefs including both Anchorage and Utqiaġvik (Barrow) portions. Include professional mentoring of government careers in HSE and careers in Arctic-oriented science and technology.	Completed (Modified from orig. workplan)	All components of this milestone are complete, with the exception of the safety briefs for both Anchorage and Utqiaġvik, as the in-person program was cancelled.
Engage University researchers associated with ADAC to	Completed	N/A

students are successfully recruited.		
Executing Outdoor leadership and Field research program 100% safely.	Incomplete	Due to the cancellation of the in-person program, ASIP leadership was unable to conduct outdoor field research.
Collecting feedback from ASIP participants accomplished at end of course survey.	Complete	N/A

Outcomes/Output/TRLs:

Outcomes/Outputs: Coached, mentored and professionally developed students who complete the ASIP program are enriched with a unique experience to advance their success in future endeavors, whether it be continued education or direct entrance into the HSE workforce or related disciplines.

Given that the duration of the ASIP program spans the transition of ADAC's program years, the outcomes and successes of ASIP Program Year 7's participants will be reported in the Program Year 8 Annual Report. As such, the following ASIP Program Year 6 students have transitioned on to pursue further education or career placements:

- 2020 ASIP Program:
 - Rachel Lewis. UAA, B.S. Computer Science – Completed her B.S., with plans to pursue an M.S. in Data Science at the University of Alaska in the spring of 2022.
 - Kevin Fitzpatrick. UAA, M.S. Biochemistry – Graduating in August 2021 with his M.S. Currently working a position as a Research and Field Technician at the Applied Environmental Research Center where he is working on contracts with the U.S. Army Corps of Engineers.
 - Jack McCaslin. UAA, B.S. Mechanical Engineering – Completing his B.S. degree at UAA.
 - Brenda Almanza, UTEP, B.S. Environmental Science – Completing her B.S. degree at UTEP.
 - Jessica Manning, UNH, B.S. Environmental Engineering – Completed her B.S. Degree in Environmental Engineering and is now pursuing her M.S. in Civil and Environmental Engineering at UNH.
 - Katherine Humpal, UNO, PhD Biochemistry – Completing her graduate degree at UNO.

- Cameron Carlson, UAA, B.S. Biology & Chemistry – Completed his dual bachelor’s degree, with plans to pursue his master’s degree in the spring of 2022.
- Jack McCaslin, UAA, B.S. Mechanical Engineering – Completing his bachelor’s degree, with plans to enter a career in the oil, gas, or mining industries in 2023.
- Sam McNeely, UNCW, B.S. Environmental Science – Completing his bachelor’s degree at UNCW and continued an internship with Bigelow Laboratories in the summer of 2021.
- Anastasia Hanson, UAA, M.S. Biology – Completing her master’s degree at UAA, with plans to pursue a career in the marine sciences following her graduation.
- Raul Reutov, UAA, B.S. Computer Science – Graduated with his bachelor’s degree at UAA and is currently a Software Engineer with NASA’s “All Points” Program.
- Sara Vianco, USNA, B.S. Oceanography – Completing her bachelor’s degree with the USNA, with plans to become a commissioned officer in the Navy following her graduation.

Technology Readiness Levels (TRLs):

N/A.

Unanticipated problems and plans for addressing them:

As explained in the preceding sections, due to COVID-19, the in-person program in 2020 was cancelled, and transitioned to an entirely online 10-week internship.

Transition Activities:

As students prepare to graduate, ADAC Education and Administrative Manager supports student career placement into the positions aligned to HSE. Transition plans will continue past lifecycle of grant for tracking and job initiatives.

The 2021 Arctic Summer Internship

Given that ASIP spans the transition of two program years, the following section will briefly discuss the status of the 2021 ASIP that took place during program year 7 up until June 30, 2021. The full details regarding the 2021 program will be covered in the following program year annual report in program year 8.

Due to complications and safety precautions surrounding the COVID-19 Pandemic, all ADAC activities proceeded virtually during the summer of 2021, including ASIP. At the end of the Spring 2021 semester, five of ADAC’s seven total fellows graduated from both their academic degrees, and the ADAC Fellowship Program. As such, only two students remained at the start of the 2021 summer, both of which had already participated in ADAC’s virtual Arctic Summer Internship Program in 2020. As a result, the ASIP of 2021 focused specifically on recruiting a new cohort of 6-7 ADAC Fellows to join the program starting in Program Year 8, with onboarding beginning during the summer of 2021. Students are recruited to the program through ADAC’s fellowship program, ADAC’s project principal investigators housed at a variety of institutions nationwide, as well as ADAC’s application website.

Once students are recruited, they apply to the program using ADAC's online application, and are screened and evaluated by ADAC's leadership team using the same criteria required for ADAC's fellowship program (discussed in the previous project section). These criteria include U.S. citizenship, the ability to pass a background check, a major in a STEM discipline, a GPA of 3.3 on a scale of 4.0, and the commitment to fulfill one year of employment within the HSE or related disciplines for at least one year following graduation.

The intent of the onboarding program was to prepare new ADAC Fellows for the 2021/2022 fellowship throughout the academic year, with the intent to have each of the new students participate in an in-person ASIP in the spring/summer of 2022 as their final capstone to their tenure with the ADAC team. As such, at the end of Program Year 7, ADAC was in the process of recruiting its newest member of the ADAC Fellowship Program, Tori Sweet, an undergraduate student in Environmental Engineering working with Dr. Nancy Kinner at the University of New Hampshire. The remaining new ADAC Fellows are to be recruited in Program Year 8 and will be discussed in more detail in the Program Year 8 Annual Report.

IV. BUDGET AND JUSTIFICATION

Year Seven Arctic Domain Awareness Center (ADAC) Financial Summary

Year Seven Budget Analysis – Summary for Center