UNITED STATES COAST GUARD

Research & Development Center

BIENNIAL REPORT 2017-2018

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Front cover

Top: The RDC cube satellite ground station at the U.S. Coast Guard Academy (page 20).

Middle: RDC staff deploy an unmanned underwater vehicle in the Bering Sea (page 18).

Bottom: Coast Guard boat crew helmet wear (page 30).

Back cover

Port of Seward, Alaska, taken from the flying bridge of CGC HEALY the night before RDC staff got underway on the 2017 voyage to conduct Arctic Technology Evaluations.

A Word from the RDC Commanding Officer

Key measures of any R&D organization include the quality and impact of the research provided. Our focus for the past two years has been on products that transfer knowledge for use in operations, policy and cost-avoidance decisions.

A few highlights:

- We completed work on some difficult challenges that impact operations, ranging from the removal of oil in the water column to laser cockpit protection for our pilots. We delivered a study on navigation systems in the Arctic and follow-on work regarding unmanned aerial vehicles. In each case we worked with sponsors to deliver on needs ranging from a practical solution to exploring "the art of the possible."
- We ventured into a space-focused research effort with the Department of Homeland Security Science and Technology Directorate (DHS S&T), sending two CubeSats into orbit to collect data on the viability of using these unique capabilities in our search and rescue mission.
- We worked with rapidly advancing technologies including virtual reality, artificial intelligence and cutting-edge pollution response. Our tight focus will present decision makers with capabilities and approaches to increase effectiveness and efficiency.
- Our Science and Technology Innovation Center, a joint effort with DHS S&T, is focused on rapid discovery, testing and transfer to the fleet … increasing the ability of RDC to have Coast Guard operators test cutting-edge tech at the speed of need.

I remain committed to working with our customers in an environment that insists on mutual respect, honors different perspectives and understands service heritage. Our bottom line: delivering MEANINGFUL, RELEVANT and IMPACTFUL products to our service!

CAPT Greg Rothrock

A Word from the
Chief, RDT&E Program

Every day, the men and women of Coast Guard Research, Development, Test & Evaluation (RDT&E) champion technological advancement and innovation on behalf of the service. We are committed to working directly with programs, stakeholders and field personnel to identify the Coast Guard's most pressing gaps and challenges; to ensuring our research, development and innovation efforts are addressing the highest priority needs of our operators and decision-makers; and that we are aligned with Coast Guard strategic imperatives.

The Commandant has challenged the service to "be bold, think anew" and "embrace ever-changing technology" in the 2018-2022 Coast Guard Strategic Plan. The Research and Development Center is a key enabler in accomplishing that goal.

Many of the projects discussed in this report have come from people like you, who have identified advancements that could potentially improve Coast Guard operations, reduce risk or enable decision making. On behalf of the RDT&E and Innovation team, I would like to take this opportunity to thank all of our idea submitters, sponsors and stakeholders for the support that you provide to the portfolio development and execution process, as well as our partners from industry, government and academia. You are critical not only to this process, but to ensuring the effective transition of products whether they be technological advancements, knowledge products or decision support, into the service.

The RDT&E and Innovation Program collects ideas year round through CG_Ideas@Work at https://cg-ideasatwork.ideascalegov.com. I invite you to sign up and send us your own unique challenges or innovative solutions. Together we can solve these challenges and ensure the Coast Guard is fully prepared to support the priorities of the nation.

Wendy Chaves

RDC Commanding Officer's Intent

RDC will research, develop, experiment and analyze. Using in-house resources and partnerships, we will address pressing issues facing our Service, we will foster enhanced operations/mission support, better decision-making, and new capabilities to meet our Service responsibilities.

The world is ever changing and the collective national demand signal for Coast Guard capabilities is growing. We are a "Center of Gravity" where innovation is cultivated and science is leveraged for Service good. With our team of dedicated civilian and military professionals we will earn a national reputation for unbiased, science-based experimentation, focused on higher Technology Readiness Level (TRL) maritime solutions. We will aggressively steward products to transition for our Service.

We will be the Service's principal advisors for questions on Science and Technology. We will cultivate and leverage partnerships within the science & technology communities of DHS, DoD, DOE, other research/academic institutions (in the U.S. and overseas), and industry. Additionally, we will strengthen partnerships with our nation's service academies, starting with CGA, military institutions of higher learning, and think tanks.

We will work with each other in an environment that honors different perspectives, respects different cultures, understands service heritage, and insists on mutual respect. We will be collaborative, maximizing the capability of our matrixed workforce to solve Service problems. We will make every dollar count. The Center will be a genuine, transparent, and welcoming environment. This will be a destination command for civilians and uniformed members alike.

This is my direction, this is my intent –
Deliver meaningful, relevant, and impactful products to our service while
being respecful, genuine and persistent (relentless) in our work.

CAPT Greg Rothrock

RDC Overview

Mission

Provide innovative technologies, premier analysis, and decision support to enhance operational performance and reduce acquisition risk across all U.S. Coast Guard missions.

What is the RDC?

The Coast Guard Research and Development Center (RDC) is the Coast Guard's primary facility authorized to conduct applied research, development, test and evaluation (RDT&E) in support of the Coast Guard's 11 missions. Research conducted at the RDC helps to sustain program infrastructure and core capabilities, knowledge, skills, experience and facilities to give the Coast Guard a strong evidence-based foundation for operational and capital investment decision-making.

The RDC falls within the Office of RDT&E (CG-926) – which also includes the Innovation Program and acquisition test and evaluation and is located at Coast Guard Headquarters in Washington, D.C. The RDC serves as the execution agent of the program, executing and delivering products to Coast Guard stakeholders.

What capabilities does the RDC offer?

The RDC has access to project lab demonstration spaces and external facilities for conducting unmanned systems, oil spill research and communications testing. Its formal partnerships facilitate close collaboration with government and industry. More importantly, the RDC maintains the greatest concentration of military and civilian researchers to help the Coast Guard. Their scientific and technical knowledge includes:

- Unmanned systems (air, surface and subsurface)
- Communication and electronic navigation systems
- Cybersecurity systems
- Space-based systems
- Augmented and virtual reality
- Pollution detection and response
- Search and rescue science, research and technology
- Aids to navigation
- Modeling and simulation
- Sensor performance
- Machine learning
- Arctic capabilities and technology testing
- Law enforcement technology including less-than-lethal
- Rapid commercial and government off-the-shelf technology evaluations and transition
- Acquisition/requirements analyses

2017 – 2018 Accomplishments

Completed Products

| 52 CY17 | 41 CY18 |

Completed Projects

| 21 CY17 | 20 CY18 |

New Projects

| 18 CY17 | 17 CY18 |

Ideas Collected

| 139 CY17 | 112 CY18 |

Completed Projects

Arctic Operations

2017
- Polar Icebreaker Acquisition Support
- Arctic Communications Technology Assessments

2018
- Arctic Operations Support
- Response to Oil in Ice
- Next Generation Arctic Navigational Safety Information System

Intelligence and Cyber

2017
- Hoax Location Systems and Methods

2018
- Assessment and Demonstration of Inertial Navigation System Technology
- Building and Retaining a Cyber Workforce

Waterways Management & Environmental Response

2017
- Bureau of Safety and Environmental Enforcement Spill Response and Prevention Support
- Scalability of Ultraviolet-Based Ballast Water Management Systems
- Mobile Asset Tracking and Reporting during an Incident of National Significance
- Western Rivers Electronic Aids to Navigation Technology Demonstration
- Shale Oil Preparedness and Response
- Equipment Surge Risk Assessment Tool

2018
- Alternatives to Pyrotechnic Distress Signals
- Oil Spill Response Technology Evaluation Process Research
- Improved In-Situ Burning for Offshore Use
- Detection and Mitigation of Oil within the Water Column

| 2018 | Maritime Safety, Security, Communication, and Navigation Standards |
| | Analysis Support for the Mandated Periodic & Practicability Reviews of Ballast Water Standards |

Operational Performance Improvements & Modeling

2017	Innovative Interdiction Patrol Tactics
	Non-Lethal Impact Munitions
	Evaluation of Helmet Wear for Coast Guard Personnel
	Evaluation of Electro-Optical Sensor Systems and Night Vision Goggle Lateral Range Curves in Search and Rescue Optimal Planning System
	Joint Non-Lethal Weapons Directorate Small Vessel Entanglement
	Evaluation of WMEC 270 Pitch/Revolutions Per Minute Schedules
	Analysis of Methods Underway Time to Develop and Maintain Crew Proficiency
	Non-Compliant Vessel Less than-Lethal Technologies Procurement Support
	Mobile, Modular, Maritime Domain Awareness
	Automatic Transport of Search and Rescue Patterns
	Electronic Health Records Alternatives Analysis

2018	Options Study: CG-LIMS Financial Interface with Legacy CG Systems
	Vectoring Over the Horizon-Cutter Boat for Non-Compliant Vessel Intercept
	Tactical Communications to Enhance Coast Guard Operations
	Mobile Technology for Operational Efficiency
	Non-Compliant Vessel Stopping Using Less-than-Lethal Radio Frequency Technologies

Unmanned Systems

| 2017 | Direction Finding Payloads |

| 2018 | Advanced sUAS Sensor Investigations |
| | Assessment of Unmanned Maritime Systems for Coast Guard Missions |

Sensor Optimization, Automation and Visualization

Vessel entanglement

Arctic operations
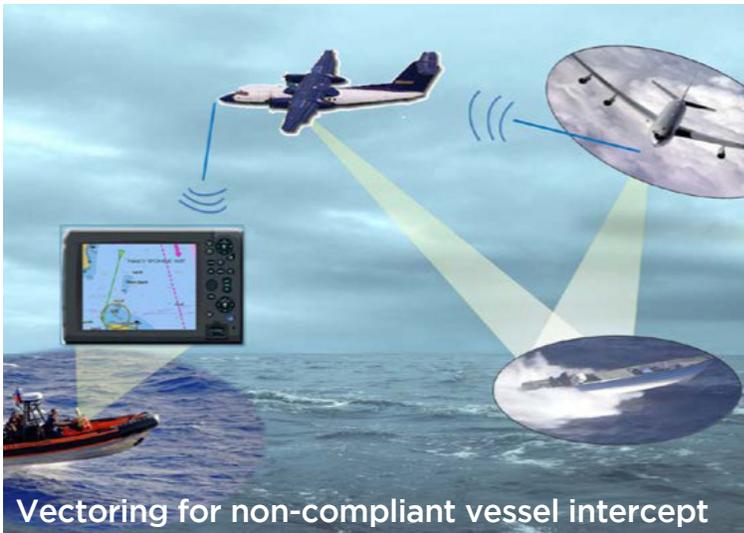
Vectoring for non-compliant vessel intercept

Evaluation
of helmet wear

Cockpit laser strike protection

Non-lethal impact munitions

RDC Partnerships

As a small research program, partnerships are vital to the RDC's success, and the organization will continue to leverage the innovative solutions that federal and non-federal partners bring to the table in order to solve the service's most complex challenges. Keeping pace with innovation and technological advancement requires engagement with the top subject matter experts from across the research and development community.

Coast Guard RDT&E is optimized to work with partners to explore research questions and develop new capabilities. Coast Guard RDT&E also works closely with DHS Centers of Excellence, Department of Defense research entities, national laboratories, academia and industry. A few of our current partners:

DHS Science and Technology Directorate
- Border, Immigration and Maritime
- First Responders and Detection
- Operations and Requirements Analysis
- Technology and Scouting Transition
- Test and Evaluation
- Federally Funded Research and Development Centers
- Office of National Labs
- Office of University Programs

Academia
- U.S. Coast Guard Academy
- Naval Post Graduate School
- Air Force Institute of Technology
- Johns Hopkins Applied Physics Laboratory

Department of Defense
- Office of Naval Research
- U.S. Air Force Research Laboratory
- U.S. Army Research Laboratories
- Naval Sea Systems Command
- Defense Advanced Research Projects Agency
- Various Naval Surface Warfare Centers
- Counter Terrorism Technical Support Office

Other Government Agencies
- Bureau of Safety and Environmental Enforcement
- National Reconnaissance Office
- Customs and Border Protection
- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration
- Defense Intelligence Agency
- Environmental Protection Agency
- Department of Energy
- Maritime Administration
- Countering Weapons of Mass Destruction Office
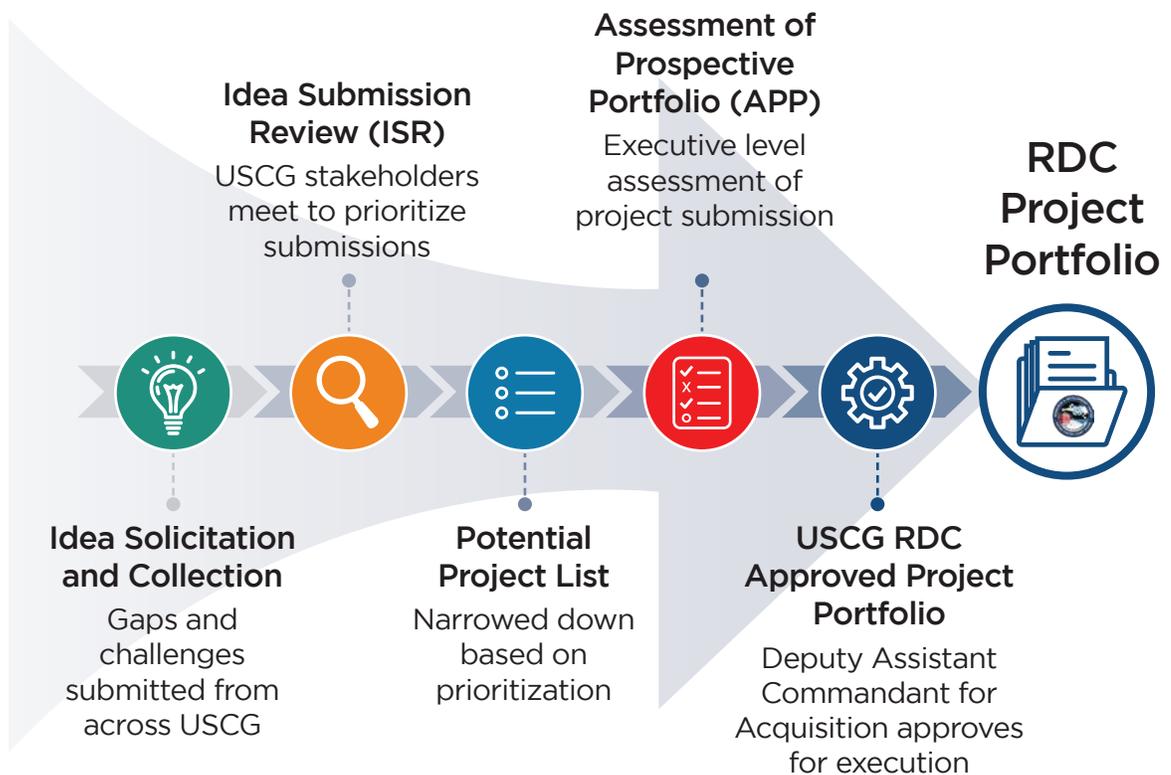
Memorandums of Understanding (MOU)

The RDC established MOUs with the following entities in 2017-2018 to promote partnerships, foster collaboration, and leverage and pursue research efforts of mutual benefit to all parties.

- **Office of Naval Research** – To develop and evaluate counter unmanned aircraft system technology as part of a larger systems approach to elements of anti-terrorism/force protection.
- **U.S. Army Research Laboratory** – To leverage technical services across multiple research focus areas including wide-area persistent surveillance, modeling and simulation, and acoustic/sensor/detection.
- **U.S. Army Engineer Research and Development Center** – To leverage technical services across multiple research focus areas including space, oil spill response, information technology, ballistic analysis and Arctic-related technology.
- **U.S. Air Force Research Laboratory** – To leverage technical services across multiple research focus areas including counter unmanned aircraft systems, long-range/ultra-long endurance unmanned aircraft systems, and modeling supporting the use of artificial intelligence and machine learning.
- **U.S. Coast Guard Shore Infrastructure Logistics Center** – To support the aids to navigation (ATON) mission, including evaluating new ATON technology and existing ATON signal equipment.
- **Customs and Border Protection Air and Marine Operations** – To leverage technology efforts and improve airborne use of force tactics.
- **The Naval Postgraduate School** – To collaborate on areas of research that are mutually beneficial, such as thesis topics developed by students and professors (use of drones, artificial intelligence and oil spill response are examples).
- **The Johns Hopkins Applied Physics Laboratory** – To leverage technical services across multiple research focus areas including cybersecurity risk analysis, unmanned aircraft systems, search and rescue analysis and satellite technology.
- **Ohio National Guard** – To enhance national security research enterprise and cyber engagements including access to cyber ranges.
- **The Oil Spill Recovery Institute** – To promote improvements in oil spill response through research and development activities.

Portfolio Development Process

How is the RDC portfolio developed?

- The RDC executes projects that directly address the most pressing gaps and complex challenges of the Coast Guard, respond to the needs of the service, and have the ability to transition and deliver results.

- Project selection is vetted through an intensive process beginning with the collection of R&D ideas from throughout the service, followed by multiple vetting forums where ideas are weighed against specific criteria. The end result is a well-balanced and strong RDC Project Portfolio, a collection of projects that aligns to Coast Guard strategic needs.

Idea Submission Review (ISR)
USCG stakeholders meet to prioritize submissions

Assessment of Prospective Portfolio (APP)
Executive level assessment of project submission

RDC Project Portfolio

Idea Solicitation and Collection
Gaps and challenges submitted from across USCG

Potential Project List
Narrowed down based on prioritization

USCG RDC Approved Project Portfolio
Deputy Assistant Commandant for Acquisition approves for execution

RDC Focus Areas

The RDC conducts applied research that falls within the following focus areas:

- ▶ **Unmanned Systems**

- ▶ **Arctic Operations**

- ▶ **Sensor Optimization, Automation and Visualization**

- ▶ **Intelligence and Cyber**

- ▶ **Operational Performance Improvements and Modeling**

- ▶ **Waterways Management and Environmental Response**

- ▶ **Coast Guard Science and Technology Innovation Center (STIC)**

A rocket carrying two 6U CubeSats, named Yukon and Kodiak, launched from Vandenberg Air Force Base on Dec. 3 2018. Photo courtesy of SpaceX.

Unmanned Systems

The Coast Guard has been researching and evaluating unmanned systems across a spectrum of missions. Unmanned systems offer the potential to lower costs in comparison with manned vessels and aircraft, and provide increased maritime domain awareness in remote or hazardous operating areas.


ViDAR detection system

▶ Advanced Unmanned Aircraft System (UAS) Sensor Evaluation

- RDC launched a research project to quantify industry improvements made in maritime surveillance and target detection technology for use with UAS aboard the Coast Guard's National Security Cutter (NSC). This effort focused on the evaluation of the latest, most technologically advanced wide-area sensor payloads.

- The Visual Detection and Ranging (ViDAR) and miniature Synthetic Aperture Radar (Nano SAR-C) sensors were identified for evaluation. These light-weight sensors use advances in miniaturization, high-resolution cameras, advanced computer algorithms and powerful onboard processors to automatically locate and track targets, as well as cue the operator to targets of interest.

▶ Robotic Aircraft for Sensor Payload – Maritime

- In 2017, RDC began a DHS Science and Technology-sponsored Robotic Aircraft for Sensor Payload – Maritime (RASP-M) project to build on the lessons learned from earlier Robotic Aircraft for Public Safety and Robotic Aircraft for Maritime Public Safety efforts. These earlier projects were used to evaluate small UAS with electro-optical/infrared (EO/IR) cameras for potential use by the first responder community and DHS operational components.

- The follow-on RASP-M project was designed to explore payloads other than standard EO/IR technologies and identify the capabilities, benefits, risks and technical limitations of operating representative UAS payload technologies in a maritime environment.

- The objective of the RASP-M project was twofold: first, evaluate different payloads and sensors suited for a maritime environment, partnering with Mississippi State University's Raspet Flight Research Laboratory from the DHS Singing River Island test site.

- Second, investigate the ability of operating UAS and associated payloads from a variety of geographical locations and aboard several classes of Coast Guard cutters.
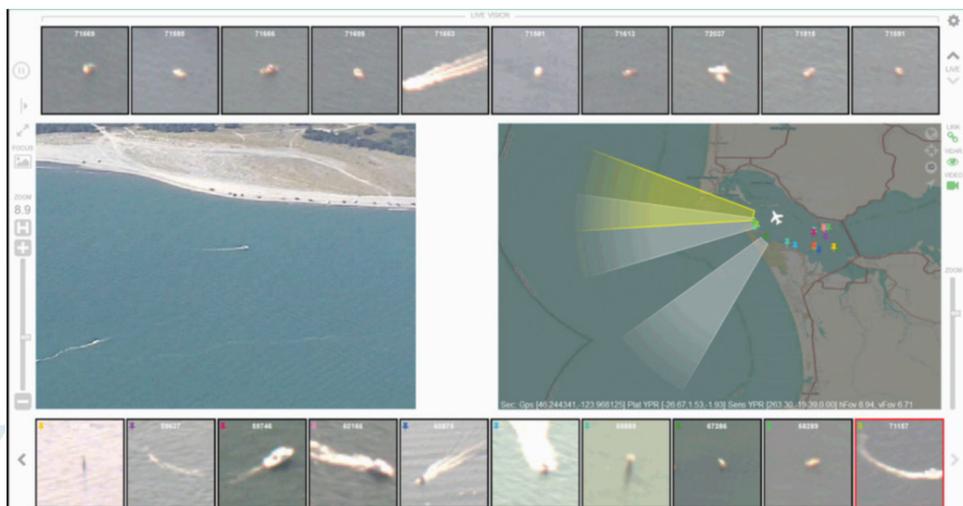
Detection, classification and pre-processing for the operator were a key part of the RASP-M project. Shown are sensor images of a "suspect" vessel through detection and classification.

▶ Unmanned Maritime System Developmental Requirements for U.S. Coast Guard Applications

- RDC has been investigating the application of unmanned maritime systems to Coast Guard missions. After outlining the concept of operations for two applications (a long-duration system supporting offshore maritime domain awareness and the remote operation of a standard USCG boat in support of safety zone enforcement), RDC examined current capabilities with respect to implementing a complete system.

- The investigation found that long-duration applications require improvements in the ability to autonomously avoid other vessels and track targets of interest.

RDC staff deploy its own unmanned system with quadcopter and robotic arm to take oil samples.

Arctic Operations

The United States is an Arctic nation, and the Coast Guard has served as the lead federal agency for homeland security, safety and environmental stewardship in the Arctic region for over 150 years. As U.S. Arctic waters become more accessible to commercial and recreational maritime users, the Coast Guard is looking for technology solutions to address the complex issues associated with operating in this remote region.

▶ **Arctic Technology Evaluation 2017/2018**

- In summer 2017, the RDC traveled on Coast Guard Cutter HEALY, a 420-foot icebreaker, through the Bering, Chukchi and Beaufort seas. During the RDC's Arctic Technology Evaluation 2017, a collaborative team of RDC staff, Surface Forces Logistics Center staff, industry partners and contractors conducted several technology evaluations.

- Research included operations of an unmanned maritime system and unmanned underwater vehicle, conducting overhead ice dives, launching a small UAS, deploying an oil skimmer in the icy water, evaluating passive sensors and deploying data collection buoys.

- In 2018, the RDC conducted research in Prudhoe Bay, Alaska, that focused on performance evaluation of unmanned aircraft systems and unmanned surface vehicles in the Arctic environment.


This overview graphic of the Arctic Technology Evaluation 2017 depicts various technologies and partners.

▶ Arctic Communications Technology Assessments

- As Coast Guard missions increase in the Arctic, reliable communications must be available for tactical control of operational units, including emergency response teams working in remote areas. The RDC has been conducting studies and demonstrations on current and emerging Arctic communications technologies for the past several years.

- Research focused on alternative and emerging satellite communications options that could improve both performance and coverage in the Arctic.

- Additionally, improvements to high frequency radio coverage for the entire Arctic area of responsibility and other terrestrial-based technologies and services that can help alleviate the lack of infrastructure were investigated.


Using ground antennas, like the one shown here, Coast Guard researchers explored deployable satellite communications.
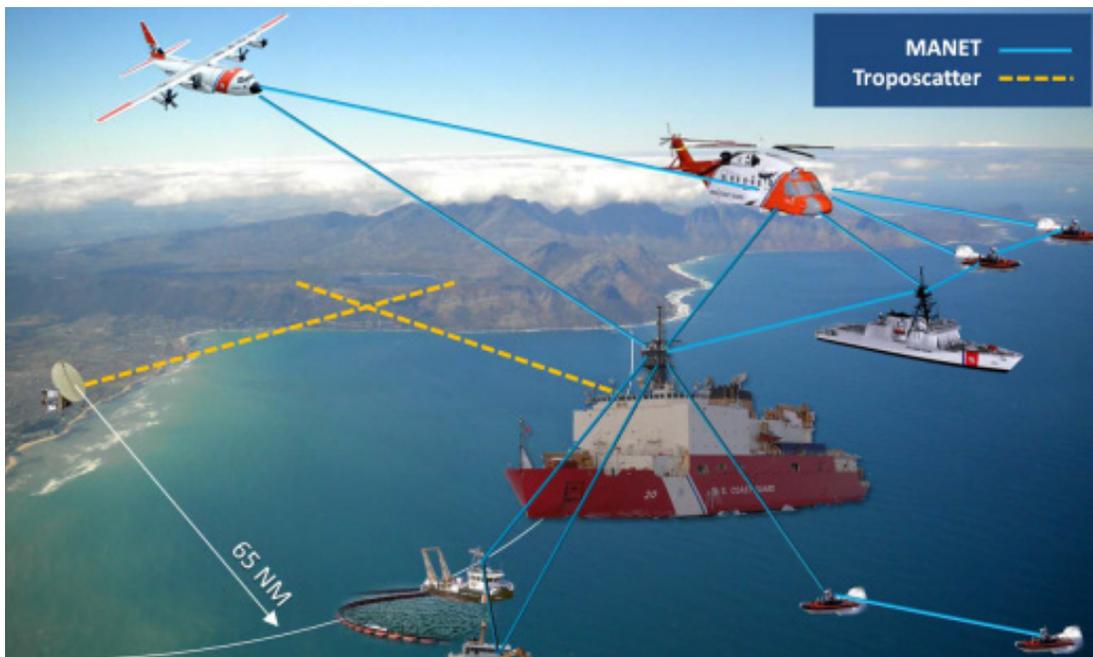
Reliable communications in the Arctic are critical to long-term mission support and engagement.

Sensor Optimization, Automation and Visualization

The Coast Guard conducts communications and sensors research to enhance every Coast Guard mission. Research into these disciplines helps the Coast Guard advance capabilities in emerging environments like the Polar regions and to employ cutting-edge technology to solve problems and improve mission performance.
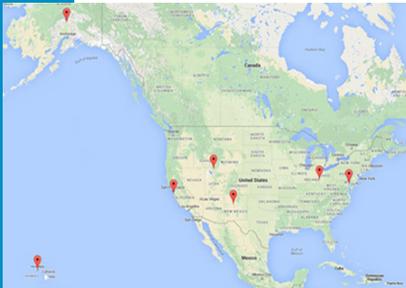
A map of the Mobile CubeSat Command and Control network indicating locations of ground stations.

Evaluation of Potential Coast Guard Use of CubeSats

- The RDC, in partnership with the DHS Science and Technology's Polar Scout project, launched two 6U CubeSats, Yukon and Kodiak, aboard a Space X Falcon 9 rocket launched from Vandenberg Air Force Base on Dec. 3, 2018. CubeSats are small satellites typically used for research that provide a low barrier to entry for organizations to access space. The RDC also acquired and built two mobile CubeSat command and control ground stations at the University of Alaska, Fairbanks, and the U.S. Coast Guard Academy in New London, Connecticut, that received the CubeSat signals during testing and demonstrations.

- These two satellites were tailored to detect search and rescue radio beacons and relay their location back to ground stations on Earth. This research will allow the Coast Guard to evaluate use of small satellites to help augment and improve communications in the Arctic, monitor large areas for illegal activity and help locate people lost at sea.
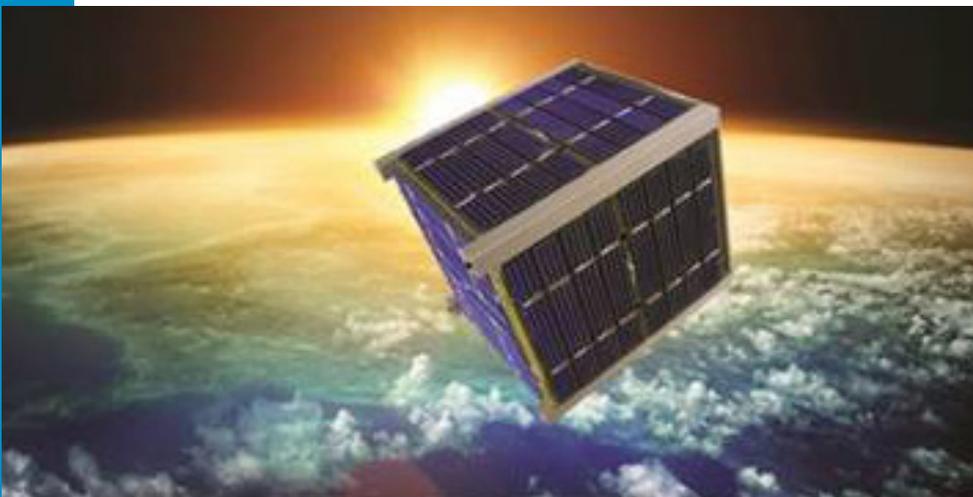
An illustration of a cubesatellite in low Earth polar orbit.

- In addition, the Polar Scout Project also allows the Coast Guard and DHS to evaluate government-developed-and-operated space solutions, compare them to congruent commercial services and inform Coast Guard direction on future use of space-based technologies.

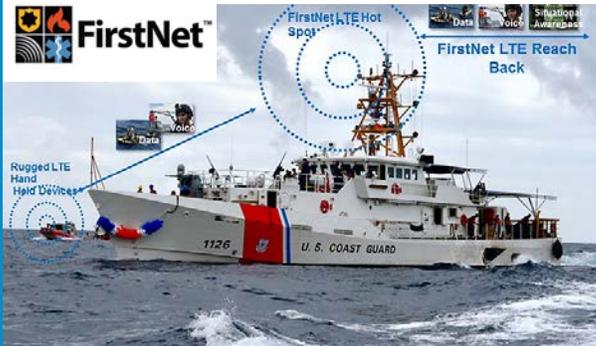## ▶ Enhanced Person in the Water (ePIW) Detection

- A persistent challenge of the search and rescue mission is the difficulty of finding a person floating in the ocean needing rescue. RDC is conducting the Enhanced Person in the Water project to gather ideas for improving the detection of a person in the water (PIW).

- Working with DHS Science and Technology, RDC conducted a "U.S. Coast Guard Ready for Rescue Challenge." DHS Science and Technology provides program and administrative contractual support for the advancement of prize challenges.

- Rather than examining changes that could be made to the existing Coast Guard asset sensor suite, the competition solicited ideas for technology that could improve the visibility of PIWs. A panel of experts judged the submissions, and five ideas were awarded prize funding to develop prototypes for at-sea field testing. The results of this ongoing technology competition may present advancements in PIW visibility that are affordable for recreational boaters to purchase and improve probability of detection when lost at sea.

Detecting persons in the water has always been difficult. The ePIW project uses a prize competition to explore options.
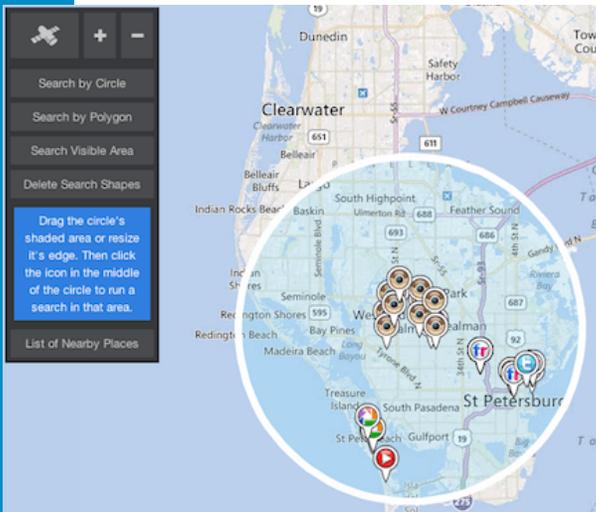

The RDC conducted a "U.S. Coast Guard Ready for Rescue Challenge." DHS Science and Technology uses its prize authority to support DHS components.

The RDC is experimenting with connectivity improvements by leveraging FirstNet cellular network for first responders.

Coast Guard Nearshore Use of FirstNet

- The RDC is investigating how to adapt FirstNet, the nationwide public safety broadband network, for maritime use. This work includes establishment of a test facility, evaluation of FirstNet offshore coverage, creation of a concept of operations for the Coast Guard, and review of current FirstNet hardware and software options.

- FirstNet use could potentially provide high-speed data, communications and interoperability between first responder organizations both on land and at sea, which would allow for more effective management, collaboration and facilitation of response operations.

Detecting and tracking serial hoax callers provides law enforcement information needed to conduct arrests.

Hoax Location Systems and Methods

- Search and Rescue (SAR) hoax calls place Coast Guard personnel at unnecessary risk, cost taxpayers hundreds of thousands of dollars annually and interfere with legitimate SAR operations.

- RDC explored options for identifying and investigating SAR hoax calls using a three-pronged approach: (1) radio direction finding, (2) social media exploitation and (3) audio forensics/voice analytics.

- Recommendations were developed for improved methods of identifying SAR hoax callers, and fly-away hoax location kits with recommended technology were assembled and distributed to Coast Guard Area units. These outcomes are directly aiding Coast Guard Investigative Service (CGIS) and law enforcement personnel in hoax call investigations.

Intelligence and Cyber

Intelligence research is identifying ways to collect and disseminate intelligence information across communities as collaboration with intelligence and law enforcement partners becomes increasingly important. Cyber research is a continuously evolving field as cyber-attack events become more complex and protection needs to be agile. The RDC is contributing to advancements in both areas that benefit both the Coast Guard and DHS partners.
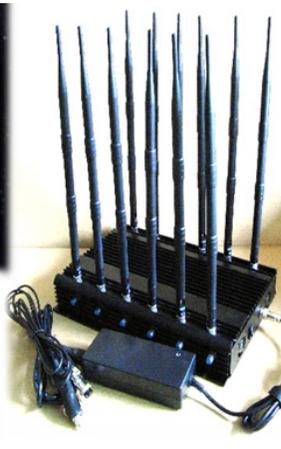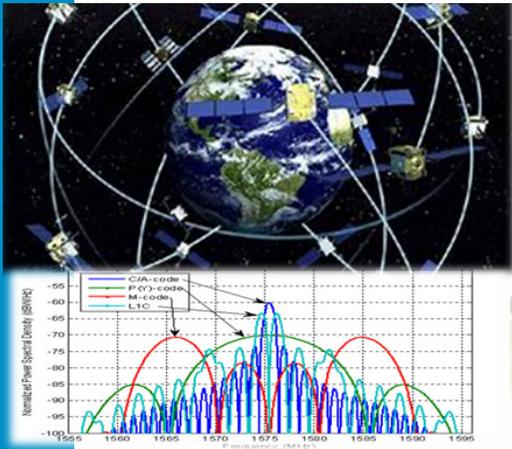
▶ **Cybersecurity Vulnerabilities, Threats and Risk Mitigation Strategies for Coast Guard Surface and Air Assets**

- The vulnerability of Global Positioning System (GPS) equipment to cyber-attack has been well documented. Denial of service attacks by jamming the GPS signal are common in many places around the world and can be done with inexpensive equipment ordered from the internet. Hacking GPS to mislead navigators is another form of attack commonly referred to as spoofing.

- RDC began this effort by participating in two DHS Science and Technology-hosted GPS jamming/spoofing events. Equipment tested consisted of a representative sample of global positioning and automatic identification systems currently in use in the Coast Guard surface fleet.

- RDC is partnering with the Office of Naval Research (ONR) in the next phase of the project to investigate the use of virtual programmable logic controllers to improve the resilience of operational technology systems for the Coast Guard surface fleet.

The vulnerability of critical systems such as GPS to cyber-attack is a strategic level issue.

The Global Positioning System is a critical national capability. This study is investigating detection and mitigation activities. Top depicts GPS satellites in orbits, bottom shows testing capabilities and a way to start looking at possible interferences.

▶ Countering GPS Interference

- The RDC is investigating how to detect and mitigate wide-area GPS jamming and spoofing. This effort compliments other RDC research into GPS interference by exploring mitigation technologies including detection systems, hardened antenna designs and jamming/spoofing incident notification methods for mariners.

▶ Identifying Candidates for Coast Guard Cybersecurity Jobs

- Cybersecurity has become a topic of concern to all federal agencies and military services, including the Coast Guard. Personnel must not only have an aptitude for cyber work, but also have the moral standards to do that work in a professional manner. RDC investigated tools that would help identify current Coast Guard members and new recruits who would make good cybersecurity personnel.

- This project reviewed two tests designed to help select personnel for cyber-related jobs: the Cyber Test, developed by the Air Force, and the Tailored Adaptive Personality Assessment System, developed by the Army. Research was presented to show how the tests were developed and validated and also explored the potential use of these tests for selecting personnel for cyber-related jobs in the Coast Guard.

▶ Document and Media Exploitation
Technology Evolution Capability Research

- Digital forensics and Document and Media Exploitation (DOMEX) data provides key and unique person-centric insights which are derived from digital media. This is critical to enabling thorough and fact-driven U.S. government screening, vetting and criminal investigation efforts as well as assisting with safety investigations, cyber network investigations or search and rescue cases.

- This effort investigates the governance strategy of various DOMEX capabilities spread throughout DHS as well as using government cloud-based solutions to improve interagency collaboration and providing cross-agency case management tools to improve mission execution.

The use of digital forensics and media exploitation has become critical to investigations; this project will explore governance strategies. Top right: The DOMEX project is looking at exploitation of a range of intelligence documents. The red box is a simulation of what happens when intelligence is fused and actionable information, like a location, is developed. Bottom left: The cell phones illustrate ways that transnational terrorist organizations or international drug cartels can communicate. The Coast Guard Western Hemisphere Strategy speaks to disrupting networks. An extensive cell phone network is part of a much larger command and control communication framework, and understanding that network will aid the criminal investigation.

Operational Performance Improvements and Modeling

The Coast Guard researches operational performance improvements through modeling, simulation and analysis, and explores methodologies and tool development for new and/or improved Coast Guard and stakeholder processes. The RDC Modeling and Simulation Center of Expertise provides an analytical capability for decision support and to assist Coast Guard offices in, for example, understanding and evaluating potential impacts of proposed policy changes.

▶ **Augmented Reality for Coast Guard Mission Support**

- Augmented Reality (AR) is being used more frequently by military and industry to bring amplifying digital information into the real world so that users can more efficiently perform essential activities such as supporting troubleshooting and maintenance requirements for increasingly complex systems.

- RDC researched available AR headsets and development tools to assess these capabilities to potentially improve Coast Guard mission support activities. RDC developed rudimentary applications to explore the functionality of a chosen headset, and researchers worked with Coast Guard Force Readiness Command and industry partners to select a Coast Guard use case that would demonstrate AR capabilities. This research supports the Coast Guard culture of continuous innovation with a future potential of creating new efficiencies with the introduction of AR technology.

An RDC intern wears virtual reality goggles while driving an unmanned maritime system off CGC HEALY.

▶ Ice Condition Update

- Lake ice can create hazardous transit conditions through which some vessels may not be able to travel. Having a method of effectively forecasting and sharing ice conditions is key to safe operations in icy regions.

- The RDC conducted research that provided an update on the progress to date, challenges and future plans for the Arctic Domain Awareness Center's ice condition (ICECON) tool. Coast Guard operational commanders in the Ninth District plan to use the ICECON tool to provide ice condition information to the public and to inform Captain of the Port decisions related to icebreaking and waterways management.
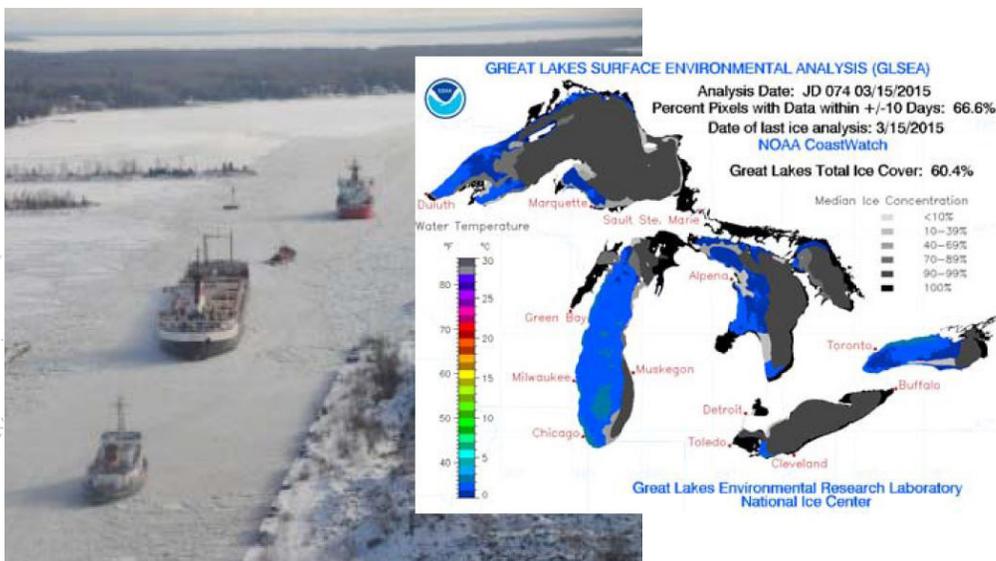
Operating within the harsh weather conditions within the Great Lakes is difficult. One gap the RDC addressed was research on the development and use of a tool to understand ice conditions.
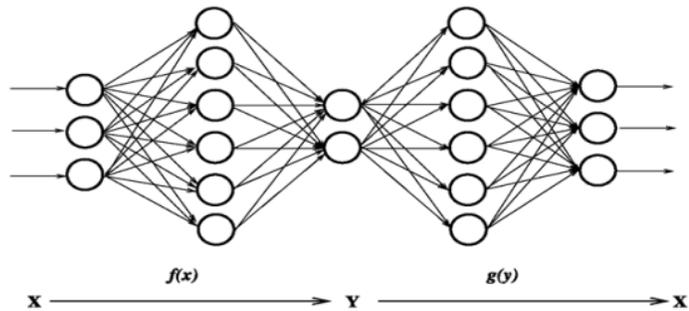
▶ 2019 Fleet Performance Analysis

- In response to a DHS Under Secretary for Management requirement for critical acquisition decision support, the RDC Modeling and Simulation Center of Expertise performed a fleet analysis to determine the impact of not implementing the crew rotation concept for major cutters and the relative performance of various cutter fleets, including the National Security Cutter, the Offshore Patrol Cutter and the Fast Response Cutter.

The RDC leveraged the use of supervised Machine Learning (ML) as part of a project to improve efficiency in domestic barge inspections.

▶ Improved Efficiency in Domestic Inspections

- To seek optimized use of limited mission resources for domestic barge compliance inspections with safety and security requirements, the RDC explored whether methods for improved, risk-based allocation of prevention resources could be developed. Predictive algorithms were developed and assessed and the effort resulted in delivery of a successful model to assess barge vessel risk of non-compliance with safety/security regulations. Also, two graphical user interfaces to implement the predictive model were delivered.


The RDC, as with many federal agencies, is exploring applications of Machine Learning. A recently concluded project validated a possible application by looking at barge inspections over an 18 year period. The circles represent a range of courses of action to epitomize what the use of Machine Learning may provide Coast Guard missions in the future.

Inspections are a critical part of the prevention mission.

▶ Exploring Machine Learning for Application in the USCG Mission Planning & Disaster Response

- This project explores methods for improving the Coast Guard's emergency preparedness and increasing response effectiveness in active disasters. To that end, it is researching the application of Artificial Intelligence (AI) and Machine Learning (ML) to disaster response course-of-action development to assess how AI/ML could improve the efficiency of Coast Guard planning and response process during a crisis.

- This effort is being conducted in collaboration with the DHS S&T Center of Excellence at the University of Illinois, University of Southern California and Harvard Univeristy.

- Future work includes execution of a proof-of-concept leveraging AI/ML for disaster-response support with a potential follow-on to demonstrate use of an AI algorithm for either a fictitious or a real-world problem with resource-allocation challenges.
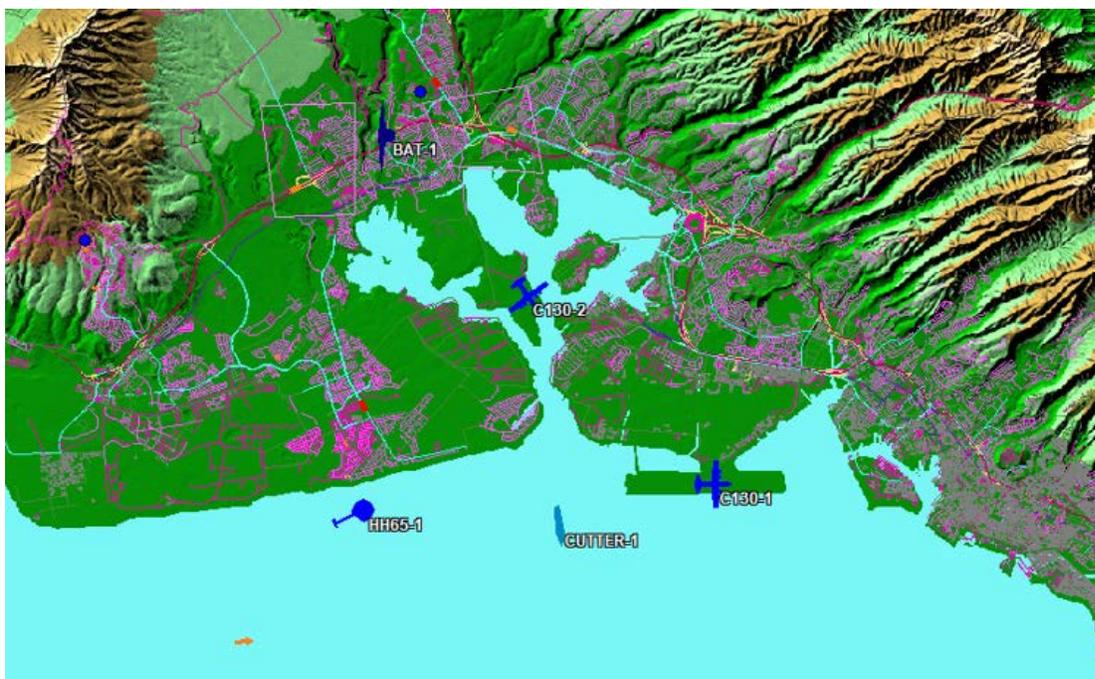
A preliminary simulation RDC developed in collaboration with Air Force Research Laboratory depicting a community with roads, buildings, topography, and response assets for use in analyzing the impact of AI and ML on a simulated response through publicly available text data using natural language processing algorithms.

The new helmet model for Coast Guard boat crew members as a result of the RDC helmet research project.

▶ Evaluation of Helmet Wear for CG Boat Crew

- Helmets are worn by Coast Guard crew members to provide head protection during hazardous conditions in various environments.

- This research explored the levels of protection that helmets provide to Coast Guard members in Boat Forces in order to ensure service members had the right tool to do their job as safely as possible.

- The RDC's recommendations informed the Office of Boat Forces' new requirements and request for proposal to purchase up to 15,200 boat crew helmets; 16,000 Coast Guard boat crew members throughout the active duty, reserve and auxiliary ranks will be safer during the execution of their missions because of this RDC project.


Students in the Heavy Weather Coxswain course at the Coast Guard's National Motor Lifeboat School learn to operate rescue boats safely in the most challenging and dangerous surface conditions. Helmets are needed to protect against severe head impact force caused when a fast-moving boat hits the surf or takes a hard turn, among other situations.

Waterways Management and Environmental Response

Waterways management and environmental response addresses technologically challenging issues in maritime rescue and survival, improvement to waterways management and aids to navigation, response to oil pollution incidents related to relatively-new sources of crude oil or tar-sands products, and developing methods to ensure compliance with regulations to stop the introduction and spread of aquatic invasive species.

▶ **Environmentally Friendly Buoy Mooring System Deployment**

- In support of the marine environmental protection mission, the RDC is conducting the Environmentally Friendly Buoy Mooring System project to evaluate if alternative mooring system technologies have the potential to minimize impact on the sea bottom.

- Through a joint prize competition with DHS Science and Technology a proposed design was selected. Inspired by this design, the RDC began testing various types of mooring systems in its search for a durable, efficient and environmentally friendly solution.

- This research describes the deployment of the buoy mooring systems and anchors and provides the results of the initial inspection of the buoy mooring systems post-deployment. These results are the baseline to compare subsequent inspection results to assess the condition of the mooring systems.
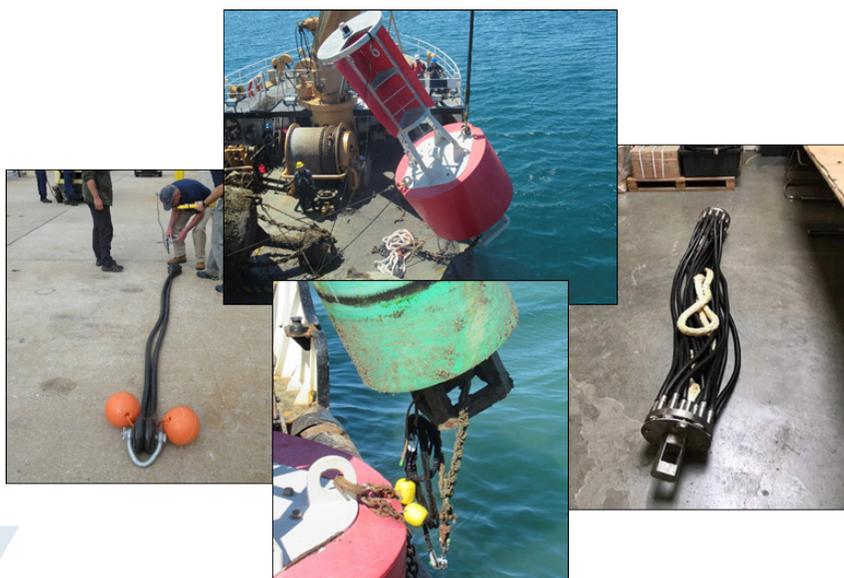
Although critically important to the country's maritime transportation system buoys also can impact sensitive environmental environments. The RDC explored ways to mitigate this impact, through experimentation, with a series of environmentally friendly buoy mooring systems.

► Alternatives to Pyrotechnic Distress Signals

- This research assessed the suitability of light emitting diode (LED) devices as an alternative to pyrotechnic flares. Additionally, through a series of laboratory and field vision-research tests that included many colors and flash patterns, the best design/signal was recommend to the Office of Design and Engineering Standards (CG-ENG). As a result, CG-ENG worked with the Radio-Technical Commission for Maritime Services, which ultimately developed a "standard on electronic visual distress signal devices" (published June 21, 2018). This advanced technology opens the door to permit a new type of LED-based visual distress signal that is safer for the user and environmentally friendly.

- A final report summarized this multi-year effort to develop specifications for an LED signal characteristic and includes recommended best signal and light configurations to support the most conspicuous nighttime visual signal.


In the past decade there has been a dramatic change in the way boaters in distress signal a problem in their voyage. The RDC explored the suitability of light emitting diode (LED) technology as an alternative to pyrotechnic flares.

► Charting the Course: Western Rivers
Electronic Aids to Navigation Technology Testing

- Billions of barrels of oil, tons of cargo and bushels of crops travel on America's rivers every year on the way to local gas stations, shopping malls and grocery stores.

- The prosperity of the American heartland pumps through the vital economic arteries of the Ohio, Mississippi and Missouri rivers. These rivers are among the inland marine

transportation corridors collectively known as the Western Rivers. Many critical American industries rely on these waterways and approximately 15 percent of the total U.S. freight travels on the Western Rivers.

- The Coast Guard and U.S. Army Corps of Engineers worked together to successfully test and demonstrate electronic routing, transmitting and monitoring of messages containing environmental, geographic, search and rescue, law enforcement, and target of interest information through the Automatic Identification System (AIS) within the test area (located in the Ohio Valley).

- The final report identified and explored areas that need to be addressed for a full AIS transmit system in the region.
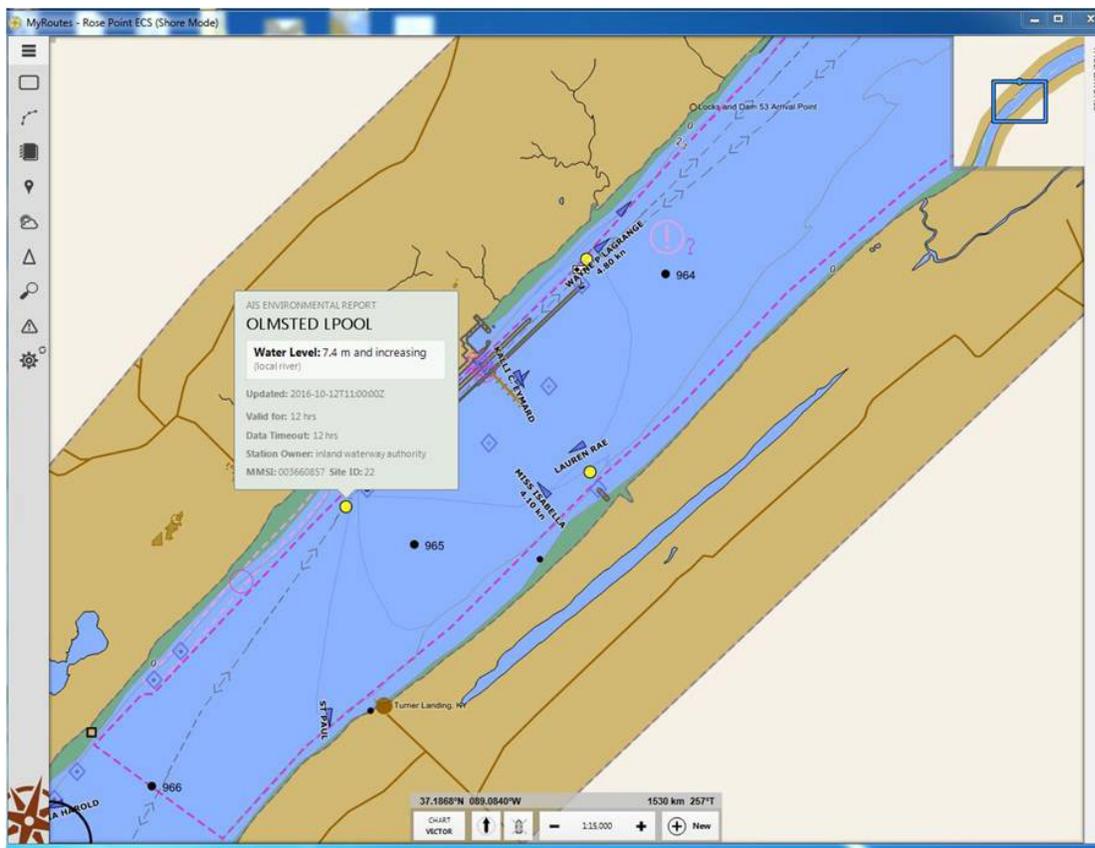
A commercial electronic chart system shows both electronic Aids to Navigation (eATON) and enhanced Marine Safety Information (eMSI) being broadcast in the vicinity of Olmsted Lock. The blue diamonds are eATONs that assist the mariner in navigating around the lock. The yellow dots are eMSI, which provide the mariner critical pieces of information that enhance situational awareness; the eMSI broadcast selected displays the current water level at that location.

▶ Sunken Oil Barrier System Field Test in the Kalamazoo River

- The RDC explored technology to improve spill response capabilities for non-floating oil due to the increase in transport of oil sands and diluted bitumen, known as dilbit, and lessons learned from the 2010 Enbridge pipeline spill into the Kalamazoo River.

- The Coast Guard selected three systems to develop and test with the aim of evaluating technology to collect spilled oil sands products that have sunken to the bottom of a river or lakebed. Two of these underwater barrier systems were tested in 2018 – one on the Kalamazoo River and one on Lake Huron. The goal is to provide the pollution response community with new tools to mitigate these difficult and costly spills.

A 25-foot section of inland underwater oil barrier is laid out on a dock prior to deployment, April 23, 2018, in Kalamazoo, Michigan. The three-foot-high barrier is made of PVC and X-Tex fabric, and is designed to let water flow through while trapping oil. Weighted chains and scour flaps prevent oil and sediment from flowing underneath the barrier.

▶ Joint Maritime Test Facility (JMTF)

JMTF, located on Little Sand Island in Mobile Bay, Alabama, allows the RDC to research methods, impacts and concerns associated with in-situ oil burning. Controlled oil burns were a key component of the Deepwater Horizon oil spill response, and are one of the most effective methods for removing large-scale spilled oil from the environment.

Full-scale in-situ test burns in progress with some members of the fire safety team, Mr. Mike Hering and MK1 Darrel Boyles, on watch.

Smaller-scale freshwater in-situ test burns in progress with research and fire safety team.

The RDC conducted analysis on a range of potential invasive species control measures including impacts on barges.

▶ Preliminary Marine Safety Risk Assessment, Brandon Road Lock & Dam Invasive Species Control Measures

- In support of Coast Guard District Nine, the RDC conducted a preliminary risk assessment to address possible impacts on marine and navigation safety due to proposed invasive species control measures located in the vicinity of the Brandon Road Lock and Dam Navigation Project on the Des Plaines River, near Joliet, Illinois.

- This preliminary risk assessment provides the Coast Guard operational commander evaluative input for the U. S. Army Corps of Engineers functional design plan. This assessment considers commercial and recreational vessel activities and how a range of potential invasive species control measures might affect the safety of waterway activities or those activities that occur on the adjacent river and approach channel banks.

▶ The Next Generation Arctic Navigation Safety Information System (ANSIS)

- Arctic scientific exploration and tourism have steadily been increasing. The Coast Guard and the Marine Exchange of Alaska (MXAK) established a Cooperative Research and Development Agreement in 2013 to develop a technological approach that would provide important safety and time-critical information to mariners in the remote and hostile waters of the U.S. Arctic Exclusive Economic Zone. This became the ANSIS Project.

- This project focused on the following three areas of technology:

1. Near Shore Automatic Identification System (AIS) Transmit – This component of the project demonstrated an operational Alaska AIS Transmit Prototype Service capable of transmitting weather, meteorological and hydrographic information, ice edge, virtual aids to navigation, and geographic safety and security information including active areas of indigenous whaling/fishing activities to 26 active AIS transmitters. A report was produced that summarized the demonstrated capability and recommendations for MXAK and Coast Guard operations.

2. Extended Range AIS – This proof-of-concept prototype and report demonstrated advanced AIS communication capabilities to improve surveillance coverage range and data integrity while resisting cyber-attack. The report recommended six different future focus areas including work required for AIS 2.0, the next generation of AIS.

3. Long Range High Frequency (HF) Digital Radio Mondiale (DRM) – RDC's year-long field test demonstrated the HF DRM system is capable of transmitting a variety of maritime and navigation safety information to the Arctic mariner.
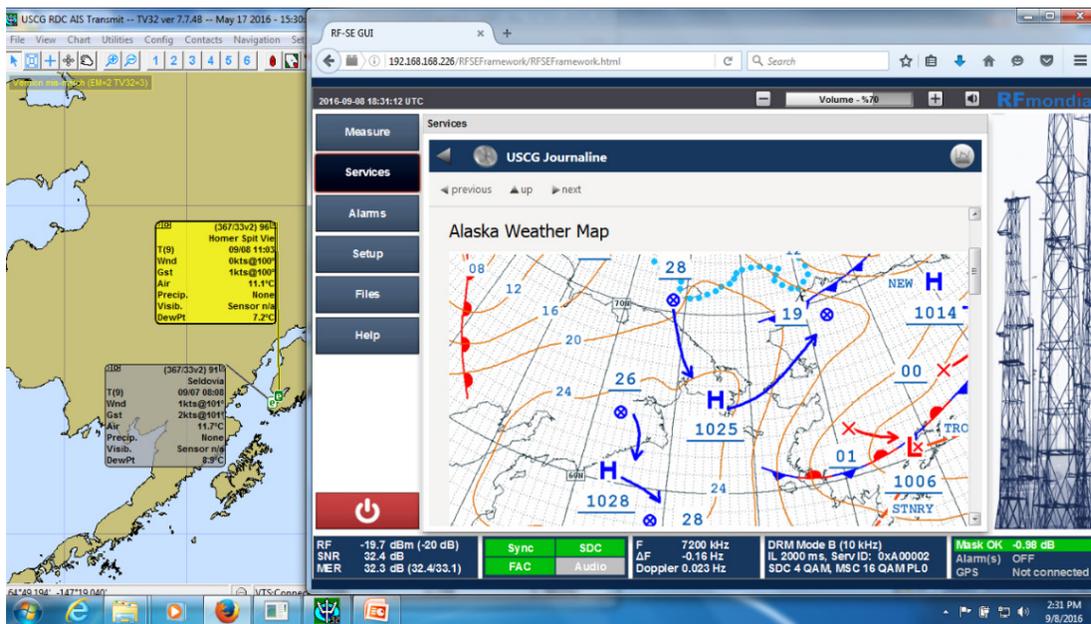
Long Range HF DRM – navigational data – shipboard electronic chart display screen capture of received information broadcasted by the HF DRM Prototype.

CG-STIC

The Science and Technology Innovation Center (STIC) was established as a collaborative effort between the Coast Guard and DHS Science and Technology to provide rapid evaluation and prototyping of high technology readiness level commercial and government technology for application to Coast Guard and DHS missions and to increase the speed of transition of technology from idea to implementation. The STIC comprises a dedicated team who are charged with finding, demonstrating, and working with Coast Guard operators to evaluate such technology.

Boat crew members deploy the MOTT during testing in San Francisco, California.

▶ Maritime Object Tracker Technology

- Keeping track of objects in the water like debris, obstacles and contraband is a large task in any Coast Guard area of responsibility, and the RDC is identifying new ways of flagging objects so the Coast Guard can effectively mark, track and recover them. During these highly complex, rapidly unfolding operations, non-compliant vessels often drop contraband overboard to remove evidence.

- This contraband can often be scattered over a large area, and due to the wind and sea currents, often shifts from its original landing spot, making recovery a challenge. Law enforcement units needed a way to mark the location of items in the water to make it easier to track their movement and relocate them at a later time.

- Designed to reduce the amount of manpower, time, and asset availability needed to track and recover jettisoned cargo, derelict vessels, and search-and-rescue cases, the Maritime Object Tracker Technology (MOTT) device is a floating beacon that can be thrown from a moving boat or aircraft that broadcasts an Automatic Information System (AIS) signal, allowing Coast Guard units to easily and accurately relocate targets in the water.

- STIC-developed MOTT, which include 3D printed parts, are intended for use on both boats and helicopters and are currently being prepared to deploy for operational testing.

► Low Cost Remotely Operated Vehicles (ROVs)

- The CG-STIC team evaluated low cost remotely operated vehicles (ROVs) to determine their effectiveness in executing Coast Guard missions. ROVs provide the Coast Guard the opportunity to increase its underwater situational awareness and are useful for inspections of ships hulls and appendages, docks and other infrastructure, and assisting in securing waterside events.

- Traditional ROV systems provide excellent capability, but at a very high cost, which has limited the extent the systems are currently being used. The evaluation process was to determine if the capability ROVs provide at the lower price point makes them a cost effective tool for executing other Coast Guard missions.

BlueROV2   CCROV   FiFish

Through market research, the STIC team identified two general form factors of ROVs. The first is controlled with vectoring capabilities, allowing the device to loiter in areas of interest. This style – of which the BlueROV2 and CCROV are examples – is well suited for inspection requirements. The second common ROV form factor is like a fixed wing aircraft in its movement, "flying" around in the water in a primarily forward orientation. This style, an example of which is the FiFish, is useful for scanning a large area.

Future Objectives and Priorities

In addition to the products and S&T advisory service we provide to the enterprise, we are excited about:

A growing list of external partners ... In the past two years we have engaged in many new partnerships. We have many new memorandums of understanding that formalized a number of them. Department of Defense labs like the Air Force and Army Research Labs have played an increasingly important role in the execution of our projects such as airborne use of force ballistics testing, and survival modeling. We will be targeting more engagement to refresh our most productive partnerships and develop new ones to include the Federal Laboratory Consortium.

Recruiting the next generation of Coast Guard professional researchers ... Recruitment of researchers is critical with a long-term impact. Today, RDC is engaged in aggressive recruitment activities including including the use of direct hire, creating science, technology, engineering and math internship opportunities, and creating entry-level ladders. This next generation of researchers will complement our reorganized Technical Division that is placing more emphasis on capacity needed to conduct scientific analysis and maritime technology test and evaluation. Our continued search and investment in talent will better position RDC to work on emerging threats and technological opportunities.

Alignment with forward-leaning strategies ... The President released his 2020 guidance to departments on S&T priorities. He cites the need for R&D on emergent technology that include artificial intelligence, autonomous systems, advance communications, cyber, space commercialization, manufacturing technologies, and new clean and affordable energy. The Coast Guard Strategic Plan 2018-2022 outlines a framework that includes modernization and the investment in technology that will enable mission success today and in the future. It acknowledges the importance of evaluating emergent

technologies and unmanned platforms, data analytics, artificial intelligence, machine learning, and delivering mission support at the need of speed. From the President to the Commandant, these are all touchpoints as we move ahead with the R&D project portfolio.

Our future research portfolio ... One of the key reasons the RDC has an engaged workforce is the research challenges presented by a constantly changing and diverse portfolio. Our portfolio research themes in fiscal year 20 include: creating efficiencies, e.g., field reporting tools for human intelligence; creating knowledge products, e.g., machine-learning to improve mission capabilities; evaluating technology solutions for new threats, e.g., counter UAS/unmanned underwater vehicles; technology refresh, e.g., next generation aids to navigation; and unlocking the potential of existing technologies, e.g., beyond-visual line-of-sight for small UAS.

On May 6, 2019 the RDC hosted – for the first time ever – the Department of Defense Lab Commanders Synch Meeting, which brings together the Chief of Naval Research (CNR), the Commander, Air Force Research Lab (AFRL), the Commanding General Army's Combat Capabilities Development Command (CCDC) and the Commanding Officer of the USCG Research and Development Lab. Pictured are the visiting Flag and General officers: MG William Cooley (AFRL), MG Cedric Wins, (CCDC) and RADM David Hahn, (CNR). The lab synch is established for these four members of the National Security Research Enterprise to work together seamlessly in areas of mutual benefit.

Supporting the Mission

Our mission and role on the Coast Guard team has never been clearer. The Commandant's guiding principles are to be **READY**, **RELEVANT** and **RESPONSIVE**. These principles extend to the R&D world of work as being ...

READY
by finding and
introducing new technology,

RELEVANT
by serving as S&T advisors with an engaged partnership network of DHS and DOD labs, industry, and academia and

RESPONSIVE
by together, solving
today's challenges.

Connect with RDC

Would you like to learn more about the RDC?
Contact us! We would love to hear from you.

For questions about the RDC or for more information on our research projects, contact **RDC.Technical-Support@uscg.mil**

For all other questions, contact **research@uscg.mil**

Coast Guard military, civilian, reserve, and auxiliary can submit ideas through **https://cg-ideasatwork.ideascalegov.com**

To access public domain reports: **https://discover.dtic.mil**

Public website: **https://www.dcms.uscg.mil/Our-Organization/Assistant-Commandant-for-Acquisitions-CG-9/Research-Development-Test-and-Evaluation/Research-and-Development-Center** (Includes link to RDT&E Project Portfolio)

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