The Maritime Security Center (MSC)

at Stevens Institute of Technology

Hoboken, NJ

Annual Report

Year 6

July 1, 2019 through June 30, 2020

draft submitted

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1. Background

The Maritime Security Center (MSC), a Department of Homeland Security (DHS) Science and Technology (S&T) National Center of Excellence (COE) was established in 2014 as a result of a competition conducted by DHS's Office of University Programs (OUP). MSC is led by Stevens Institute of Technology and this report is based on activities that were conducted by the MSC at Stevens under the Cooperative Agreement during Year 6 (July 1, 2019 through June 30, 2020).

MSC is composed of a consortium of internationally recognized research universities, including Stevens, Rutgers University, University of Illinois at Urbana-Champaign (lead university for the Critical Infrastructure Resilience Institute Center of Excellence), MIT, the University of Miami, the University of Puerto Rico, Louisiana State University, Florida Atlantic University, Purdue University, and Elizabeth City State University as well as industry partners, including the American Bureau of Shipping (ABS). The contributions of each partner institution during the reporting period are provided with the corresponding projects in this report.

MSC's mission is to develop both fundamental and applied research to support DHS's and other agencies' maritime security mission goals, including improved detection and interdiction capabilities, enhanced capacity to respond to catastrophic events, and a more secure and efficient Marine Transportation System (MTS). MSC has been focusing on interdisciplinary DHS mission-driven research, education, and technology transition in maritime security, maritime domain awareness, and resiliency issues. Our goal is to develop and transition research and technology solutions and educational programs to DHS maritime stakeholders, such as the US Coast Guard, Customs and Border Protection, Immigration and Customs Enforcement, and other related agencies and to improve capabilities and capacities for preventing and responding to events in the maritime domain. The next section describes the research projects.

2. Research Projects

This section discusses the Low-Cost Covert Sensors for Remote Locations, RF Surveillance, Safety and Security of Remote Bridge Operations, and VTS Radar for Small Vessel Detection research projects. These projects were in the work plan that was approved for Year 6.

2.1 Low-Cost Covert Sensors for Remote Locations Project

2.1.1. Changes from Initial Workplan

Due to the COVID-19 pandemic and travel restrictions, several changes of the initially approved workplan were made. These changes are mainly connected with the travel restriction that did not allow us to conduct the planned tests in the Padre Island area. Also, the development of the new system software and hardware progressed slower than originally planned, because the research team members did not have access to the laboratory and offices and had to work from home.

We conducted the first Padre Island test in January 2020. This test provided the basis for the development of an integrated system that can combine data from the sensors tested. The MSC's work from April through July concentrated on the development of prototype algorithms for data fusion of AIS, acoustic, optical, and radar data that can be used to generate a target contact report, including alerts to the USCG regarding detected targets.

This work was conducted according to the initial workplan, but it progressed slightly slower than the original schedule. Due to the inability to conduct another test at the Padre Island area, we decided to conduct the field tests in the Hudson River, where we can detect and tack a large number of various boats. We installed the low-cost sensor suite on the Stevens campus on the sixth floor of a building facing the riverfront. This setup allowed radar, optical, and IR detection of various boats on the Hudson River under various environmental conditions. The collected data was used for the development of a data fusion algorithm. The results of this work were reflected in an interim report that was shared with DHS and the USCG on July 10, 2020.

2.1.2. Objective/Purpose

Detection of small boats, semisubmersibles, and underwater vehicles is required for several USCG missions, including drug and alien migrant interdiction, monitoring, control, and surveillance of illegal, unregulated, and unreported (IUU) fishing, as well as protection from maritime terrorist activity. Detection and monitoring of vessels involving illegal activity occur principally through the collection, analysis, and dissemination of tactical information and strategic intelligence combined with effective sensors operating from land, air and surface assets.

The USCG is looking for low-cost, unmanned, maritime domain awareness technologies and sensors that can monitor remote locations covertly and provide actionable information. We had planned to build and test in the field a low-cost sensor suite prototype that can work autonomously at sea using available platforms (oil rigs, navigation and communication buoys, land communication and security towers, etc.). Therefore, we proposed an experimental sensor suite that uses low-cost COTS sensors (marine radar, optical/IR cameras, and AIS receivers) and the Stevens passive acoustic system prototype with low-cost hydrophones. The acoustic sensors will enable reliable detection of small boats at night and in fog conditions, Semi and Fully Submersible, and boats covered by blue tarps, that other methods cannot detect reliably (see Figure 1). The acoustic system will employ modern methods of signal processing that have been recently developed for acoustic target detection, tracking, and classification. Data integration of the acoustic data with other sensors will be applied to generate a target contact report that will be sent in the form of an alert to an appropriate operations center. The suggested system has the following advantages:

1. The main detection sensors are radar and acoustics. A camera is pointed to a Target of Interest (TOI) by the main sensors and used for classification and confirmation. AIS is used for separation of legitimate boats.

2. The system is autonomous. It does not require a human in the loop. The system sends an alert and contact report with target images to a command center.
3. Acoustic sensors have longer coverage than radar and allow detection of Self-Propelled Semi-Submersibles (SPSS). SPSS are loud and can be detected at long distances (up to 40 km).

Figure 1. Targets of Interests: Panga with contraband (top left), Lancha conducting illegal fishing (top right), Self-Propelled Semi-Submersibles (lower left), and floating contraband (lower right).

The schema of the suggested low-cost system installed on an oil rig is shown in Figure 2.

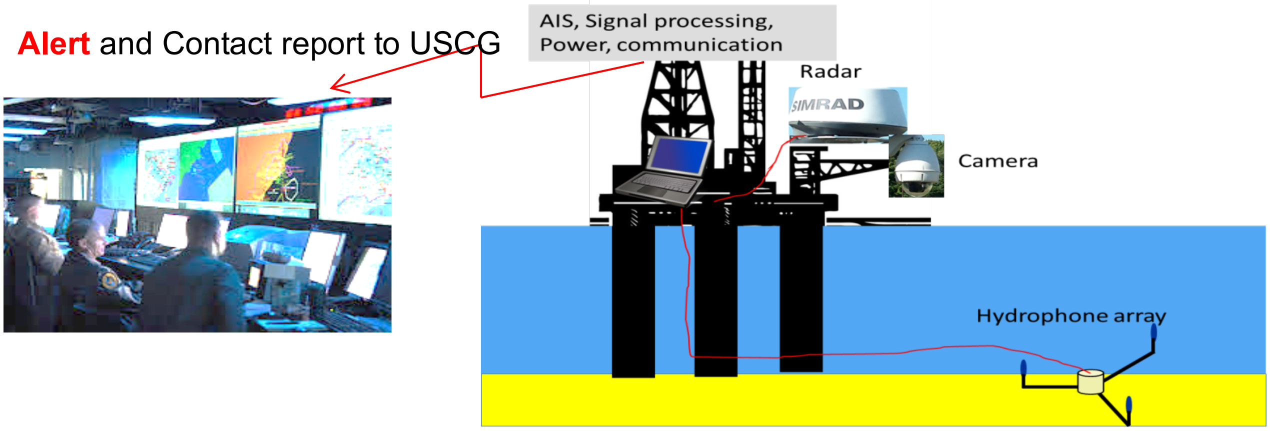

Figure 2. Schema of the suggested low-cost system installed on an oil rig.

There is currently no low-cost system available on the market to provide autonomous, persistent maritime domain surveillance for the detection and classification of small boats, go-fast boats, and semi-submersibles. This research will contribute to testing the applicability and practicality of such a system for use by the USCG for illegal traffic detection.

2.1.3. Baseline

The USCG has various sensors installed on land, cutters, aircraft, helicopters, unmanned aircraft systems (UAS) and satellites that detect small illegal boats (Figure 3).

Figure 3. USCG systems used for detection of small illegal boats.

These systems have several limitations:

- The land-based radar and EO/IR systems have limited coverage and can detect small boats in the proximity of a USCG sensor tower.
- Aircraft and helicopter radar and EO/IR systems are expensive, and their operation is labor intensive and costly.
- UAS based sensors are less expensive, but still labor intensive since they require a team of UAS operators.
- Satellite images are expensive and satellite coverage is very limited and not always available.

The suggested low-cost automated sensor system has a cost that is several orders of magnitude lower than current land and air-based sensors and does not require a human in the loop for its operation. This system can be installed on abandoned oil rigs, various meteorological and navigation buoys, and remote shore locations.

State of the Art for Small Boat Detection Sensors

There are various kinds of sensors that can be used for the detection of illegal small boats. COTS sensors that can be used for open sea surveillance include:

Automatic Identification System (AIS). AIS is an inexpensive sensor and an absolutely necessary component of Maritime Domain Awareness (MDA). In multi-target scenarios (which are usually the case), it is essential to associate AIS data with other sensor data in order to separate large ships equipped with AIS from small boats with no AIS. US regulations require ships of 65 feet long or longer, self-propelled vessels that are certified to carry more than 150 passengers, towing vessels of 26 feet long and more, and all flammable cargo vessels to carry AIS.

Radar. Radars are the major marine surveillance tool with quite a long surface ship detection range. Because of that, radars are often considered as a primary MDA sensor. There are two major classes of MDA radars: impulse and FMCW (Frequency Modulated Continuous Wave). In both classes, there are three types of radars: mechanically scanned small array (“radome”), mechanically scanned large open array, and electronically scanned arrays. Large open array impulse radars provide high angular resolution and are used in ports for VTS (Vessel Traffic Service), which make those sensors a natural candidate for MDA in ports and harbors. An example of such a radar is the Terma Scanter 5202 VTS and Security Surveillance radar. It can detect a small boat at nine nautical miles with angular resolution of 0.3° and a range resolution of ten feet (Moller-Hundborg, 2013). The price of that class of radar is in the $100,000 to $300,000 range (Ender, 2013). In rough sea conditions, starting from sea state 3 on Beaufort scale (wave height 3.5ft), it is almost impossible for the radar to detect a small boat. There are special computer algorithms and software for clutter suppression, but that signal processing requires a powerful computer. For example, Rutter Inc. (Canada) offers a SigmaS6 Radar Processor which by itself needs a full-scale computer platform with 300W power consumption (Sigma S6 processor brochure).

Optical camera. In most existing MDA surveillance systems, a camera is used as a target recognition (identification) tool. It can be slaved to a radar and directed to the targets. To be recognizable, the target must be represented by at least 32x32 pixels in the camera image (Tollabara, 2009). For a standard HD network security camera with image size 1080x1920 pixels, a small boat at one nautical mile distance is presented by only a few pixels, so true optical zoom is needed. This is why a camera in the “master-slave” configuration is usually a PTZ (pan, tilt and zoom) camera with at least 10x true optical zoom, and a sophisticated slew-to-cue control and query algorithm is required (Cortese, 2016). Newer cameras provide ultra HD 7360x4128 pixels (Avigilon 7K HD Pro). Canon is working on a super HD surveillance camera with 19580 x 12600 pixels (Gray, 2017). Axis Communications Inc. offers an ultra HD dome camera (Axis Q3709-PVE) with three sensors providing 3x(3840x2880), 11520x8640 pixels total, with 180° field of view for $2058. Such types of cameras represent a small boat at about four nautical miles distance with enough pixels for target recognition without PTZ. The whole camera field of view (usually about 80° or more) is preserved and the camera can work as a small boat detection tool at long range and with a wide field of view, comparable to the radar. Such processing algorithms exist already (Broek et al, 2008), (Toet and Wu, 2008). Even with standard HD cameras, a kayak was detected at 1250m range after applying those methods (Bouma et al, 2008).

Acoustic systems. Single hydrophones and hydrophone arrays are widely used in the ocean for fish and mammal detection, tracking and estimation of their population. These systems are used for the detection, tracking and classification of surface and underwater vehicles. A large number of acoustic buoys are used by the US NAVY for submarine detection (Wignall 2003). It is an easily-deployable system that can be deployed from the air or from a boat. Different sonobuoys like Superdirective Directional Sonobuoys, Planar Array Directional Sonobuoys, Monostatic Active Sonobuoys, Multistatic Source Sonobuoys, Omnidirectional Sonobuoys, etc. are used depending on the type of application. They have different specifications (bandwidth, working frequency, dimensions, etc.). The main disadvantage of the NAVY sonobouys for the USCG purposes is their short lifetime, that does not exceed eight hours. Also, the use of US NAVY systems by other agencies may be complicated and sometimes restricted.

A number of various underwater acoustic recorders were developed for marine mammal investigation. A review of autonomous recorders for Passive Acoustic Monitoring (PAM) of marine mammals is given by Sousa-Lima et al, 2013 and Dudzinski et al, 2011. These systems only provide recording of the acoustic signals similar to the Stevens Portable Acoustic Recorder (PARS), that will be used in the first phase of the suggested project for recording of the acoustic signatures of boats and ambient acoustic noise. A real time underwater acoustic surveillance system can be realized with a system providing communication with a C2 center. These systems can send raw acoustic signals there or provide onboard signal processing and send information about any target detected.

A list of the experimental and COTS systems with communications capability is presented below.

RTsys Marine Technologies. One of the most suitable systems for boat detection is the Remote Hydrophone Buoy developed by the French company (RTsys Marine Technologies, 2017). RTsys offers moored or drifting buoys that are able to store recorded acoustic data or to transmit them if they are within range of Wi-Fi or a radio transmitter. This system fits our purposes, but its high cost does not provide the desired low-cost sensor suite that the USCG is seeking.

Seiche PAM systems (http://www.seiche.com/). Specializing in underwater acoustics and noise measurement, Seiche claims to be the worldwide market leader in the provision of Passive Acoustic Monitoring equipment for the oil and gas, renewables, construction and marine science sectors. Seiche produces various types of sensors and their shore-cabled PAM looks similar to Stevens Passive Acoustic Detection System (SPADES) and may potentially provide similar performance for small boat detection, tracking and classification if specialized software is developed for this purpose. The cost of the system is too high for a low-cost sensor suite application. Also, the current system will require significant time and cost to modify its software, given the resources that were required to develop SPADES algorithms and software.

SA Instrumentation PAM **(**http://www.sa-instrumentation.com/**).** This company produces Data Acquisition Cards for Passive Acoustic Monitoring. Stevens has been using data acquisition cards from National Instruments and is satisfied with its performance and cost-competitiveness.

Acoustic Vector Sensors from Microflown (http://microflown-maritime.com/products/buoy/). Microflown has developed a new kind of sensor that measures pressure and velocity. This sensor allows direction measurements for acoustic sources. Microflown produces these sensors for acoustic buoys and for sea bottom mounted platforms. Technically, the Microflown sensors can be used for acoustic surveillance, but their cost exceeds a hydrophone cost by a hundred times and they do not provide any significant advantage over SPADES, that can justify this substantial cost difference.

The following acoustic systems were used in various experiments, but they are not available on the market for purchasing, and it is not clear that they can be produced inexpensively or quickly for the USCG applications.

SOBEK. SOBEK is a cabled microphone array that was developed and built by the Netherlands Defense Institute, TNO. This system uses 19 hydrophones with fixed separation and was tested for diver detection in joint tests with the Stevens SPADES in Den Helder, Netherlands (Fillinger et al, 2010). This system is heavy and is expensive to manufacture. Also, it requires a significant amount of signal processing as compared to SPADES.

DMON. The digital acoustic monitoring (DMON) instrument consists of a single hydrophone (Baumgartner et al, 2013, 2014). It provides real-time reporting of baleen whale passive acoustic detections from ocean gliders. This system is capable of recording low-frequency audio (continuous or duty-cycled), detecting, characterizing, and classifying the calls of right, humpback, and fin whales, and relaying detection and classification data to the platform to which it is attached. It was used on gliders and on moored acoustic buoys as a part of NEPAN: A US Northeast passive acoustic sensing network for monitoring (Van Parijs et al, 2015). These platforms transmit summary and detailed detection data generated by the DMON/LFDCS to a shoreside server via Iridium satellite, where it is immediately posted to a Website (http://dcs.whoi.edu). This is also an experimental system with a single hydrophone that cannot provide bearing to the acoustic target and its localization.

Seaweb and RACOM. The Naval Postgraduate School (NPS) and its research partners have advanced the "Seaweb" system to a point where it now routinely demonstrates capability for maritime surveillance, anti-submarine warfare (ASW), oceanographic sampling, instrument remote-control, underwater navigation, and submarine communications at speed and depth (Rice et al, 2010; Seaweb, 2012). Seaweb is a distributed network of autonomous underwater sensor nodes, repeater nodes, and gateway nodes. Digital communications are performed with through-water acoustic modems. In 2010, NPS implemented and deployed a true maritime surveillance network in partnership with the University of Texas Applied Research Laboratory and SPAWAR Systems Center Pacific. A Seaweb network with underwater passive acoustic directional sensors was fielded in the Intracoastal Waterway at Morehead City, North Carolina on the U.S. eastern seaboard. Seaweb through-water acoustic communications delivered the contact report via a scalable wide-area underwater network including multiple acoustic repeater nodes and a Racom gateway buoy. The Racom gateway telemetered the contact report via Iridium satellite communications to an ashore command center with low latency. The in-situ acoustic detection was corroborated using shore-based video surveillance to classify the contact as friendly or hostile. This system is extremely complicated, heavy and expensive to build and operate.

POAWRS. The passive ocean acoustic waveguide remote sensing (POAWRS) – Huang et al, 2017 – consists of 160 hydrophone elements, providing roughly two orders of magnitude higher array gain than a single hydrophone is used to detect underwater sound radiated by surface ships over wide areas. This system is too expensive for a low-cost sensor suite application.

Some of the systems described above can be used in the proposed low-cost sensor suite, but they are rather expensive. We decided to use a low-cost radar and a camera and to build our own acoustic system that costs a fraction of a COTS acoustic system.

2.1.4. Methodology

This project's overall objective is to show a proof of concept of a low-cost sensor suite to assist the USCG and partner law enforcement agencies (e.g., CBP, ICE, police departments, etc.) to detect illegal maritime activity, such as drug trafficking, illegal fishing, and illegal immigration. The proposed main part the work was based on a real deployment of a low-cost sensor suite in an operational area near the Padre Island National Seashore (PINS) and the collection of data for various boats, including Targets of Interest, legitimate water traffic, and USCG boats that can be used to imitate a smuggler boat behavior. The collected data had to include acoustic, radar and optical signatures of various boats and environmental noise data that limit the detection distances.

Due to COVID 19, work and travel restrictions did not allow us to conduct all planned tests at the Padre Island National Seashore. The first test was conducted there in January 2020 and given the current state of the pandemic and resulting travel/work limitations, there is little chance that we will be able to conduct additional tests there in the near future. We developed contingency plans to conduct our tests in the Hudson River, where the variability of surface vessels is large and far exceeds the variability of vessels in the Padre Island area.

The data from acoustic, optical and radar boat signatures collected in the Padre Island and in the Hudson River tests are used for the development of special software for automated acoustic, optical and radar target detection, tracking and classification. Data integration of the acoustic data with other sensors is applied for the development of software generating a target contact report that can be sent in the form of an alert to an appropriate operations or command center.

2.1.5. Milestones and Performance Metrics

The project milestones and performance metrics were identified in the work plan. The milestones and the performance metrics were reviewed with the USCG and DHS representatives as shown in Table 1.

Table 1. Review of the milestones and the performance metrics with the USCG and DHS representatives.

Time of event	**Meetings with USCG**
Sept. 2019	Kick-off meeting
Oct. 2019	Stevens team visit to Corpus Christi and Padre Island National Seashore
Jan. 2020	Discussions with USCG Sector Corpus Christi during the field test at Padre Island National Seashore
May 2020	Online Stevens Maritime Security Center Annual Review Meeting

Table 2 below presents the milestones according to the initial work plan.

Table 2. Milestones according to the initial work plan.

No.	**Milestone**	**Time Frame**
M1	Kick-off meeting to discuss project plan, objectives, and outcomes	9/19/19
M2	The experimental sensor suite showing data recording from radar, optical and acoustic sensor for detection tracking and classification of surface and underwater targets will be built and successfully deployed on the oil rig in the Padre Island National Seashore area.	05/19/20
M3	The advanced prototype algorithms and prototype software showing surface and underwater target detection, tracking and	12/19/2020

	classification for radar, optical camera and acoustic sensors. The data fusion algorithm will generate an alert (contact report) that will be sent to the UCCG sector for illegal traffic interdiction. The developed software and its description will be delivered to the USCG.	
M4	The sensor suite prototype will be capable of operating in an unattended mode enabling reliable, persistent detection of vessels in the Padre Island National Seashore area.	3/19/2021

Milestone 1 was completed on 9/19/19. The planned output of Milestone 2 was the low-cost small boat detection system tested in real conditions at on an oil rig in the Padre Island National Seashore area. The experimental sensor suite showing data recording from radar, optical and acoustic sensor for detection, tracking, and classification of surface and underwater targets was built and tested in slightly different conditions than planned. The developed system could not be installed on an oil rig due to COVID-19 travel restrictions. According to our contingency plan, the two setups were installed and tested in New Jersey.

In January of 2020, the first test was conducted in the Padre Island area in Texas in the Area of Responsibility of the USCG Sector Corpus Christi. The original plan was for the installation of a prototype sensor suite with recording capability at an oil rig in the Padre Island area, however, due to logistical delays with offshore wellheads and oil rigs in the area, a shore-based setup was deployed instead. The shore-based setup provided the information needed for the development of the sensor suite appropriate for this area, whether the final result is shore-based, or offshore. Pictures of the installed system are shown in Figure 4.

A Portable Acoustic Recording System (PARS) was deployed 1.5 nautical miles (nmi) offshore, to record underwater noise that can be used to detect powerboats and other noise sources. This setup allowed us to study the environment in terms of background noise from the perspective of radar and acoustic sensors and approximated the depth, and noise levels at an offshore oil rig.

The focus of this specific deployment was to study the area in terms of sources of noise and clutter and study targets specific to the location (uncooperative Lancha boats).

Due to foggy conditions, only one target - a low-profile boat with 25 ft in length was investigated. The test results demonstrated that the acoustic detection distance reached 8.7 km and the radar detection distance was about 2 km.

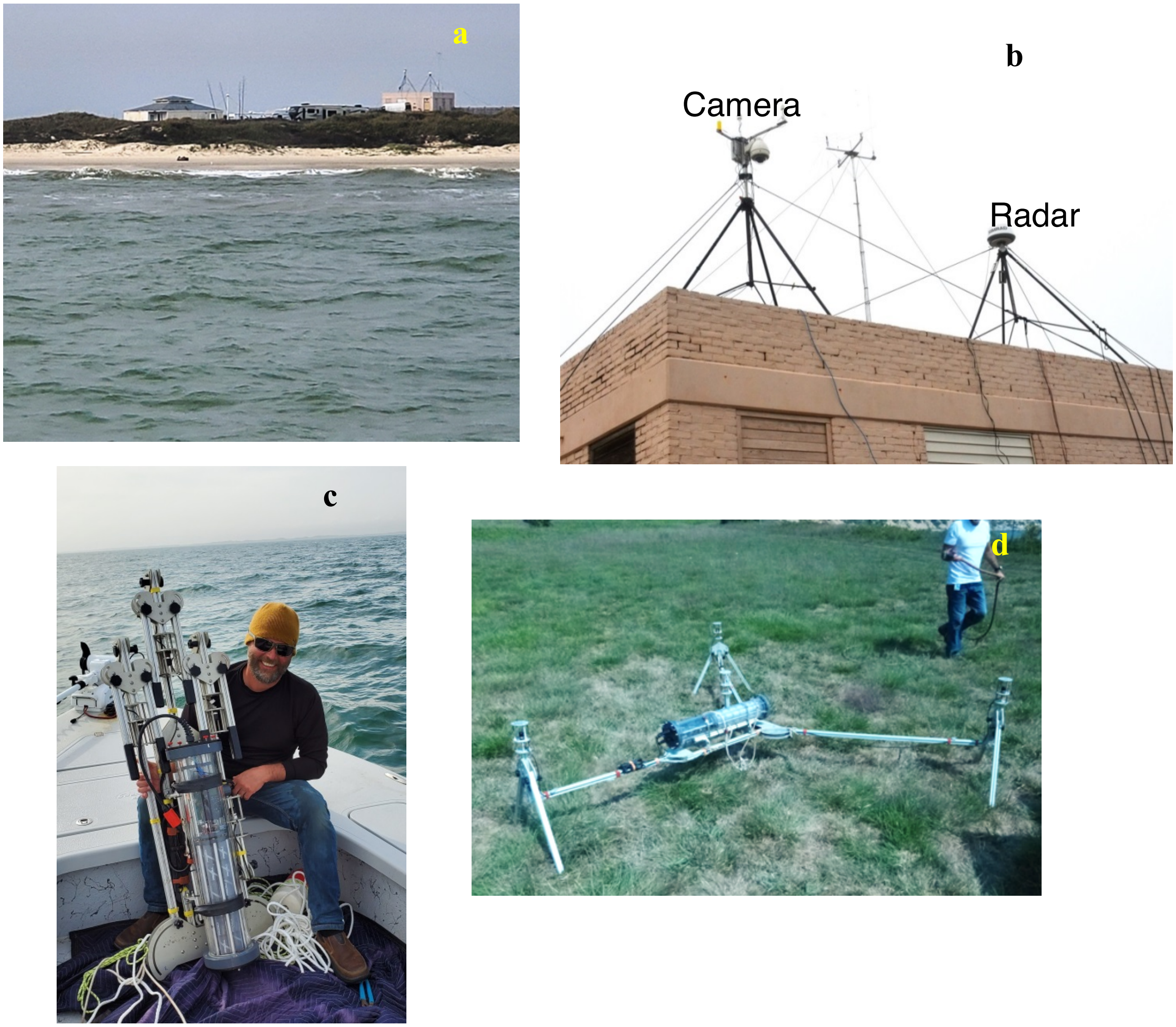

Figure 4. Low cost sensor set up installed at Padre Island: a) View of the warehouse with sensor installed. b) Camera and radar on the warehouse roof. c) Folded acoustic recording system on the boat before deployment, d) Unfolded acoustic recording system on the land.

A similar system including a radar and camera was installed at the Babbio Center building at Stevens (see Figure 5). The building (Babbio Center) has a patio that provides a clear view to vessel traffic on the Hudson River. The setup allowed radar, optical, and IR detection of various boats on the Hudson River under various environmental conditions. Work on an improved acoustic system based on lessons learned from the Padre Island testing is progressing.

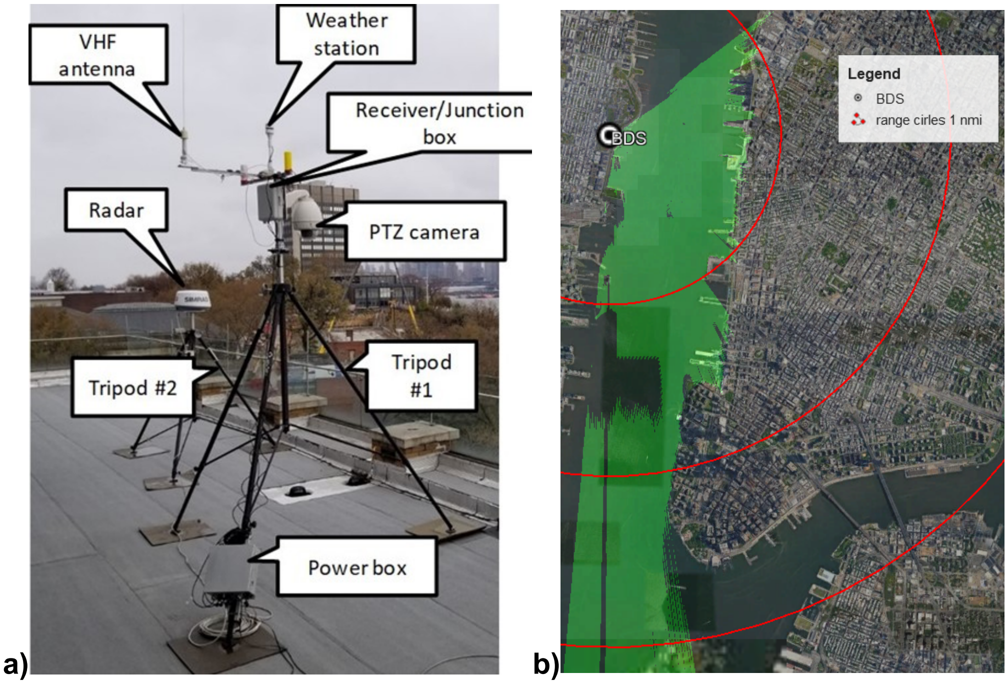

Figure 5. Boat detection system (BDS) installed at the Babbio Center building at Stevens Institute of Technology: a) picture of the system installed and parts, b) map of deployment and viewshed of the system (the green area is visible from the standpoint of the system).

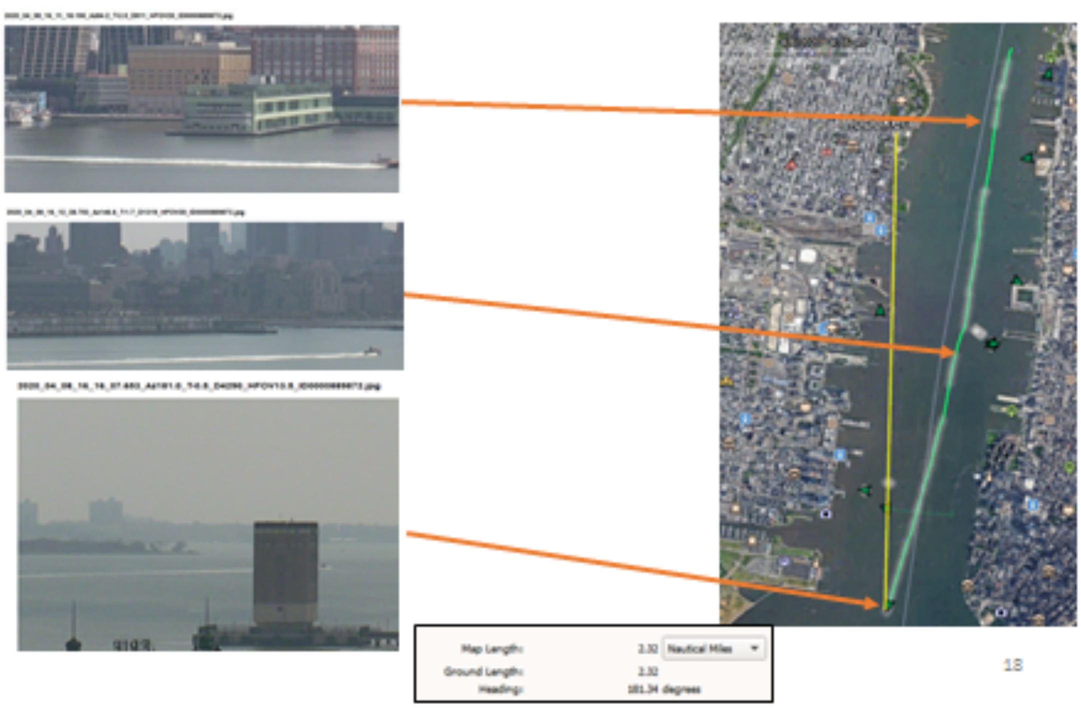

Figure 6. Radar and optical images of a small police boat at distances up to 2.32 nmi (4.3 km).

The installed system provided data recording for different types of boats in the Hudson River. The example of Figure 6 shows radar and optical images of a small police boat at distances up to 2.32 nmi (4.3 km).

2.1.6. Transition Considerations

The suggested low-cost sensor suite will effectively improve surveillance, detection, classification, and identification of vessels both on and below the water surface and to enhance homeland security mission capabilities in providing persistent surveillance of ports, coastal approaches, maritime sanctuaries, protection of sunken military vessels and wrecks, fisheries, and smuggling activities and will reduce personnel costs without degrading mission performance.

Given the state of maturity of the developed sensors and the experience we have in transitioning solutions to an operational setting, we feel that this solution has a path to be successfully transitioned to the USCG. Also, given that the system does not need to use USCG operational data or its network, it makes transition easier and quicker.

The land-based part of the low-cost sensor suite consisting of radar, camera and AIS with the developed software for automated boat detection and tracking is near completion. A picture of this system is shown in Figure 7. The cost of the sensors and computer is approximately $6K. Solar power and communications may be added.

Figure 7. The land-based part of the low-cost sensor suite consisting of Radar, Camera and AIS.

The software providing automatic radar detection of boats and cueing of the camera to the detected boats was developed and tested.

The full system includes an acoustic sensor that provides longer coverage than radar and optical sensors, as well as the ability to detect Semi Submersibles and classify targets based on acoustic and optical signatures. The estimated cost of the Stevens Passive Acoustic Detection System (SPADES) with a cable connection is $20K. It requires sensors on the sea bottom and a land-based computer. An oil rig is the best place for the system deployment.

This system can be installed at remote shore locations and on various carriers including oil rig, buoys, and Unmanned Surface Vehicles (USV) – see Figure 8.

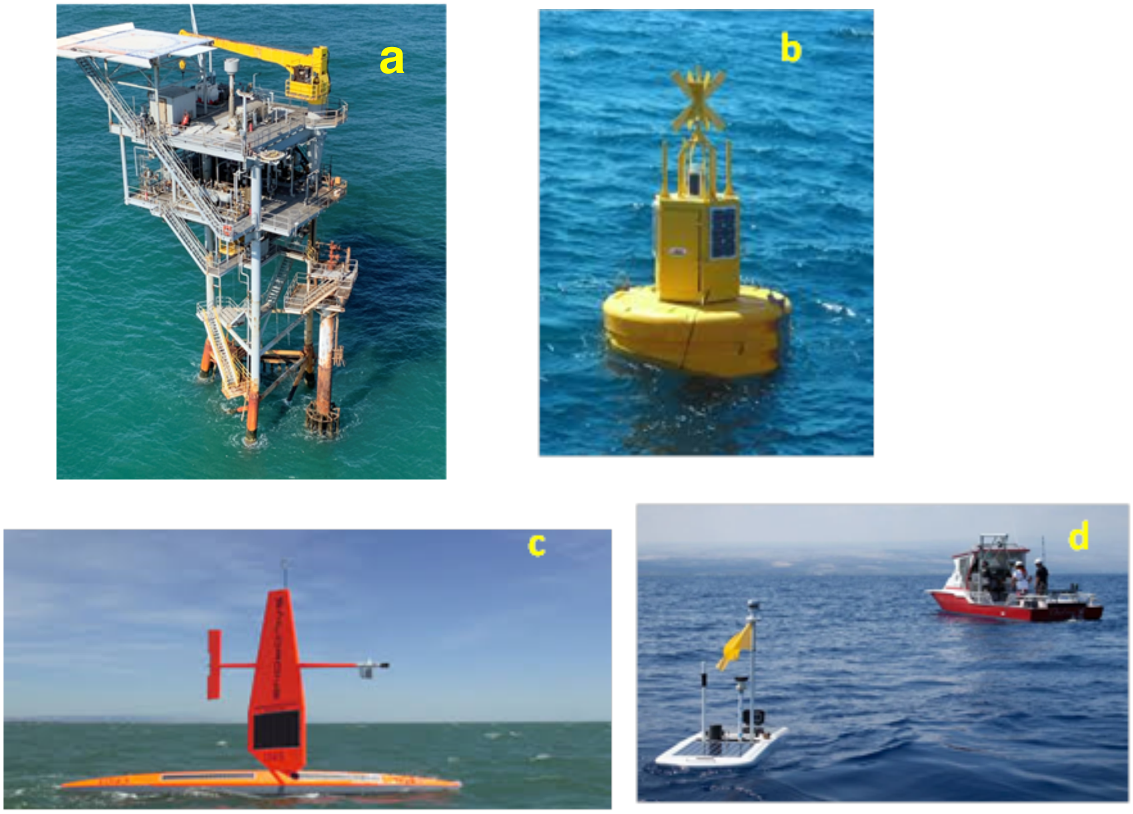

Figure 8. Possible carriers for the low-cost sensor system installation: a) Oil rig near Padre Island that was initially planned for the system installation, b) Meteorological buoy, c) USV produced by Saildrone Inc. of Alameda, California, d) USV Wave Glider manufactured by Liquid Robotics.

The development steps will include preparation and adjustment of the system for installation on the chosen carriers, and organization of power and communications. Additional work can include:

- Increasing the detection range of the land-based system with radar and camera, including the addition of an IR camera to the system, and preparation of documentation for system transition.
- Development of software for localization of TOI using triangulation from several acoustic sensors.

Intellectual Property Management Plans

The principles of acoustic signal detection are based on two Stevens patents:

1. Salloum, H., Sedunov, A., Sedunov, N. and Sutin, A., Stevens Institute of Technology, 2017. Passive acoustic detection, tracking and classification system and method. U.S. Patent 9,651,649.
2. M. Bruno, B. Bunin, L. Fillinger, H. Goheen, A. Sedunov, N. Sedunov, A. Sutin, M. Tsionskiy, J. Turner, M. Kahn, H. Salloum. Passive acoustic underwater intruder detection system. Patent number: 8195409. Issue date: Jun 5, 2012.

During the work on the project, numerous improvements to the existing SPADES have been made. Improvements continue to be made. We are planning to submit an improvement patent application to include the modifications made so far. We will also be seeking companies to license the technology.

Market Specific Considerations

This project's main goal is to prove the concept of a practical, low-cost sensor suite for assisting the USCG in their drug interdiction mission. At the conclusion of this project, the applicability of the work, the practicality of the system, and the ease of operation will be discussed with the USCG to determine transition path and requirements.

If the system provides the functions and performance needed by the USCG, we will seek a company to license and manufacture the sensor system. Our priority will be given to companies that have been selling maritime products to the USCG. Then the existing USCG acquisition process can be used to purchase this system.

During the preparation stage for system manufacturing, we plan to prepare all system documentation as well as training materials as we have done in the past for similar systems and provide these as part of the transition for future phases of this work. These will include the following: principles of operation, system architecture, system specifications, system configuration and revision history, Level 3 drawing package, Interface Control Documents (ICDs), component supplier noted on drawings, set-up/tear down manual, permission to operate, operator manual, maintenance and spares requirements for 3 years of operation. The software will be prepared as an executable package with installation and user manuals for the USCG to evaluate.

2.1.7. Stakeholder Engagement

The USCG is the primary stakeholder for this work. This work will also benefit the USCG partners that are connected with the US efforts for drug and human traffic interdiction, including CBP, Joint Interagency Task Forces, ICE, Drug Enforcement Administration (DEA), as well as local and state law enforcement agencies.

The need of the USCG for the suggested work has been articulated by USCG Sector Corpus Christi in discussions with researchers from Stevens. The Stevens team visited Corpus Christi in February of 2017, October of 2019 and in January of 2020. The USCG provided information needed about Targets of Interest (Lanchas), conducted helicopter surveillance of oil rigs, and provided access to the land deployment side. The team was able to gain first-hand insight into the terrain where illegal drug operations often occur in order to propose technical solutions to improve drug interdiction operations. The team also observed the environmental limitations, including access to the beach area, protected species, available locations for installation and communications, etc. associated with the geographical area.

The MSC team actively engaged the USCG stakeholders in this project. The USCG POC was engaged throughout the planning and execution of this project and has acted as the liaison with other USCG personnel.

2.1.8. Potential Programmatic Risks

There are several risks connected with restrictions due to the COVID-19 pandemic as well as risks connected with the physics of the optical, radar and acoustic waves and sensor sensitivity in harsh sea conditions.

COVID-19 Connected Risks

Travel and work restrictions due to COVID-19 did not allow us to conduct the planned field tests in the Padre Island National Seashore area. According to our contingency plans, the field tests will be conducted in the Hudson River where the environmental conditions are slightly different from the conditions in the open sea. For example, waves in the Hudson River are much smaller. Also, the ambient acoustic noise is very different. The Hudson River has higher noise due to industrial activity, water and land vehicle traffic but the river has no snapping shrimp noise that can limit acoustic detection during the summer months. We expected that the developed system will be used by the USCG in real operational scenarios, but the USCG need to gain experience with the developed system before its use. This may delay the system transition to the USCG.

Sensor Connected Risks

The following risks with the physics of the optical, radar and acoustic waves and sensor sensitivity exist:

- Risk may be connected with the limited performance of the low-cost sensors and some of them may not provide the required sensitivity. Low cost IR sensors have low resolution. Optical cameras require light and do not perform at night. The detection range of radar and acoustic systems decreases as sea waves increase. This risk will be mitigated by identifying better sensors for the suite, data fusion of various sensors, balancing their cost versus their performance. This risk will be significantly reduced by implementing a passive acoustic sensor that works in the dark, rain, and fog and can detect low-profile smuggling vessels.

- Another risk is connected with the developed system's operation in exposed harsh sea conditions. All sensors and equipment are affected by long-term exposure to a damp and salty atmosphere. This risk will be mitigated by identifying and acquitting special marine radars, cameras, computers, communication and power systems. Several months of sea field tests will allow estimating the wear and problems with the system and additional methods for system ruggedizing and weather hardening will be applied.

2.1.9. Progress Against Milestone Outcomes

The planned output of **Milestone 2** was the low-cost small boat detection system installed and tested in real conditions on an oil rig in the Padre Island National Seashore area. The initial test was conducted in January 2020 and the following tests were moved to the Hudson River due to COVID-19 restrictions. The system currently installed at the Babbio Center building at Stevens (see Figure 5) provides optical and radar boat detection. The development of the new Stevens Passive Acoustic Detections System (SPADES) is delayed due to the inability to have access to the mechanical shop for building system hardware. The expected completion of SPADES and its deployment in the Hudson River is planned for the second half of September/early October.

Milestone 3 that includes the advanced prototype algorithms and prototype software showing surface and underwater target detection, tracking and classification for radar, optical camera and acoustic sensors (see Table 1) was initially planned to be completed on December 19, 2020. We still plan to complete this milestone on time. The MSC team is actively working on developing the software. The focus of the current ongoing work is to develop prototype algorithms for data fusion of AIS, acoustic, optical, and radar data that can be used to generate a target contact report, including alerts to the USCG regarding detected targets. Currently, several prototype algorithms have been developed and are being tested using the setup installed locally at Stevens. A fusion tracker for AIS and radar data capable of ingesting multiple data streams was developed. A new controller software for the optical camera has also been developed. Finally, a prototype algorithm has been developed to provide the ability to report an alert when any of the sensors has a track of a boat.

2.1.10. Unanticipated Problems

The main unanticipated problems are the secondary effects due to COVID-19. Mainly, these were travel restrictions and the inability to use the lab and machine shop. We addressed these problems according to our contingency plans. We will continue to use our contingency plans to deal with these problems.

2.1.11. Information Supported by Data

The suggested low-cost sensor suite for illegal boat detection will effectively improve surveillance, detection, classification, and identification of vessels both on and below the water surface to emphasize illegal water traffic detection. The suggested sensor suite will also enhance USCG mission capabilities in providing persistent surveillance of ports, coastal approaches, maritime sanctuaries, protection of sunken vessels and wrecks, fisheries, and smuggling activities and will reduce personnel costs without degrading mission performance.

Due to the low cost and simple installation of this system, it will allow permanent surveillance of a much larger ocean area than the currently used USCG sensors at a much lower cost. The data collected during the Padre Island and the Hudson River field tests demonstrates the feasibility of the suggested low-cost sensor suite for illegal boat detection and tracking. These tests allowed the system performance parameters and limitations to become known.

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2.2. RF Surveillance Project

2.2.1. Changes from Initial Workplan

The unforeseen COVID-19 pandemic has decreased the MSC team's ability to develop and build the RF Surveillance System (RFSS) due to limitations of access to the laboratory and field testing. The unavailability of the laboratory for the team to work was partially compensated by organizing small electronic laboratories at the researchers' homes. These small home laboratories allowed the continuation of the RFSS development and testing but made the process slightly slower than it was originally planned. The team is fortunate however, that it managed to conduct a system sea test in Padre Island in January 2020 before the pandemic, as the test was not originally included in the initial workplan. In a stroke of luck, the team was able to leverage a field-test being conducted by another MSC research project and to send along its equipment for a joint field-based test. The research engineers conducting the tests had been working on both the RF and low-cost sensor projects for the Center. This allowed the RF team to pretest its set-up and ultimately to save money in travel costs. The January test demonstrated the ability of the team's first version of the RF signal detector to detect RF communication signals from a small boat at distances up to 13 km.

During the pandemic, we paid more attention to the theoretical part of the work and were able to extend our analysis beyond what the team had previously planned. The novel model for estimating RF signal detection distances was developed and applied for real sea conditions in the proximity of Padre Island. The team developed an antenna simulator that provides simulation of real RF signals for the system testing in laboratory conditions. Currently, we are not able to conduct the planned tests in NJ due to COVID-19 restrictions and have concentrated our efforts on laboratory tests. All other planned tasks will be completed according to the initial workplan.

2.2.2. Objective/Purpose

The USCG plays a crucial role in the nation's efforts for interdicting and countering dangerous narcotic drugs transported in maritime environments. Detection and monitoring of vessels trafficking narcotics occurs principally through the collection, analysis, and dissemination of tactical information and strategic intelligence combined with effective sensors operating from land, air, and surface assets. The USCG is looking for low-cost, unmanned, maritime domain awareness technologies and sensors that can provide an additional layer of intelligence and locate illegal boats and their shore accomplices.

Our work is aimed at the development and building of a low-cost RF Surveillance System (RFSS) that can detect and find the direction to the source of RF signals. RF communication signals radiated from crews of illicit boats and by their accomplices can provide significant intelligence about a boat, its position, its intent and may even be used to detect and localize persons waiting for illegal delivery.

Another application of detecting RF signals from smugglers relates to tactics that allow traffickers to leave a shipment at high-sea attached to GPS-enabled radio or satellite buoys. For this purpose, satellite and radio buoys adapted from the fishing industry are used and the RFSS developed can detect and localize RF radiation from these buoys.

The objective of this project is to investigate opportunities of radio monitoring and localization of various RF emitters onboard of an illegal vessel, on shore and on RF buoys. In this project, we are investigating various opportunities for the development of a radio monitoring system that can detect and localize different RF emitters on boats and emitters on shore (cellular and satellite phones, maritime communication systems, two-way radios, CB radio, GPS trackers using satellite or radio communications, etc.). The experimental RFSS setup was developed based on low-cost COTS components that will allow building a low-cost RF surveillance prototype in the future. This project's goal is to prove the concept of the feasibility of a low-cost capability. Modern electronics, computers and signal processing methods will allow building such a system with features that are higher and comparable with current Electronic Intelligence and Direction-Finding systems that are costly to acquire and operate.

An option of using small Unmanned Aerial Systems (UAS) for recording RF signals is also under investigation. A Software Defined Radio installed on a UAS was tested for recording and localizing RF communications signals from boats. This system can be used on a small tethered UAS to significantly extend the system detection range and operation capacity. This project will provide a proof of concept for a low-cost method that will assist the USCG in detecting suspicious boats at distances exceeding current system detection ranges, will allow detection of GPS buoys, and will provide additional intelligence that can assist in increasing the narcotic and human traffic interception rates.

2.2.3. Baseline

The current methods of Electronic Intelligence and Direction Finding provide a natural background for the development of similar methods for the USCG. The current methods are very costly to acquire and operate and require highly qualified operators. The USCG currently employs a radio monitoring system (Rescue 21) that practically covers the whole US coastline. However, this system is expensive (100s of millions and 10s of millions of dollars to operate) and can only detect and localize distress calls. This system provides detection of the distress call but is not for interception of RF communications.

The USCG has equipment with RF directional finding capability. Practically, all USCG aircraft and helicopters are equipped with direction finders. One main system is the DF-430 Multi-Mission Direction Finder. The DF-430 is specifically designed to receive and interrogate all current international distress frequencies including 121.5 MHz, 243 MHz, 406 MHz, as well as the ARGOS and COSPAS-SARSAT encoded beacon signals.

All current USCG systems are very expensive and require well-trained personnel, which prevents their wide application for illegal boat detection. Their application for USCG needs requires the development and implementation of software for automated short RF communication signal detection and direction finding. Modern electronics, computers and signal processing methods allow the development of a portable, low-cost RF surveillance system that can be used from various platforms including shore USCG stations, cutters, aircraft, and UAS. Note that our proposed method does not require listening in on calls or messages as it detects the RF spectrum of a signal rather than its contents.

2.2.4. Methodology

The primary objective of this project is to provide a proof of concept of an RF communication system for detection, direction finding, and localizing communications made by bad actors performing illegal activity in the maritime environment. A set of target radio bands was selected with advice from the USCG to focus the research experiments on typical radio communication bands. An analysis of communication systems and RF buoys allowed choosing frequency bands that may be used by a crew of an illegal boat. These bands include Citizen Band (CB) radio with frequencies around 27 MHz, VHF, and UHF two-way radios (150-174 MHz and 421-512 MHz) and Satellite phone (1525-1616 MHz).

A method for estimating the detection distances of various communications for parameters of RF sources was developed based on direct Line-of-Sight (LOS) and link budget energy evaluation. The link budget method is especially important for a CB radio that can propagate over the horizon and uses spectrum range that is much less occupied than other frequencies used for communication. The estimation of detection distances was conducted based on known experiments of RF wave propagation above the sea and RF ambient noise measurements in various areas of the US.

The initial detection system was built based on low-cost Soft Defined Radios (SDR). Tests conducted at Padre Island confirmed the feasibility of this approach for reliable detection of communication systems at sea. In this experiment, the detection distance in the VHF band was about 13 km. Analysis of the conducted laboratory and sea tests was used for the design of a few experimental RFSS prototypes providing automatic detection and direction finding of CB radio communication signals. This system is close to completion with laboratory tests expected to be conducted in the near future.

Also, a compact SDR based radio signal recording system for installation of an unmanned aerial system (UAS) was developed and built. The system was investigated in the laboratory and on a grounded UAS. Flight tests were postponed due COVID-19 restrictions.

2.2.5. Milestones and Performance Metrics

Deliverables and Milestones

The project deliverables are shown in Table 1.

Table.1. Planned and modified project deliverables.

	Initial Deliverable	**Deliverable Completion and Modification**
1	Building several setups to prove the concept of the RF surveillance system for the USCG applications in monitoring boat illegal activity.	Completed/exceeded. We conducted a sea field test in Padre Island that was not included in the initial work plan.
2	Investigating a laboratory setup and one at sea at the NJ shore. Finding system parameters and demonstration the applicability of the suggested solution for implementation in USCG operations.	Due to COVID-19 restrictions, the tests were not conducted at the NJ shore. The field test in Padre Island and a number of laboratory tests were conducted.
3	Writing a final report that describes the test and test setups in full, including all research and analyses performed prior to the tests, the testing procedures, data collected, and findings. The report will also include recommendations for building a system optimized for USCG applications.	The final report will be submitted at the end of this project.

The protect milestones and their completion is presented in Table 2.

Table 2. The protect milestones and their completion.

No.	Planned Milestone	Planed Time Frame	Completion
M1	Kick-off meeting to discuss project plan, objectives, and outcomes.	October 2019	Complete.
M2	Experimental RF surveillance setups for land and ship application tested in the lab.	February 2020	Completed. Padre Island field test that was not included in the original workplan was conducted.
M3	An RFSS test platform using laptop computer as main processor has been designed. Simulation of expected signals developed to aid in processing pipeline and algorithm, design while forced outside of the lab.	May 2020	Complete.
M4	Perform laboratory testing of the RFSS test platform upon regaining access to facilities. The goal is to validate system design and detection methodology.	August 2020	70% complete. The system is almost complete and laboratory tests have started.
M5	Create a set of requirements for compressing the RFSS into an integrated SDR platform that is capable of being installed on a UAS and determine if such a design is feasible.	September 2020	Expected to be completed in September 2020.

RFSS Setup and Sea Test in Padre Island

The picture of the sea test setup for detection of RF signals radiated from a small boat is shown in Figure 1. The RFSS sensor setup consisted of three separate raw-data RF monitoring systems and a single wideband analyzer system. Each raw-data RF monitoring system recorded 14-Bit I/Q RF data at a rate of 10 MHz. The wideband analyzer consisted of a Keysight FieldFox, wideband antenna and monitoring PC. Three specific bands were investigated, each with their own antenna deployed on the roof: CB Radio (27 MHz), VHF (144 to 148 MHz), UHF (450 to 470 MHz).

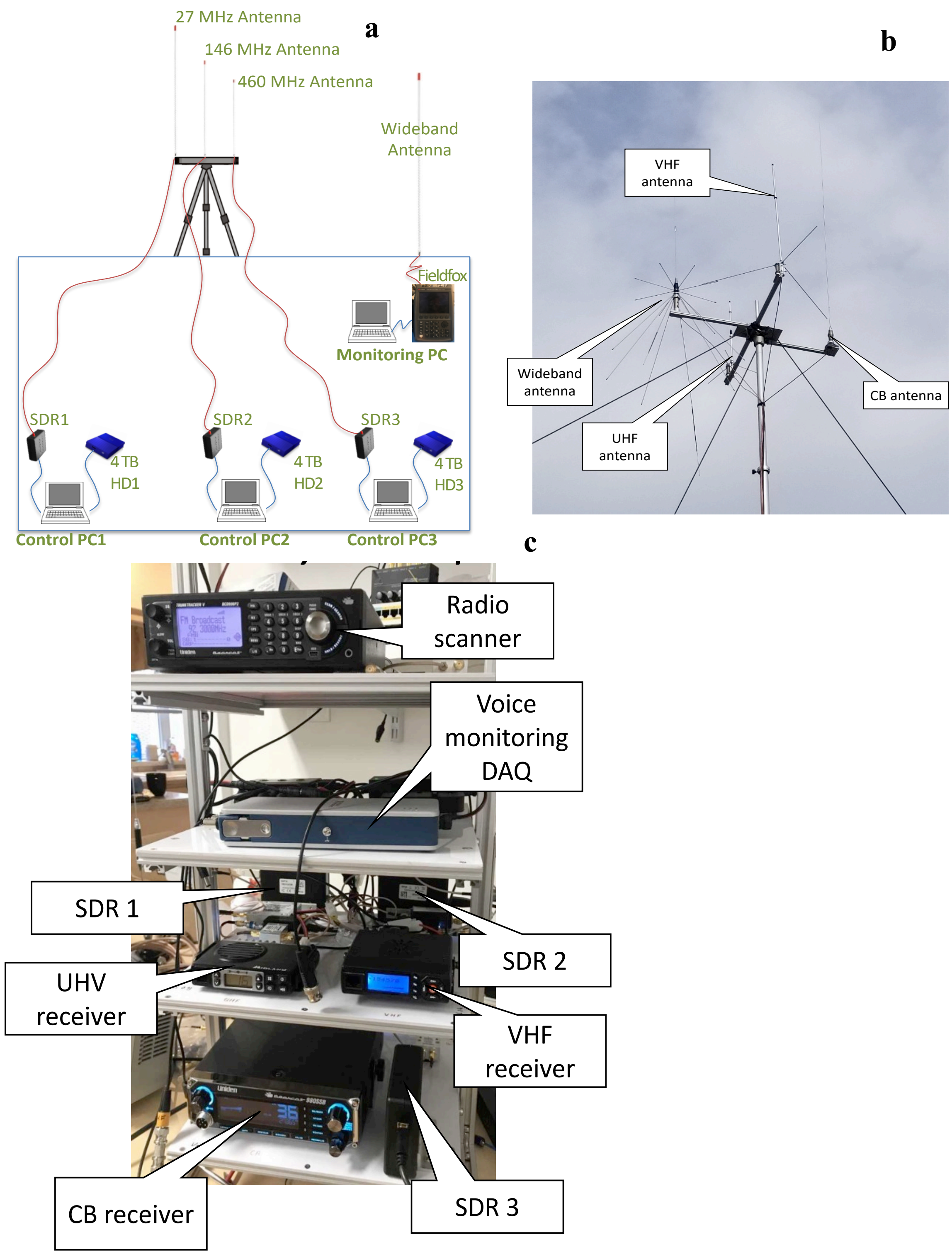

Figure 1. The RF signal receiving setup used in the Padre Island field test: a) Schematic of the shore-based RF receivers setup; b) Antenna system; c) Picture of the equipment.

RFSS Prototype with Direction Finding Capability

We are building an automated Radio Frequency Surveillance System (RFSS) that has a radio direction finder (RDF) based on a Software-Defined Radio and pseudo-doppler principles of direction-finding at its center, along with software that facilitates processing, display, and integration with mapping systems. It is capable of automated multi-channel direction finding in the frequency bands of interest, equipped with a user-friendly interface built using low-cost commercial off-the-shelf components. Currently, the software and the hardware for the initial system are being built for 27 MHz CB radio. The schema of the system with pictures of various system elements is shown in Figure 2.

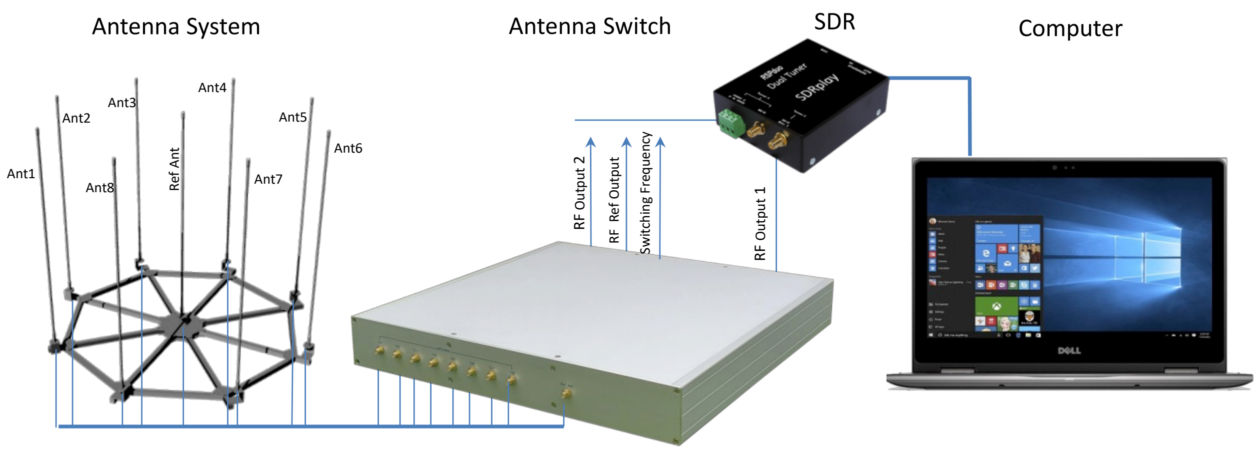

Figure 2. RFSS CB band radio direction finding system.

During this reporting period, software for the angle of arrival (AoA) finding was developed, including a graphical user interface (GUI) for monitoring radio frequency spectrum in real-time and directions towards received signals. The software was tested using simulated RF spectrum data. Additional drivers for interfacing a low-cost dual-channel SDRPlay RSPDuo SDR were developed, along with communication protocols and formats for processed data allowing to transfer data from the low-level software to the GUI and for storage of logs on a disk.

RFSS for UAS Installation

Stevens has developed and built a lightweight and mobile system for RF signal recording from a UAS. This system, dubbed the SDR for Experimental Aerial Mounting (SDREAM) Test Bed, is small enough to be handheld or even attached to a drone in order to facilitate multiple GPS-tagged RF signals recording in a single drone flight. The picture of the RFSS SDREAM attached to the drone is shown in Figure 3.

Figure 3. SDR for aerial recording of RF signals installed on a DJI S1000 UAS.

The SDREAM Test Bed's SDR can operate as a full duplex, multiband radio. The radio has a total operational bandwidth ranging from 70 MHz to 6 GHz, allowing it to function across ISM frequency bands of interest (915 MHz, 2.4 GHz, and 5.8 GHz), as well as many other common communication channels including but not limited to UHF, VHF, 700, Cellular, AWS, PCS, 2600, and L-Band.

The DJI S1000 aircraft was considered as a mounting platform. In order to incorporate the SDREAM Test Bed onto the DJI S1000, a special harness was also 3D printed to facilitate a natural integration between the two systems. As shown in Figure 3, the final construction of the system was able to seamlessly attach to the DJI aircraft. COVID-19 restrictions did not allow us to conduct flight tests of the developed system. SDREAM is ready for testing when restrictions are removed.

2.2.6. Transition Considerations

The resulting research and project report generated from this endeavor will include a prototype of an RF surveillance system optimized for USCG applications. The applicability of such an RF surveillance system, its practical limitations, and its ease of operation will be discussed with the USCG to determine transition requirements and tasks at the end of the project. A user-friendly prototype of an optimal, low-cost system can be built and tested in a Phase II of the project. The proposed system should deliver proven surveillance capabilities of illegal vessels and their accomplices, providing a unique opportunity to enhance the USCG mission capabilities via persistent surveillance of ports, coastal approaches, maritime sanctuaries, and smuggling activities that will reduce operational costs without degrading mission performance.

During the work, Stevens researchers found several novel technical solutions in the RFSS design and signal processing that could be the basis for patent applications. A provisional application (or applications) can be filed at the beginning of a Phase II of the work.

If the system provides the functions and performance needed by the USCG, we will seek a company to license and manufacture the RFSS. Our priority will be given to companies that have been selling maritime products to the USCG. Then the existing USCG acquisition process can be used to purchase this system.

During the preparation stage for system manufacturing, we plan to prepare all system documentation as well as training materials as we have done in the past for similar systems and provide these as part of the transition for future phases of this work. These will include the following: principles of operation, system architecture, system specifications, system configuration and revision history, Level 3 drawing package, Interface Control Documents (ICDs), component supplier noted on drawings, set-up/tear down manual, permission to operate, operator manual, maintenance and spares requirements for three years of operation. The software will be prepared as an executable package with installation and user manuals for the USCG to evaluate.

2.2.7. Stakeholder Engagement

The USCG is the primary stakeholder for this work. A possible list of Stakeholder organizations may include the USCG, NAVY, Customs and Border Protection, Immigration and Customs Enforcement, the Federal Emergency Management Agency, the U.S. Secret Service, the Domestic Nuclear Defense Office, the Federal Bureau of Investigation, Bureau of Alcohol, Tobacco, Firearms & Explosives, the Department of Defense, DARPA, NOAA, DOT Office of Maritime Security, Alliance for Coastal Technologies – ACT, and the National Maritime Security Advisory Committee.

The need of the USCG for the suggested work has been articulated by USCG Sector Corpus Christi in discussions with researchers from Stevens. Stevens team visited Corpus Christy in February of 2017, October of 2019 and in January of 2020. We learned first-hand insight into the terrain where illegal drug operations often occur in order to propose technical solutions to improve drug interdiction operations and illegal fishing interdiction. We also learned about the environment limitations, including access to the beach area, protected species, available locations for installation and communications, etc.

MSC team has actively engaged the USCG stakeholders in this project. The POC from the USCG HQ was engaged throughout the planning and execution of this project and acted as the liaison with other USCG personnel. The results of the work were actively discussed and shared with USCG Project Champions.

2.2.8. Potential Programmatic Risks

We do not foresee any potential programmatic risks that may prevent the successful completion of the project. Previously described risks that can prevent or limit the application of RFSS by the USCG include:

- Risk may be connected with the limited sensitivity of the developed low-cost Electronic Intelligence and Direction Finding setups. We will work on mitigating this risk by adjusting the RF antennas, using specific antennas for various frequency bands, improving of preamplifiers and signal processing algorithms.

- Another risk is connected with the awareness of the illegal boat crew that RF surveillance may be conducted. They may limit RF communication and use short messages for communication. This risk can be reduced by developing signal processing methods for interdiction of direction finding of short communications.

2.2.9. Progress Against Milestone Outcomes

The progress against each milestone outcomes is shown in Table 1. All planned items for the end of July 2020 have been reached, but not in the full scale because of the COVID-19 restrictions. The planned field tests at the NJ shore were not conducted and the development of RFSS system prototype with DF capabilities is moving slower than it was initially planned. COVID-19 restrictions also did not allow us to conduct flight tests of the SDR recording system installed on a UAS.

2.2.10. Unanticipated Problems

We do not foresee any risk for the completion of this project. Due to the COVID-19 pandemic, we have already had to adjust our timeline and tests plans. We concentrated our efforts on the mathematical modelling, software development and laboratory tests that allow successful completion of the project.

2.2.11. Information Supported by Data

The suggested RFSS can effectively improve surveillance, detection, classification, and identification of illegal vessels, their accomplices on the land or at sea and RF buoys used for location of contraband left at the sea. For this project, our aim is to show a proof of concept of a simple low-cost RF surveillance system that can be used by the USCG to aid them with the detection of illegal activities from vessels.

The sea field test conducted in Padre Island demonstrated the reliable detection of RF signals used for two-way communications at a distance of 13 km. We have developed novel algorithms for RF signal detection distance prediction that can be used for estimation of the system performance in the USCG operational conditions.

The RFSS system prototype with direction finding capability (see Figure 2) will be the main output of the project. All parameters describing the RFSS performance are being investigated in the laboratory and sea field tests confirming the predicted and laboratory measured performance parameters will be conducted in a Phase II of the work.

2.3. Safety and Security of Remote Bridge Operations Project

2.3.1. Changes from Initial Workplan

The unforeseen COVID-19 pandemic has inhibited our team's ability to hold face-to-face engagements with bridge owners, operators, and stakeholders as originally stated in our work plan. In response to these circumstances, we have moved our engagements to remote methods. To facilitate gathering the data needed for our researchers the team has engaged with stakeholders through the American Association of Railroads (AAR). In collaboration with USCG and AAR, we have authored a survey to solicit the bridge data needed which will be disseminated to rail operators by AAR. This alternate method will allow us to access a much larger sample set than originally anticipated. We believe this will allow us to conduct a more thorough analysis.

2.3.2. Objective/Purpose

The objective of this project is to enhance the security and resilience of the nation's movable bridge infrastructure by assisting the USCG in developing a sound, voluntary, standardized risk management regime to help guide bridge owners and operators in the implementation and maintenance of remote bridge operations in a more secure and resilient manner.

2.3.3. Baseline

Current and legacy movable bridges are operated by human operators at the bridge site. As the category name implies, remote bridges are operated remotely through commands delivered via information and communications technologies (ICT) to remotely signal the actuators and other components that operate the bridge.

The current baseline concept of operations for cyber risk assessment and management of remote bridges is essentially BYOP (bring-your-own-policy) and BYOS (bring-your-own-standard). Each bridge owner and operator address cybersecurity and cyber risk management in a bespoke manner. There is no mandated or recognized voluntary cybersecurity standard, policy, or framework representing industry/domain best practices. Consequently the various remote bridges stakeholders — the bridge owners & operators; maritime, land and rail shipping companies; regulators; insurance carriers; municipalities, etc. — are unable to accurately assess the relative risk of various remote bridge designs and/or operational procedures and unable to accurately assess the relative cyber risk management maturity of owners/operators that are operating remote bridges. Most importantly, without sound, standardized cybersecurity standards and risk management processes in place, those responsible for public safety and the safety of waterways and highways are unable to accurately assess the safety of movable bridges that have transitioned to cyber-operated remote operations and/or the cybersecurity maturity of their operators.

This project will deliver sound cybersecurity standards and risk assessment and management processes and procedures for voluntary adoption by remote bridge stakeholders to directly address the current deficiencies addressed above. These proposed standards and procedures will be based on sound and thorough research into the potential vulnerabilities in remote bridge architectures and the cybersecurity and operational processes of the operators of those bridges. The framework for the proposed standards and procedures and the security controls required to comply with the proposed standards will be based entirely on national standards issued by the National Institute for Standards and Technology (specifically the NIST Risk Management Framework, NIST Cyber Security Framework and NIST SP800-53).

2.3.4. Methodology

With the support of USCG and engagement with the AAR, this project is conducting a thorough analysis of remote bridge operational architectures to determine best available practices and required security considerations for remote bridge operations. Our analysis will consider analogous operations in distributed cyber-physical systems and identify practices and protocols from other sectors such as pipeline supervisory control and data acquisition (SCADA) systems. Informed by this analysis, the project will develop and publish an annotated Risk Management Plan based on the NIST Risk Management Framework that can be used by USCG as a foundation for policy and guidelines of the domain.

This project will also develop and publish a Remote Bridge Operations Profile based on the NIST Cybersecurity Framework (CSF). Lastly, the project will implement the Remote Bridge Operations Profile in the CIRI/DHS-developed Cyber Secure Dashboard for use by the remote bridge operations community to guide and manage conformance to the Profile.

2.3.5. Milestones and Performance Metrics

Milestone	Description	Completion Date
1	Kickoff Meeting (All)	100% Complete
2	Landscape & Scoping Study	100% Complete
	2a. Bridge Inventory	100% Complete
	2b. Systems Inventory	100% Complete
	2c. Regulatory Review	100% Complete
3	Taxonomy	50% Complete. Expect to finalize the document by August 31, 2020
4	Site Visits	30 June 2020
5	Risk Management Framework (RMF)	Due 30 Sept 2020 10% Complete
	5a. Best Practices	
	5b. Interviews and Sight Visits	
	5c. Draft RMF and tool development	

Deliverable 3 requires engagement with bridge owners and operators to gain a solid foundation of the movable bridge architectures. Deliverable 3 has been delayed due to travel restrictions caused by COVID-19 and the inability to hold face-to-face meetings. An alternative engagement plan was identified in collaboration with the American Associate of Rail (AAR) and USCG and is currently being executed. The identified engagement plan will allow us to capture a broader scope of moveable bridge architectures.

The performance metrics used to evaluate progress and assessments of current concept of operations and baselines/state of the art in use are provided below.

KPM #	Key Performance Metrics (KPM)	Baseline	
		Threshold	Objective
1	Site visits with operators (Remote)	1	5
2	Beta RMF Profile incorporates stakeholder feedback on Alpha profile	Pass	Pass
3	Pilot test of dashboard	3 organizations	5

2.3.6. Transition Considerations

This project intends to transition to the public domain an annotated Risk Management Plan template and the Remote Bridge Operations CSF Profile, based on the NIST CSF. Once these standards are complete, they will be embedded in the Cyber Secure Dashboard.

The Remote Bridge Operations Profile will be implemented in the CIRI/DHS-developed Cyber Secure Dashboard which will be made available on a voluntary basis for use by the remote bridge operations community via commercial license subscription to guide and manage conformance to the Profile.

2.3.7. Stakeholder Engagement

Stakeholders	Role	Interaction date	Outcome
Janet St. John	Director, Cyber Security Association of American RR	6 March 2020	Janet (AAR): Initial discussion to gauge interest, AAR is interested and willing to work with us but due to COVID, schedule is in flux. AAR's intention is to take our project goals and brief them to railways as an opportunity to get involved from an industry perspective on industry/domain best practices. We shared with AAR the following: • Research project summary & objectives • Requested documentation for each bridge

			• List of questions we would ask company representatives • List of bridges we are interested in assessing. AAR requested edits to our document and identified they would like to present the engagement opportunity to all their members. AAR also requested to participate in the objectives of the project in such a way that they reflect a joint guidance document. Modifications were made and AAR will deliver anonymized results from their members by Aug 30, 2020.
Jeff Hieb	Port Security Specialist, Milwaukee	13 March 2020	Jeff agreed to develop a list of key contacts within the City of Milwaukee and to help arrange and coordinate site visits either physical or virtual.
Kamal Elnahal, Ph.D., P.E.	Chief, Bridge Operations and Engineering Division (CG-BRG-1), Bridge Program, U.S. Coast Guard	30 Jan 2020 30 Apr 2020 23 Jun 2020 17 Jul 2020 24 Jul 2020	• USCG updated and satisfied with progress to date. • USCG provided Office of Bridge Programs data for use in landscape study. • USCG sent draft taxonomy and project update. • USCG provided updated objectives per AAR request and satisfied with edits. • USCG provided update on AAR engagement.
Christopher Barkan, Ph.D.	George Krambles Director, Rail Transportation & Engineering Center, UIUC	7 May 2020	Initial discussion to map out engagement with RR owners and operators and rail industry associations.

2.3.8. Potential Programmatic Risks

We do not foresee any risk to the completion of the project. We do however feel there may be potential programmatic risk to the project's timeline. Due to the COVID-19 pandemic, we have already had to adjust our timeline and engagement approach. We have done our best to layout a specific timeline to completion pending further COVID-19 disruptions.

2.3.9. Unanticipated Problems

Due to the COVID-19 travel restriction, we were unable to deliver a taxonomy document according to our project timeline. In response to this unanticipated problem, we moved to a remote engagement with bridge owners and operators to gather the architecture data needed. We pivoted the projects engagement strategy from a smaller face-to-face sample size to engaging with the American Associate of Rail members to collect pertinent data. Our team created a survey that is being distributed on our behalf to AAR.

2.3.10. Information Supported by Data

As stated above, there is no domain-wide cybersecurity standard or standardized cyber risk assessment and management process or even a published compendium of best practices being applied to the transition to remote bridge operations. Bridge owners and operators are individually left to develop, implement, and maintain a cybersecurity posture and risk management process on their own. This lack of standards makes it difficult to assess the relative underwriting risk posed by a particular remote bridge operator which in turn impedes the development of a robust and mature market for cyber insurance in this domain. Likewise, those federal, state, and local government agencies with oversight responsibility for safety of rail, highway, and maritime transportation have inadequate reference points for assessing the safety and security of remote bridge operations.

The outcomes from this project will directly address these issues by delivering proposed cybersecurity standards and best practices that are in compliance with NIST standards and guidelines. Domain-wide adoption of such standards and best practices will establish the foundation for assessing the relative risk of specific remote bridge operations (and the owners and operators of those bridges) based on their level of compliance and adherence to those standards and best practices. This will facilitate the maturation of the cyber insurance market in the domain — resulting in more available and more affordable policies — lowering costs and reducing financial risk to bridge owners and operators. Likewise, adoption of sound cybersecurity and risk management standards and best practices will ease the burden on regulators by providing sound metrics upon which to base policy and oversight.

2.4. VTS Radar for Small Vessel Detection

2.4.1. Changes from Initial Workplan

The COVID-19 pandemic prevented the research team from completing all the in-person visits to the Vessel Traffic Service (VTS) centers as originally outlined in the work plan. With the help of the USCG, we were able to conduct phone interviews with the remaining VTS centers to gather requirements for radar and other sensors within the VTS operations.

2.4.2. Objective/Purpose

Rutgers University was funded through the Maritime Security Center (MSC) to develop a needs analysis for the USCG Vessel Traffic Service (VTS) centers with respect to radar remote sensing for small vessel detection and other applications.

2.4.3. Baseline

There are 12 VTS centers across the United States, 10 of them are managed by the Coast Guard and two are cooperatives where the Coast Guard provides watchstanders. The location of the VTS centers is shown in
. Eight of the top ten ports in the US are covered by a VTS [1]. The 12 VTS in this study provide situational awareness for 3,000 vessels per day so having the proper sensors to collect and distribute that information is essential.

No.	Vessel Traffic Service
1	New York, NY
2	St. Mary's River
3	Louisville, KY
4	Tampa, FL
5	Lower Mississippi River, LA
6	Berwick Bay, LA
7	Port Arthur, TX
8	Houston/Galveston, TX
9	Los Angeles-Long Beach, CA
10	San Francisco, CA
11	Puget Sound, WA
12	Prince William Sound, AK

Figure 1: Map of the US showing locations of the Vessel Traffic Service Centers. The two stars in yellow indicate VTS that are run as a cooperative.

The Coast Guard is currently developing plans for its next generation Vessel Traffic Service (USCG Capability Analysis Report for Vessel Traffic Service, 2019). The Capability Analysis Report (CAR) [2] identified 12 capability gaps within the VTS, two pertaining to radar. The first being lack of sufficient resolution from the radar systems, the second being the inability to properly display the desired resolution in the Port and Waterways Safety System (PAWSS). One of the major challenges that the CG is facing within VTS right now is the obsolescence sustainment of their radar systems. The two radar systems utilized within the VTS are the Terma Scanter 2000 (end of life 2027) and Furuno FAR-3000 (end of life 2015).

This work plan will utilize all the information obtained from the previous MSC radar project [3], especially to identify radar vendors. These vendors will receive a request for information that will be developed in this project. The main objective is to gather USCG requirements to develop the request for information (RFI), analyze responses, and make recommendations to seek potential new VTS radars that are capable of detecting small vessels with acceptable performance to the USCG VTS mission. The focus will be to find radars that will replace existing radars and help the USCG identify radars that provide the best performance for detecting small vessels and other non-reporting vessels.

We have identified the VTS mission needs statement for radar and other sensors:

The system surveillance capability will have sufficient resolution to detect, classify, and identify vessels and objects that may disrupt marine traffic or become hazards to navigational safety in both day and night situations, as well as in low visibility environments. The sensors will be connected to their local hub via an infrastructure with adequate bandwidth (e.g. potentially leveraging 5G, fiber optics, or other high-speed networking technology) for further connection to a networked system. There will be multiple levels of sensing capabilities, such as radars and cameras, tailored to the unique geographical layout and specific mission needs of each VTS, which will be adequate to provide coverage throughout each VTS area of responsibility (AOR) as defined in 33 CFR 161. The display system will be capable of transmitting and receiving the signals with minimal loss of fidelity and will have a configurable display.

This research project will consist of the tasks outlined in Table 1. This report summarizes work in support of Tasks 1-4. The cells marked in green are complete.

Table 1: List of tasks defined for this research study.

No.	Task	Time Frame	Status
T1	Visit USCG VTS Centers	Months 1 to 2	Complete
T2	Document requirements for small vessel detection	Month 1 to 6	Complete
T3	Develop market survey of existing radars	Month 1 to 8	Complete
T4	Develop request for information (RFI) and release it	Month 6 to 8	Complete
T5	Analyze received RFI responses	Month 8 to 10	In Process
T6	Tabulate RFI responses and provide recommendations	Month 9 to 11	In Process
T7	Final report	Month 12	

2.4.4. Methodology

Kickoff Meeting

The Rutgers team started the project with a kickoff meeting at Coast Guard Headquarters. Representatives from CG-741 Office of Shore Forces, CG-761 Office of Sensor Capabilities, CG-771 Office of Requirements, CG-681 C4IT and CG-NAV. Dr. Roarty introduced his project, then there was an open discussion on the project.

Each VTS has its own capability feeds and there's no interconnection between them. But there is standardization across the VTS centers in terms of sensors and components. The USCG is currently in the pre-acquisition phase for next generation VTS. They've built the case for recapitalizing and redesigning the system.

The Coast Guard is solution agnostic. They are not bound to any one vendor. They are open to sensors other than radar, thermal, optical, signals intelligence. There is a big emphasis in the Coast Guard for innovation and leveraging new technologies. The USCG would like to perform an analysis of alternatives for VTS sensors that includes examination of cost, user effectiveness and mission effectiveness. The Coast Guard would like to see this report shed light on VTS mission needs that the Coast Guard is unaware of.

There was a discussion of radar particulars. Does the USCG have the proper support infrastructure to maintain these radars? The digitization of the radar needs improvement. The analog signal looks good, the digital picture is poor. The need for radar within the VTS is real. Small vessel detection is what the VTS centers need. VTS Seattle needs to be able to manage the large number of tribal fishing boat while VTS San Francisco has a large recreational boating community that is a challenge. All of these vessels fall under the SOLAS class vessels (300 gross tons and above) that most of the VTS centers are focused on.

The team then laid out a series of dates where we would travel to certain VTS centers to talk with the directors, watchstanders, Electronics Material Officer (EMO) about the needs for radar within the VTS.

VTS Visits

The Rutgers team developed a questionnaire that was delivered to a VTS center before the visit. We planned to visit each of the VTS centers in person, but the COVID-19 pandemic prevented us from travelling. So, the remainder of the interviews were conducted on the phone. The dates for the interviews with the VTS centers are presented in Table 2.

Table 2: Dates and modes for interviews with VTS centers on radar needs.

No.	Vessel Traffic Service	Interview Date	Mode
1	New York, NY	February 6, 2020	In person
2	St. Mary's River		
3	Louisville, KY	February 26, 2020	In person
4	Tampa, FL		
5	Lower Mississippi River, LA	April 6, 2020	Phone
6	Berwick Bay, LA	April 28, 2020	Phone
7	Port Arthur, TX	March 13, 2020	In person
8	Houston/Galveston, TX	March 13, 2020	In person
9	Los Angeles-Long Beach, CA	June 24 & July 28, 2020	Phone
10	San Francisco, CA	April 22, 2020	Phone
11	Puget Sound, WA	April 14, 2020	Phone

12	Prince William Sound, AK		

We received valuable input from each of the VTS centers. We also conducted two interviews with personnel from the C5i Service Center on February 19, 2020 and June 3, 2020. A complete documentation of the VTS input will be provided in the final report. We received two pieces of information that we would like to share for this report. The first piece of information was the need for radar within the VTS as provided by VTS New York (Figure 2). This outlined the capability requirements that radar currently delivers within VTS NY. We will look to see how new generations of radar or other sensors (camera, infrared, laser, etc.) can meet the same requirements. The second piece of information came from VTS Port Arthur (Figure 3). This is a screenshot from the PAWSS display showing a vessel moving south through the VTS. The AIS information is only displayed as a dot on the map. The radar provides the bounds of the vessel within the channel which the operators have communicated is essential for the management of the traffic.

Thomas, Ashly L LT

Subject: VTS NY Radar Uses/Future Needs

The requirements for commercial vessels to have a properly installed AIS shifted the primary means of VRMS and VTS user tracking from RADAR to AIS. However, VTS NY still utilizes RADAR as a normal part of the job. Anchorage monitoring and tracking of Non-AIS VMRS Users are the more common uses of RADAR in daily operations. RADAR is crucial in small vessels tracking, mission support (e.g., Security Zone Violations, and SAR) and breakaways where AIS is not available or may be unreliable in detection of developing situations.

1. Anchorages:
-VTS NY leverages control of over 9 Federal anchorages that are used continuously by the commercial vessels (CFR authority); to best manage these anchorages and maximize the number of vessels simultaneously, we assign the vessels specific spots within the anchorage. To ensure that the vessels ultimately anchor in these spots, we rely heavily on the radar return to ensure we tell the pilot when to drop anchor so as to not impede the adjacent vessels: as the vessels anchor, our operators are guiding them into the center of the spot allocated for them.
-On a yearly basis, we have over 6825 vessels using the anchorages (2017 stats for example), Average duration of anchorage: 30 hours, approximately 911 are Tankers(13%) and 5462 barges with or without tugs(80%). (Barges without tugs do not have AIS).
-Radar is the primary means of monitoring the fact that the vessels are not dragging while at anchor. If they drag anchor, we have a potential allision and marine casualty, with all sorts of negative impacts.
-Through our efforts and resources, we have avoided a Marine Casualty on the 6825 potential times it could have occurred.
- RADAR paints the vessel and gives a more accurate visual representation of the overall length. This is how VTS NY identifies the bow of the vessel and the position of the anchor when dropped. AIS transmits to location of the pilot house and would lead to less accurate swing circle plots. Swing circles are generated by the PAWSS utilizing location of the anchor, Vessel LOA, and Length of chain. VTS primarily monitors the RADAR plot while a vessel is at anchor. RADAR clearly displays changes in aspects in real time to aid in determining vessel swings, identifying potential close quarter situations and early detection of vessels dragging anchor.

2. Smaller Vessels:
-RADAR is still the primary means of tracking for a self-propelled vessel of 65 feet not engaged in commercial service, and towing vessels of 26 feet and less than 600 HP. --These vessels are VMRS Users and are not required to carry AIS. These vessels include Private Yachts, Military vessels, and 4+ towing vessels that normally operate in New York Harbor. When RADAR is not available standard routes and cameras are utilized for vessel tracking.
-Towing vessels not required to carry AIS are becoming more common in our AOR, and are difficult to track/manage
- RADAR is also the primary method for small vessel detection in NY Harbor. In the summer months smaller private vessels become more active in the Harbor. Private vessels have impeded channel restricted vessels by either becoming disabled or by fishing in or near the channels. RADAR is used in association with cameras in detecting such hazards to navigation. Additionally, RADAR is instrumental in detecting vessels that qualify for Operation Small Fry, Operation Clear Channel, and vessels encroaching Security Zones.

3. Break-aways:
a) Ships:
Over the last few years vessels breaking away from berths and moorings has become more frequent. In May 2018 a container ship parted bow lines in Port Elizabeth during severe weather. The RADAR displayed the bow of the vessel swinging off the berth almost perpendicular to the berth. The AIS location was in vicinity of the pilot house and displayed little to no movement. Detecting that the vessel was being pulled off the berth by the bow would have taken significantly more time than the real time vessel paint provided by RADAR.
b) Barges:

Additionally, Barges did not carry AIS. RADAR is a reliable sensor for barge breakaways at moorings, anchorages and berths, and depending on the location, it may be the only method for detection. Since 2018, we have more than 4 new authorized mooring areas for barges - several are in the vicinity of high traffic/congested areas. Inclement weather greatly increases the risk of these barges breaking away and causing severe damage to other vessels and/or shore facilities.

4. Debris: More sensitive radar could greatly assist us in detecting hazards to navigation. During severe weather or following severe weather, we often have 3 or 4 instances of floating debris with potential to cause damage to passing vessels - this primarily includes logs/pilings and floating docks. Due to their low sail area above the water, these are usually very difficult to detect via camera during the day, and nearly impossible to detect via camera at night.

5. ATON:
We can utilize the radar for ATON location verification. i. e. we can easily identify all the Ambrose channel marker buoys via radar. While we can't necessarily verify if the aid is on station but we can clearly see radar return on most aids - a more sensitive radar will increase/improve our ability to at least verify that the ATON is offstation.

6. AIS Failure:
Another reason we utilize the radar is for detection of vessels that are VTS users with a nonfunctioning AIS (LOD or not). We had an instance yesterday in which a vessels AIS failed shortly after getting underway. We were able to track them via radar until they exited the AOR.

Figure 2: Radar requirements for VTS as delivered by VTS NY personnel.

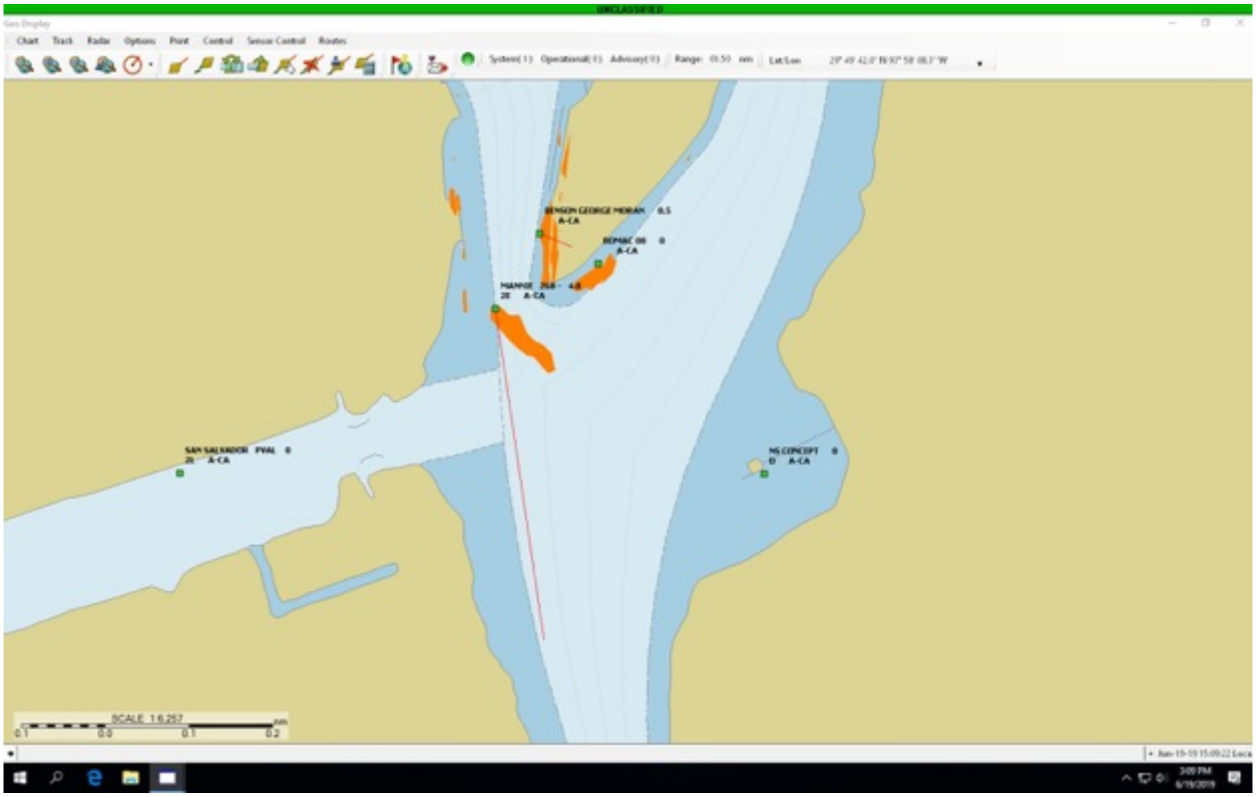

Figure 3: Screenshot of the PAWSS situational awareness tool for VTS Port Arthur. The image shows a 45-degree difference between the AIS and radar vessel bearing.

2.4.5. Project Milestones and Performance Metrics

The project milestones are listed in Table 3.

Table 3: List of milestones defined for this research study.

No.	Task	Time Frame	Status
M1	Kick-off meeting to discuss project plan, objectives, and outcomes	Months 5	Complete
M2	Release RFI	Month 8	Complete
M3	Select recommended radars	Month 12	In Process

The performance metrics are listed below in Table 4.

Table 4: List of performance metrics for this research study.

No.	Task	Time Frame	Score
PM1	Gather requirements from at least six VTS centers and HQ	Months 6	Gathered requirements from nine VTS centers, HQ and C3Cen
PM2	Submit RFI to at least five vendors	Month 8	Submitted RFI to nine radar vendors

PM3	Recommend at least two radars for consideration	Month 12	In Process

2.4.6. Transition Considerations

The Rutgers team released a request for information to radar vendors on July 31, 2020. We will utilize the responses to help inform the Coast Guard of radar vendors and models that will be sufficient for VTS usage. We have corresponded with DHS and have reviewed the responses to their RFI No. 70RSAT20RFI000004 "Unattended Sensor Technologies for Monitoring Riverine and Littoral Zone Vessel Traffic". Of the 36 respondents to that RFI, six of the submittals are applicable to the Coast Guard's need for radar within the VTS. We plan on communicating with those six companies as well as others to develop radar and other sensing capabilities for the VTS mission. We will also utilize the HTZ Warfare modelling software in the coming months to develop a radar model for each of the VTS areas which will allow us to experiment with different radar parameters to determine if a particular radar model will fulfill the VTS mission.

The Rutgers team has met with nine of the 12 VTS centers to compile requirements on the use of radar within the Vessel Traffic Service Centers and requirements for small vessel detection. This meets Performance Metric #1 to gather requirements from Headquarters and at least six of the VTS centers. Several of the VTS (New York, Puget Sound and San Francisco) stressed the need for small vessel detection to help manage the nonparticipating vessels and recreational traffic that are present within the VTS. We have located the camera and radar sensor locations within each of the VTS areas. This will allow us to model the existing sensor coverage and how new radar or other sensors will factor into the next generation VTS as envisioned by the Coast Guard. The Rutgers team has developed a request for information (RFI) for radar and other sensor needs with respect to Coast Guard Vessel Traffic Services. We have released it to nine radar vendors which satisfies Performance Metric #2 to release it to at least five vendors.

2.4.7. Stakeholder Engagement

The Rutgers team placed heavy emphasis on stakeholder engagement from the outset of the project. Effective stakeholder engagement focuses on building relationships with the Coast Guard based on mutual trust and understanding. Table 5 lists the Coast Guard stakeholder organizations with whom the Rutgers team has engaged with during the project.

Table 5: List of Coast Guard stakeholders the Rutgers team has been engaged with during the project.

Unit	Office
741	Office of Shore Forces
761	Office of Sensor Capabilities
681	Sustainment Program Manager for PAWSS

C3-CEN	Sustainment Eng. Lead for VTS
CG-NAV	
CG-771	Requirements Officer
New York	VTS Director
New York	VTS Training Director
New York	EMO
Louisville	VTS Director
Houston	EMO
Houston	VTS Director
Port Arthur	VTS Director
Port Arthur	EMO
New Orleans	EMO
New Orleans	Training Officer/Coordinator
Puget Sound	VTS Director
Puget Sound	EMO
New Orleans	Director
Search and Rescue	Chief
San Francisco	Director
San Francisco	Training Officer/Coordinator
San Francisco	EMO
Berwick Bay	Director
Berwick Bay	EMO
C5i Service Center	VTS Project Manager
C5i Service Center	PAWSS Project Manager
LA/LB	Executive Director, Marine Exchange
LA/LB	Ops. and Training Manager, Marine Exchange
LA/LB	VTS Director

2.4.8. Potential Programmatic Risks

We do not foresee any risk to the completion of the project. We would like more in person meetings with Coast Guard Headquarters to discuss progress. We will discuss with the POC about the possibility of in person meetings and if that is not available we will transition to remote virtual meetings.

2.4.9. Unanticipated Problems

The COVID-19 pandemic prevented the Rutgers team from completing all the in-person visits to the Vessel Traffic Service (VTS) centers as originally outlined in the work plan. With the help of the USCG POC, we were able to conduct phone interviews with the remaining VTS centers to gather requirements for radar and other sensors within the VTS operations.

2.4.10. Information Supported by Data

VTS Activity Reports

The USCG provided monthly transit data for each of the VTS centers which are all vessels that are considered "active tracks". The transit data is comprised of ferry passenger, freight, tankers, tug/tow and other. A summary plot of the data is provided in Figure 4. The VTS centers break into 3 categories as shown in Table 6, greater than 10,000 monthly transits, between 10,000 and 1,000 and less than 1,000 monthly transits. This provided the team with a scale for the volume of traffic that each VTS needs to manage.

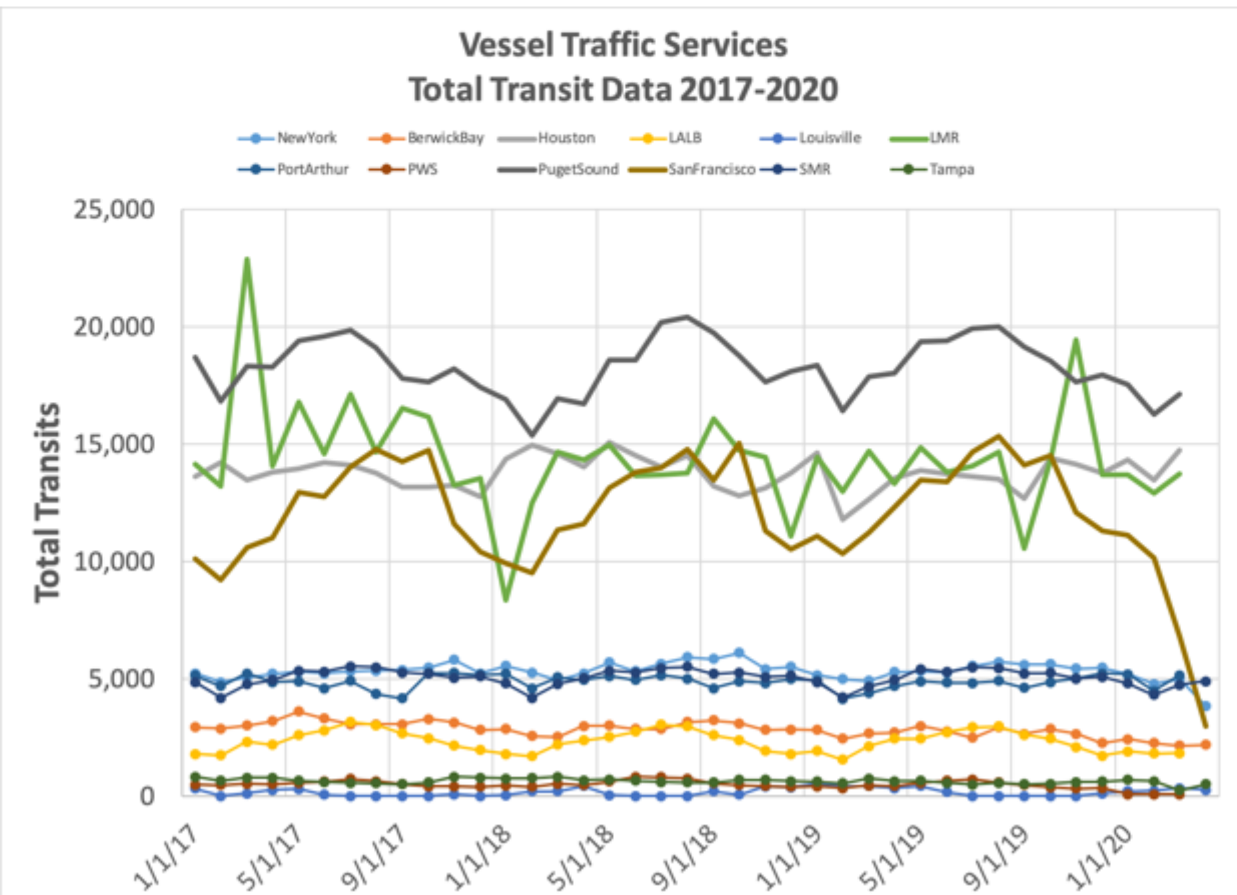

Figure 4: Three-year (January 2017 to April 2020) record of VTS transit data. The legend for the particular VTS location is provided at the top of the figure.

Table 6: Breakdown of VTS centers by monthly transit activity.

Greater than 10,000	Greater than 1,000	Less than 1,000
Puget Sound	New York	Louisville
San Francisco	Port Arthur	Prince William Sound
Lower Mississippi River	Berwick Bay	Tampa
Houston/Galveston	Los Angeles-Long Beach	
	St. Mary's River	

Geospatial Analysis

The Rutgers team discovered that the area of responsibility (AOR) for each VTS had been developed into a GIS shapefile as part of a National Transportation Safety Board study [4]. Dr. Eric Emery, Chief, Safety Research Division NTSB was able to deliver the shapefile to the team. This saved the project of having to recreate the data file. An example of the shapefile is provided in Figure 5 which shows the AOR for VTS New York. Having the shape file allowed us to calculate the area that each VTS is responsible for as shown in Figure 6. The figure displays the VTS locations ranked from smallest AOR (Louisville 6 mi^2) up to the largest (Puget Sound 2,980 mi^2).

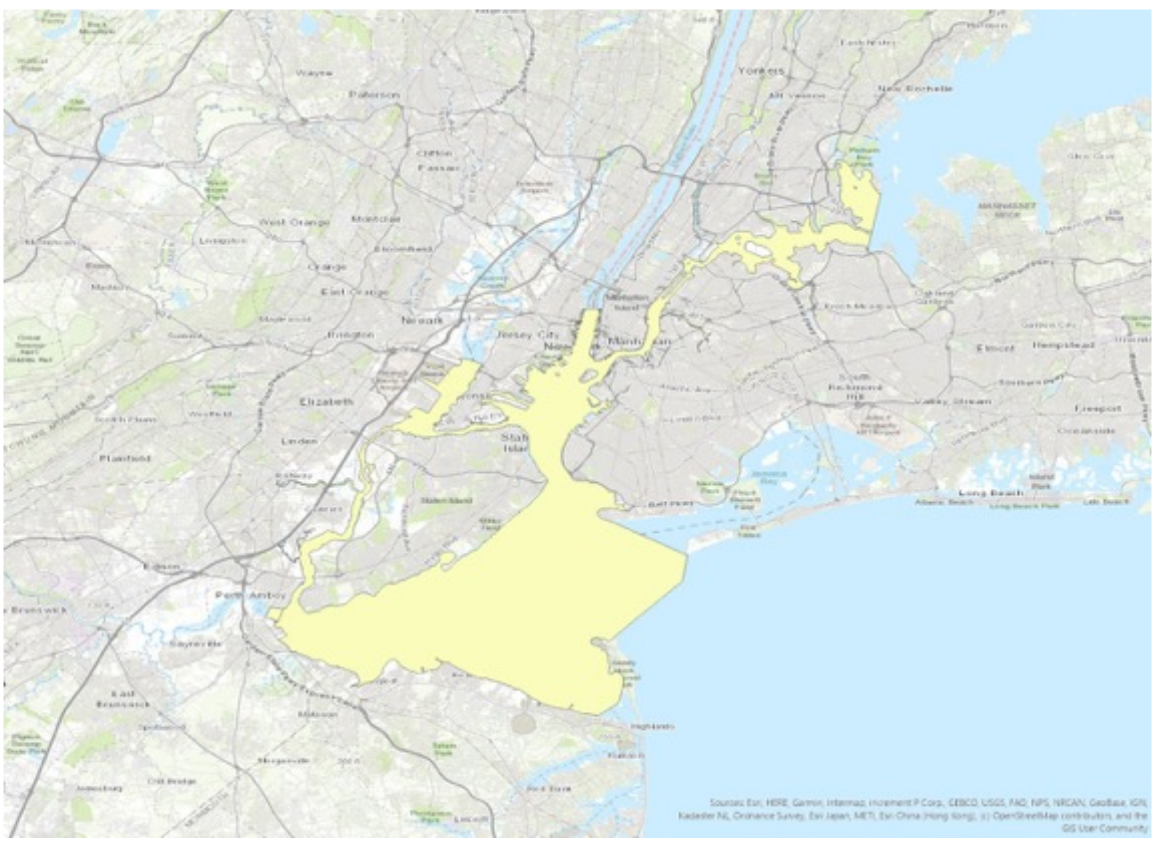

Figure 5: GIS shapefile visualization for VTS New York shown as the yellow area.

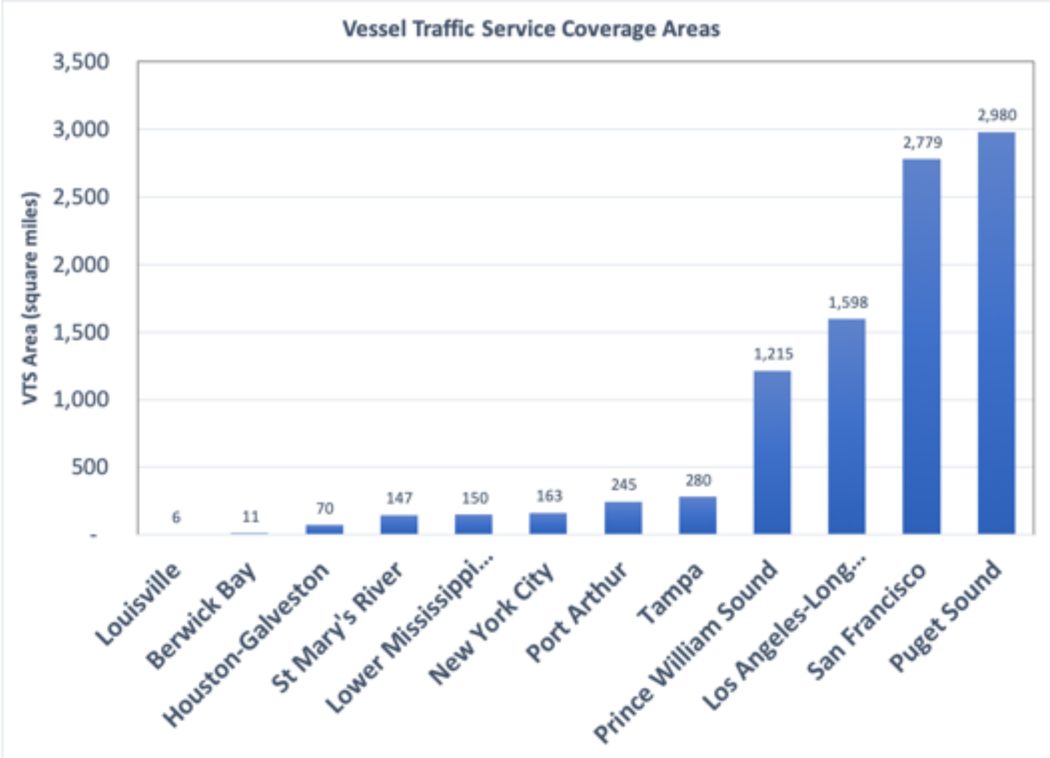

Figure 6: Area of responsibility (square miles) for each of the VTS locations.

VTS Remote Locations

We have complied the most up to date locations of radar and camera locations within each of the VTS centers. The Rutgers team has used the information on the sensor type and location to develop models of each VTS to determine how well the VTS area is covered by sensors. Figure 7 provides a map of VTS NY showing regions where there is only 1 sensor coverage (tan) and greater than 1 sensor coverage (rusty red). This map shows there is only a small portion of the VTS not covered by sensors (western side of Raritan Bay) and also indicates that the majority of the VTS has redundant coverage which is a positive note for the resiliency of the VTS to outages. Another type of analysis the team will conduct in the second half of the project is HTZ modelling of radar coverage. An example of this type of analysis is shown in Figure 8. This will allow us to experiment with radar particulars (power, frequency, bandwidth, model type) to determine the efficacy of the radar choice for the next generation VTS.

Table 7 provides a status of geospatial analysis for radar and camera coverage within each of the VTS areas. Green indicates analysis that is complete, yellow shows analysis that is underway and red for analysis that is planned.

Table 7: Status of geospatial analysis of each of the VTS areas. The legend is located at the top of the table.

Geospatial Analysis Progress by Program Status: ● Planned ● Underway ● Completed				
VTS No.	**Vessel Traffic Service**	**Google Earth**	**ArcGIS PRO**	**HTZ Warfare**
1	New York	Completed	Completed	Underway
2	St. Mary's River	Planned	Planned	Planned
3	Louisville	Completed	Completed	Planned
4	Tampa	Planned	Planned	Planned
5	Lower Mississippi River	Completed	Completed	Planned
6	Berwick Bay	Completed	Completed	Planned
7	Port Arthur	Completed	Completed	Planned
8	Houston/ Galveston	Completed	Completed	Underway
9	Los Angeles/ Long Beach	Planned	Planned	Planned
10	San Francisco	Completed	Underway	Planned
11	Puget Sound	Planned	Planned	Underway
12	Prince William Sound	Planned	Planned	Planned

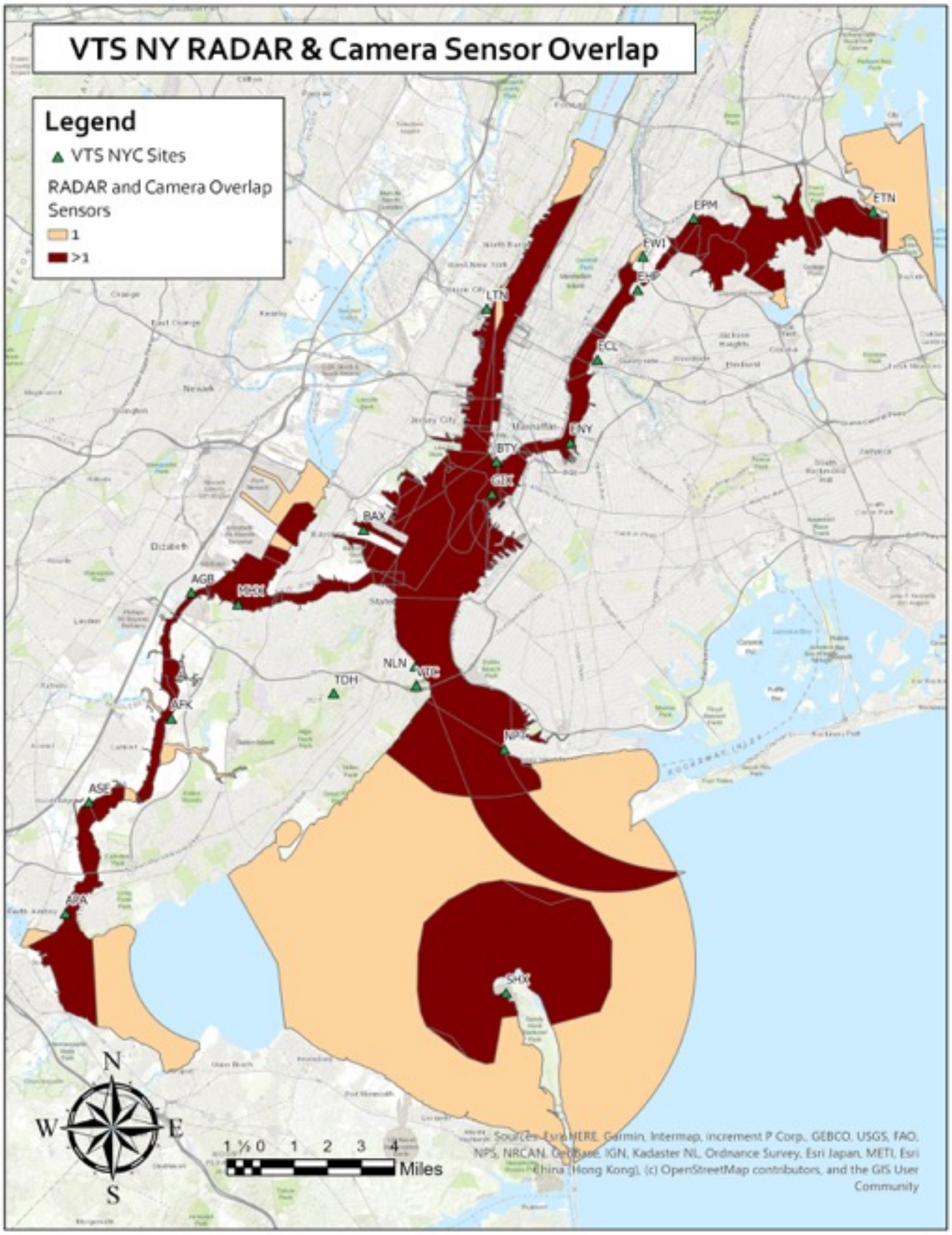

Figure 7: Map showing the radar and camera coverage of VTS NY. The colors indicate areas where there is only one sensor type covering the VTS (tan) and greater than one sensor type (rusty red).

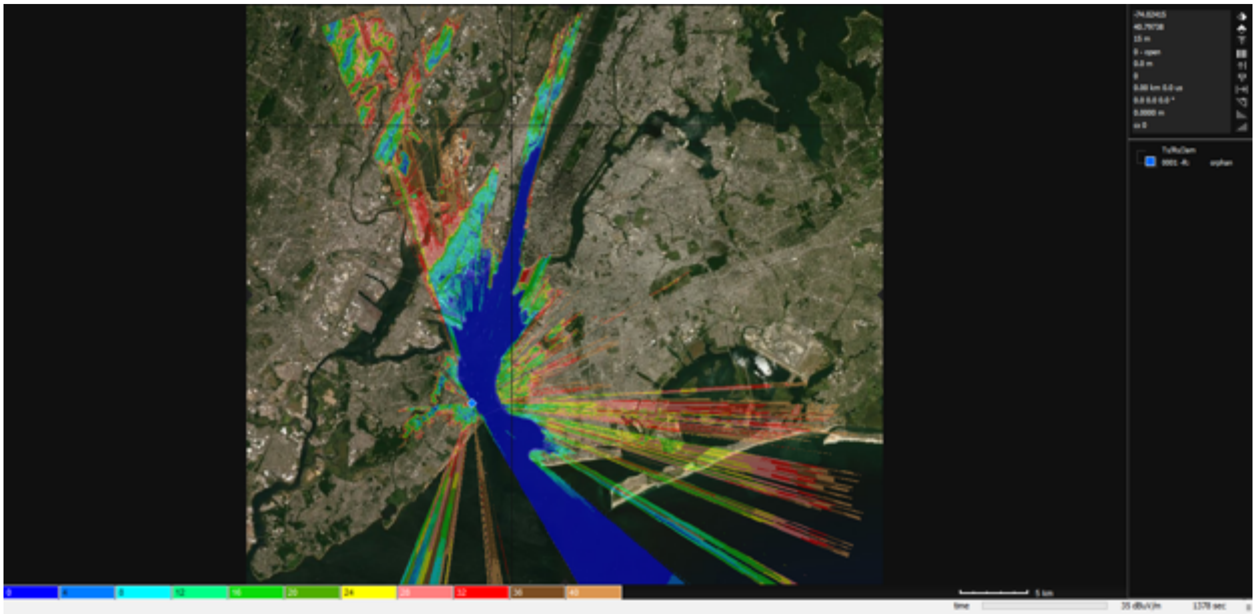

Figure 8: HTZ modelling of radar coverage for the New Lane radar site within VTS NY. The colors indicate the height of the target that radar is capable of detecting (blue - smallest up to brown - largest).

Request for Information

We released the request for information (RFI) on July 31, 2020. The RFI was modelled after DHS RFI 70RSAT20RFI000004 "Unattended Sensor Technologies for Monitoring Riverine and Littoral Zone Vessel Traffic". We would like to recognize Ms. Brenda Long from the DHS Science and Technology Directorate for providing their RFI. The MSC RFI is posted on the MSC website (https://www.stevens.edu/research-entrepreneurship/research-centers-labs/maritime-security-center/research/center-projects). We have also been in discussion with a number of radar vendors and service providers. The list of potential respondents for next generation VTS is presented in Table 8.

Table 8: List of radar manufacturers and radar service providers we are communicating with in the release of the RFI.

Vendor	Product	Website
Furuno	radar	https://www.furunousa.com/en/products/radars
Gem Electronica	radar	http://www.gemrad.com/radar-systems/
Sperry Marine	radar	https://www.sperrymarine.com
Simrad	radar	https://www.simrad-yachting.com/simrad/type/radar/
Terma	radar	https://www.terma.com/surveillance-mission-systems/radar-systems/vessel-traffic-services/

FLIR	camera and radar	https://www.flir.com/browse/government-defense/land-systems/radar/
Hensoldt	radar	https://www.hensoldt-inc.com
Pacific Radar	Radar services	
SSR Engineering	Radar services	

References

[1]. "U.S. Port Ranking By Cargo Volume". American Association of Port Authorities. 2013. Retrieved October 9, 2015.

[2] "Capability Analysis Report for Vessel Traffic Service". United States Coast Guard. August 22, 2019, Version 01

[3] "Vessel Traffic Service Radar Research Project" Final Report, Stevens Institute of Technology, Maritime Security Center, November 30, 2017

[4] National Transportation Safety Board. 2016. An Assessment of the Effectiveness of the US Coast Guard Vessel Traffic Service System. Publication Type NTSB/SS-16/01. Washington, DC.

3. Education and Outreach

MSC has established a robust portfolio of high-impact educational programs designed to provide learning opportunities for current and aspiring homeland security professionals. The Center's educational programs leverage the subject matter expertise and research capabilities of its academic partners to provide relevant programs for a broad audience of students, DHS stakeholders, and STEM educators. During Year 6, MSC offered the following homeland security-focused educational programs:

- The Summer Research Institute (SRI)
- Research Assistantship Program
- Coordinated Homeland Security STEM Internship Program
- MSI Educator's Workshop
- MSI Summer Research Team Program
- Maritime Cybersecurity Professional Development Course

MSC's educational programs are offered in collaboration with the Center's network of stakeholders. Participating stakeholders have included representatives from the U.S. Coast Guard (Sector NY, Sector SE New England, Cyber Command, Research and Development Center), Customs and Border Protection, (Field Operations at the Port of NY/Newark and the CBP New York Laboratory), and the National Urban Security Technology Laboratory (NUSTL) among others. MSC's stakeholders have contributed to the Center's educational programs by serving as guest lecturers and webinar speakers, providing data and subject matter expertise for student research projects, assisting with program curriculum development, and by facilitating internships and opportunities for MSC student employment.

This section of the report provides a summary of MSC's education milestones, followed by a detailed account of the MSC's educational programs and outreach activities during Year 6.

3.1. Summary of Education Milestones

3.1.1. Summer Research Institute (SRI)

The Center's 11th annual Summer Research Institute was held virtually for the first time in the program's history, due to the COVID-19 public health crisis. The program occurred as planned otherwise and was held June 1 to July 24, 2020, leveraging multiple online learning and communications platforms. The 2020 SRI program included 22 students representing five U.S. universities and participating from three different time zones. The students were organized into six research teams. MSC's stakeholders provided input into student research project topics and served as webinar speakers and subject matter experts throughout the eight-week virtual program. Video recordings of the student research presentations as well as copies of their power point slides and research posters can be found on the SRI program webpage at https://www.stevens.edu/SummerResearchInstitute.

3.1.2. Undergraduate and Graduate-level Research Assistantships

MSC provided tuition and stipend support for three Graduate Research Assistants during the 2019/2020 academic year. As part of their Assistantship requirements, the students each engaged in 20 hours per week of homeland security relevant research. The student's research projects included the development of a new methodology to efficiently and effectively detect fentanyl at ports of entry, an analysis of offshore windfarms and their potential impacts on Coast Guard operations, and the hydrodynamics of open-ocean waystations for autonomous drone charging. The three Graduate Research Assistants presented their research in a virtual presentation session for MSC and DHS stakeholders on May 19, 2020.

The Center also engaged four undergraduate students in research tasks and projects throughout the academic year. Funding support for the undergraduate students was provided by Stevens Institute of Technology.

3.1.3. Coordinated Homeland Security STEM Internship Program

The Maritime Security Center established a coordinated internship program to place STEM-focused students in internships with the Center's DHS stakeholders. The MSC awarded four ten-week internship placements in Year 6. Due to COVID 19, the internships were held virtually. Two students conducted work with the National Urban Security Technology Laboratory (NUSTL), one with the USCG Research and Development Center, and one with CBP New York Laboratory. Feedback from the internship hosts included praise for the quality of the student's work, their initiative and motivation, and contributions to the organization's operations.

3.1.4. MSI STEM Educator's Workshop

The MSC held a workshop tailored to Minority Serving Institution (MSI) STEM educators focused on Maritime Transportation System Cybersecurity curriculum. The objective of the workshop was to create greater awareness of maritime security concerns and the significance of the maritime enterprise to the Nation's safety, security and economy. Due to COVID-19, contingency plans were put in place to postpone the workshop and hold it virtually via Zoom on May 29, 2020. The workshop included educators from five MSIs, and featured a guest presentation by LCDR Alexander Kloo, USCG Sector New York.

3.1.5. MSI Summer Research Team Program

MSC collaborated with Dr. Bruce Kim from City College of New York to submit a research proposal for the 2020 DHS MSI Summer Research Team Program (MSI SRTP). The proposal was selected for award and Dr. Kim and his student team engaged in a ten-week research project focused on the development of a sulfur emission detection handheld device. The team completed their research virtually as part of the MSC's Summer Research Institute. The MSI Summer Research Team presented their research in a formal presentation to the Center's stakeholders on July 23, 2020. The team's presentation slides and a recording of the student team's presentation can be found on the MSC Summer Research Institute webpage (https://www.stevens.edu/SummerResearchInstitute).

3.1.6. Maritime Cybersecurity Professional Development Pilot Course

MSC in conjunction with Coast Guard Cyber Command and USCG Sector New York developed a Maritime Cybersecurity pilot course tailored to marine inspectors. The professional development course is designed to provide basic cybersecurity principles within the context of the maritime domain. The pilot course was scheduled to be held in April 2020, however, due to the COVID-19 pandemic, the course was postponed to the Fall of 2020 and plans have been made to deliver the course remotely. The professional development course was adapted from an existing Stevens Institute of Technology graduate-level course and was modified to meet the educational needs of Coast Guard personnel.

College-Level Experiential Learning and Research-Based Programs

3.1.7. The 2020 Summer Research Institute

Milestones	Performance Metrics	Status/Discussion
1. Featured lectures by MSC researchers and invited guests. (Weeks One – Eight) (6/1/2020 – 7/24/2020)	- A minimum of three faculty/guest lectures will be provided during the eight-week research program. -The quality of and knowledge learned from the lectures will be assessed through a post- program student survey.	Completed: MSC hosted over eleven guest speaker webinars and faculty lectures throughout the virtual SRI program.

		Completed: A post-program student survey was conducted.
2. Field visits and field-based activities. (Weeks One – Seven) (6/1/20 – 7/24/20)	- Students will engage in a minimum of two field-based activities during the summer research program. (e.g., participation in a stakeholder meeting/workshop/training, research experiments/deployments, operational facility tours) -The impacts of the field visits and field-based activities on student professional development and networking skills will be assessed through a post-program student survey.	Incomplete: Due to COVID 19, the SRI program was held remotely and therefore no field visits or field-based activities occurred. Completed: A student survey was administered and completed by all of the SRI students.
3. Diversity of student participants. (6/1/20 – 7/24/20)	-Diversity will be measured according to the range of engineering and science majors represented in the program. A minimum of four different disciplines will be represented per SRI program. - Student diversity will be measured by the percentage of women and minority students participating in the program each summer. A diverse student population will include a minimum of 50% women and/or minority students.	Completed: The SRI 2020 cohort included students from 12 academic disciplines. Partially Completed: 48% of the students who participated in the SRI were from underrepresented communities (women and minority students). Out of the five universities represented in the SRI, two were MSIs.
4. Research Reports, Presentations and Posters. (Week Eight) (7/20/20 – 7/24/20)	-A minimum of two student research team reports will be prepared at the end of each SRI program. -Students will engage in weekly status update presentations during weeks three – seven. -Stakeholder engagement will be assessed by representation of MSC stakeholders attending the final student team presentations. -Quality of SRI research outcomes will be assessed by MSC research mentor feedback and the number of projects	Completed: Six student reports, presentations and posters were prepared. Completed: The students provided status update presentations and discussed their research during Weeks Two – Seven via Zoom. Completed: More than 40 homeland security stakeholders partici-

	selected for presentation at conferences and/or for publication. -Program impacts, e.g., professional development, technical skills learned, student interest in advanced academic study or careers in homeland security will be assessed by a post-program student survey.	pated in the virtual student research presentations event. Completed: Responses to the SRI survey showed that students significantly improved their capabilities in several skill areas. 73% of the students reported that the SRI had enhanced their interest in careers in homeland security.
5. SRI Post-Program survey. Post-program survey to be conducted (Week Eight) (7/20/20 – 7/24/20	-A minimum of one student survey will be conducted at the end of each summer research program. The survey will be used to measure the strengths and weakness of the program, the program's impacts on student interest and skills development, and to gather feedback to enhance the future delivery of the program.	Completed: A student survey was completed to assess the virtual delivery and impact of the SRI program. All 22 student participants completed the survey.

MSC held its 11th Annual Summer Research Institute virtually this year due to the COVID-19 public health crisis. A decision to hold the program online was made in mid-April to provide an opportunity for the students, faculty and MSC program administrators to plan accordingly. MSC leveraged several existing online platforms including Zoom, Webex, and Slack to host the program from June 1 to July 24, 2020. In lieu of the program's annual field-visits and field-based activities, the Center organized a series of webinars featuring DHS guest speakers who exposed the students to a broad range of homeland security topics and concerns.

The SRI 2020 student projects were determined several months prior to the start of the program, in response to a solicitation the Center put out in its monthly stakeholder newsletter. Distribution for the newsletter reaches over 200 Federal, state and local homeland security stakeholders. Responses to the posting resulted in project requests related to risk management tools, maritime cybersecurity concerns, offshore windfarms and vessel emission detection. Collectively, the MSC developed a program of six student research projects based on the requests of its stakeholders. Discussions on each of these projects follows below in section 3.1.13.

Figure 1. SRI 2020 Program Brochure.

The MSC's 2020 Summer Research Institute included 22 students. A copy of the SRI 2020 program brochure is shown above in Figure 1. Altogether, the students represented five universities including Boston University, City College of New York (MSI), Montclair State University, Stevens Institute of Technology, and Texas Southern University (HBCU). 20 out of the 22 students were undergraduates and 48% were from underrepresented communities (e.g. women and minority students).

To offset the costs of the SRI (e.g., faculty costs, etc.) the Center leveraged existing Stevens Institute of Technology programs to recruit students who could attend the program fully funded through external funding sources. Out of the 22 program participants, nine students attended the program leveraging funding from Stevens Institute of Technology, including the university's Pinnacle Scholars Program (7), and Clark Scholars Program (2), and two students attended the program through a grant provided by the DHS Minority Serving Institute Summer Research Team Program (MSI SRTP). Funding for the remaining eleven students was provided by the Maritime Security Center.

The MSC-funded students were selected through the Center's academic partnerships and through a competitive admission process. The students admitted into the program were endorsed by their academic professors and met or exceeded the Center's admission criteria. Figure 2 shows the collective images of the SRI 2020 student research teams and Table 1 identifies the participants and the funding sources leveraged to support their participation.

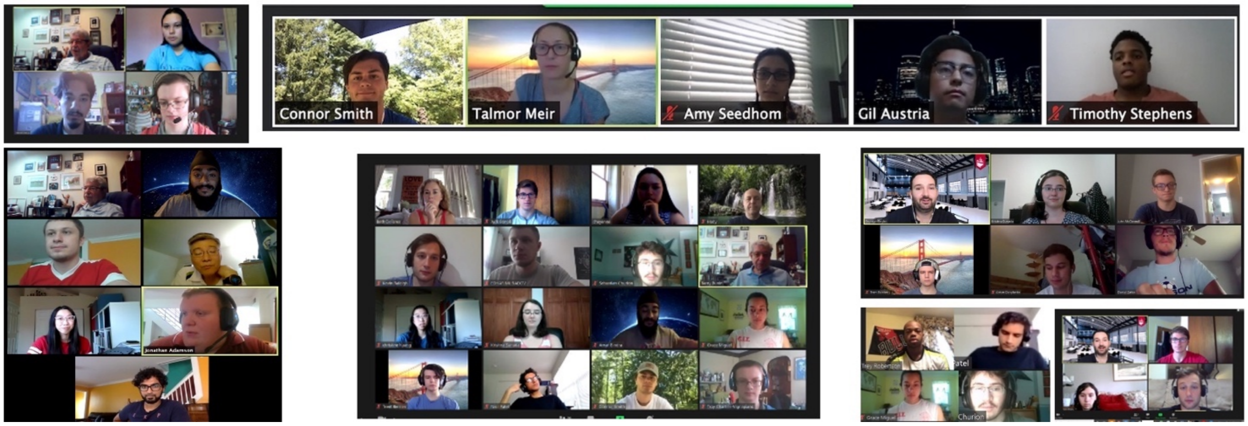

Figure 2. The SRI 2020 program was held virtually due to the COVID-19 pandemic. Student participants participated in the program via Zoom, among other online platforms.

Table 1. Summer Research Institute 2020 Participants and Leveraged Funding.

University	Student	Major	Funding Source
Boston University	Amy Seedhom	Mathematics/Computer Science	MSC
City College of New York (MSI)	Edhar Muradov Satesh Ramnath	Electrical Engineering Computer & Systems Engineering	MSI SRTP
Montclair State University	Cheyenne Petzold	Mathematics	MSC
Stevens Institute of Technology	Gil Austria Trent Berrien Amar Bindra Jack Bonoli Troy Chartier- Vignapiano Sebastian Churion Anton Danylenko Gabriel Garcia Christine Huang Grace Miguel Nisil Patel Kevin Raleigh Connor Smith Timothy Stephens Kristina Sunada Tyler Wright	Computer Science Mechanical Engineering Chemical Engineering Naval Engineering Physics Computer Science Computer Science Electrical Engineering Mechanical Engineering Software Engineering Computer Science Ocean Engineering Engineering Management Computer Science Mechanical Engineering Computer Engineering Computer Engineering	Pinnacle Scholar MSC MSC MSC Pinnacle Scholar Pinnacle Scholar Pinnacle Scholar Pinnacle Scholar Pinnacle Scholar MSC Clark Scholar MSC MSC MSC Pinnacle Scholar MSC Clark Scholar

	Daniel Zatko		
Texas Southern University (HBCU)	Trey Robertson	Maritime Transportation	MSC

3.1.8. Student Qualifications and Documentation

Participation in the SRI requires that students be actively enrolled in an undergraduate or graduate-level degree program at an accredited university. Undergraduate students must possess a minimum GPA of 3.0, and graduate-level (Masters and PhD) students are required to have a GPA of 3.5 or better. This past summer's participants were required to complete an online application form, write a personal statement of interest, submit letters of recommendation and transcripts upon request.

3.1.9. Summer Research Stipends

MSC-funded students received a summer stipend of $4,000 dispersed in two equal payments of $2,000 at the start and end of the program.

3.1.10. Program Administration

The 11th annual SRI was organized and coordinated by MSC Director of Education, Beth Austin-DeFares in conjunction with Dr. Barry Bunin (Research Professor, Civil, Environmental and Ocean Engineering). Ms. Austin-DeFares served as the primary program facilitator, while Dr. Bunin participated as the lead faculty mentor and curriculum developer. He also served as the overall technical lead on the summer research projects and provided assistance to students in both theoretical and practical implementation of their projects. SRI student team mentorship was also provided by Dr. Brendan Englot, Director of the Robust Field Autonomy Laboratory and Assistant Professor in Mechanical Engineering at Stevens Institute of Technology, Dr. Talmor Meir, Lead Data Scientist, Verisk Analytics and SRI 2010 student alumni, and Dr. Bruce Kim, Associate Professor Electrical Engineering, City College of New York.

3.1.11. Program Format and Curriculum

The virtual eight-week program included faculty lectures, a series of homeland security webinar speakers, and student-led research projects. Prior to the start of the program, the students were organized into one of the following six project teams and were provided with information on their respective team assignments:

- Risk Management Dashboard and Predictive Analytics Team
- Maritime Cyber Risk Team
- Sulfur Emission Detection Team
- Offshore Windfarm Safety and Security Team

- BlueROV Team
- Wave Glider Team

During Week One of the program the students attended introductory lectures via Zoom, delivered by Dr. Barry Bunin. The lectures oriented the student group to the maritime and homeland security domain, and included topics related to maritime security policies, current and emerging threats in the maritime domain, and an overview of port facility infrastructure and operations.

Starting Week Two, the students began to meet a minimum of three times per week with their faculty mentors and teammates and attended guest webinars provided by MSC's DHS colleagues and stakeholders.

During Weeks Three - Seven, the student teams began to provide status reports on their research projects in the form of weekly status update presentations. Each team was responsible for providing a ten to fifteen minute slide presentation discussing their research topic, the team's progress and research activities, and any challenges they were encountering. Throughout this time period, MSC administrators also arranged for the student teams to meet virtually one-on-one with subject matter experts in the fields of maritime safety and security, port security, offshore windfarms, and cybersecurity and critical infrastructure protection. Some of the student teams were also invited to provide tailored briefings of their research to USCG Sector NY, USCG Cyber Command and USCG Sector Southeastern New England personnel.

During Week Seven, the student teams synthesized their research outcomes and started to prepare their final reports, presentations and research posters. In Week Eight, the last week of the summer research program, students presented their research in a virtual presentation event for the Center's DHS stakeholders. Over 40 DHS and homeland security personnel attended the virtual presentation event including representatives from the DHS S&T network (Office of University Programs, partner COEs and NUSTL), CBP, USCG (USCG HQ, USCG Research and Development Center, Cyber Command, and Sector's New York and SE New England), as well as other Federal and state organizations including the NJ State Police and the Texas Military Department, among other representatives from industry and academia.

Tables 2 and 3 below illustrate the program activities and webinar speakers for each week of the 2020 summer research program.

Table 2. SRI 2020 Program Activities Weeks One to Eight.

Schedule	Topic	Faculty /Guest Speakers	SRI 2020 Activities
Week One June 1 – 5	MTS and Maritime Security Overview	Faculty: Dr. Barry Bunin	Group orientation and discussions/lectures on maritime security and vulnerabilities. Team homework assignments.

			Dashboard and Sulfur Detection teams meet with John Hillin, USCG Sector NY.
Week Two June 8 - 12	Team Research Projects	Webinar Speakers: Michael Egerton, Manager of Port Security, PANYNJ and Acting Branch Chief, Scott Rutledge, CBP Field Operations	Webinar presentations and SRI group and student research team meetings via Zoom.
Week Three June 15 - 19	Team Research Projects	Webinar Speakers: CPT Frank Hooten, Texas Military Department and Frank Fiumano, Port Security Specialist, USCG Sector NY	Webinar presentations and SRI group and student research team meetings via Zoom.
Week Four June 22 – 26	Team Research Projects		Windfarm team provides briefing for CDR McSorley, USCG Sector SE New England. Student team weekly status update presentations.
*Note that activities after July 1 for the SRI are considered planned activities for Year 6 but are reported here for consistency and program continuity.			
Week Five June 29 – July 3	Team Research Projects		Student research team and SRI group meetings.
Week Six July 6 – 10	Team Research Projects	Guest attendees for the student status update presentations: John Hillin, USCG Sector NY, Grace Python, USCG RDC, Drs. Qi Yi and Robert Morgan, TSU.	Student team weekly status update presentations. Guest attendee participation by USCG and TSU.
Week Seven July 13 - 17	Research Synthesis		Report writing, presentation slide preparation and research posters. Status update presentations and rehearsals.
Week Eight July 20 – 24	Virtual Student Research Presentations and presenta-	DHS S&T stakeholders & industry guests (USCG, CBP, DHS S&T, NUSTL)	Dashboard Team provides briefing for Captain Merchant, Deputy Commander, USCG Sector NY. SRI student research teams

	tion video recording reports and posters		presented their research in a virtual presentation event held via Webex on July 23, 2020. Completion of SRI feedback survey.

Table 3. SRI 2020 Webinar Speakers.

Guest Speaker	**Organization**	**Lecture Topic**
Mr. Michael Egerton, Manager Port Security	Port Authority of NY/NJ	Security Risk Assessment and Management
Mr. Scott Rutledge, Acting Branch Chief	CBP Field Operations Port of NY/Newark	CBP Missions and Seaport Operations
CPT Frank Hooten	Texas Military Department	Cybersecurity Concerns in Homeland Security
Mr. Frank Fiumano, Port Security Specialist	USCG Sector NY	USCG Operations in the Port of NY/NJ
Mr. John Hillin, Safety and Security Division Chief	USCG Sector NY	Briefings and discussions with the Risk Management Dashboard Team and Sulfur Emission Detection Team
CDR Brian McSorley, Deputy Sector Commander	USCG Sector SE New England	Briefings with the Offshore Windfarm Team
Drs. Philip Orton and Reza Marsooli	Stevens Institute of Technology	Lecture and discussion with the Offshore Windfarm Team
Ms. Grace Python	USCG Research and Development Center	Briefing and discussion with the Offshore Windfarm and Risk Management Dashboard Teams
Dr. Greg White	Director, Center for Infrastructure Assurance and Security, University of Texas San Antonio	Lecture and discussion with the Maritime Cyber Risk Team

3.1.12. Meetings with Practitioners

Due to the COVID-19 pandemic, the MSC was forced to hold its Year 6 summer research program remotely. In lieu of the program's annual field visits to ports and homeland security facilities, the Center organized a series of webinar speakers and created opportunities for the student teams to meet one-on-one virtually with homeland security professionals.

Interactions with professionals in the maritime and homeland security domain are a key feature of the Center's summer research program. It is through these meetings and interactions that students are able to learn first-hand about the current state of affairs in the field and to better understand stakeholder and end-user needs. Student/stakeholder interactions also provide an opportunity for MSC's stakeholders to observe and engage with student talent and to contribute to the education of homeland security career-focused students. These engagements also provide students with the opportunity to learn about jobs and careers that they may not have known about otherwise.

3.1.13. Student Research Projects

The SRI 2020 student research projects were developed at the request of and in conjunction with the Center's stakeholders. The Risk Management Dashboard and Predictive Analytics and Sulfur Emission Detection projects for example were inspired by Mr. John Hillin, Safety and Security Division Chief, USCG Sector New York, and the Offshore Windfarm project built upon a research project that had engaged USCG Sector SE New England personnel. The summer research projects and student team assignments are described in detail below.

Research Team/Project: ***Risk Management Dashboard and Predictive Analytics***

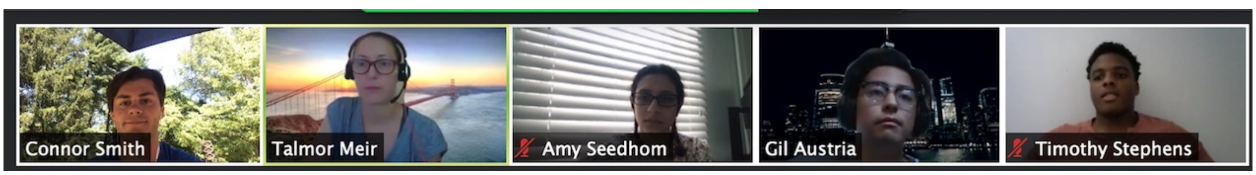

Figure 3: The students on the Risk Management Dashboard team met weekly via Zoom, with their research faculty mentor, Dr. Talmor Meir, Senior Lead Data Scientist, Verisk Analytics.

Students on the Risk Management Dashboard and Predictive Analytics team were led by faculty mentor, Dr. Talmor Meir, Senior Lead Data Scientist at Verisk Analytics. The team is shown in Figure 3 above. Dr. Meir is an alumna of the Summer Research Institute 2010 program and received her PhD in Ocean Engineering from Stevens Institute of Technology. Working in collaboration with Mr. John Hillin, Safety and Security Division Chief, USCG Sector New York and Dr. Meir, the team built upon a maritime incident visualization tool that had been conceived and prototyped during the Center's 2019 summer research program. The students in the SRI 2020 were tasked with operationalizing the tool and expanding upon and building out the original dashboard display and data sets. The team was also encouraged to incorporate new features, to include predictive analytic capabilities.

The team used open source incident data provided by USCG Sector NY to create a custom database and then in an iterative process designed and built the dashboard structure and functionality using Tableau visualization software. Figure 4 shows the graphical user interface and data display of the Dashboard.

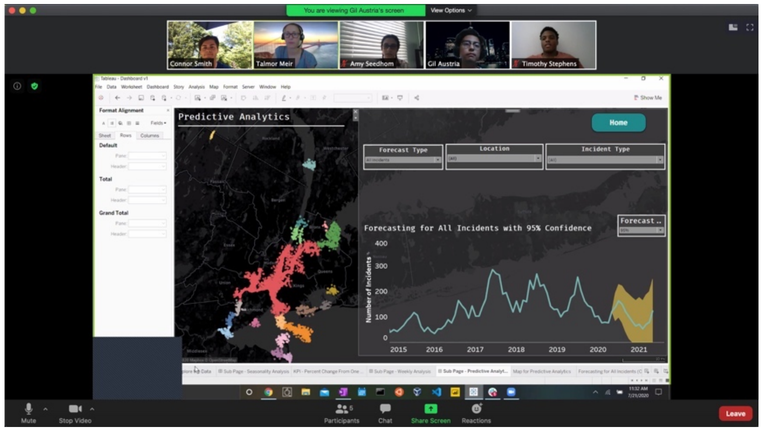

Figure 4. The Risk Management Dashboard tool graphically displays incident data collected in the USCG Sector NY AOR.

A synopsis of the student team's research, including the team's research question, importance to homeland security, methodology and outcomes are provided below in Table 4.

Table 4. SRI 2020 – Risk Management Dashboard and Predictive Analytics Overview.

Project Title: Risk Management Dashboard and Predictive Analytics
Research Question: *How can USCG Sector New York MISLE incident data be displayed and analyzed more effectively?*
Importance to Homeland Security: ● The Risk Management Dashboard allows for quick visualization and an analytical perspective into incident trends. ● The tool allows the USCG to be data driven and proactive versus reactive in resource planning and allocation.
Prospective End-user: The Dashboard was customized and developed for USCG Sector NY. The framework for the tool however, can be modified and used broadly across all USCG Sectors.
Project Abstract: The USCG MISLE database is a collection of national maritime incident records. The database, however, is not Sector or port specific and does not allow for efficient and proactive analysis of trends in maritime incidents. The objective of the SRI 2020 student research team was to address this issue, assess the prospect of using MISLE data for both risk management and predictive analysis, and ultimately to construct a dashboard that incorporated these capabilities and additional findings. At the end of the summer research program, the student team developed an operational prototype of a maritime incident visualization dashboard tailored to USCG Sector NY. The tool was developed using Tableau and allows end-users to analyze data across time scales and includes predictive analytic capabilities for the planning and asset allocation purposes.
Approach/Methodology: The team developed the Graphical User Interface (GUI) for the Risk Assessment Dashboard utilizing Tableau data visualization software. Leveraging incident data received by Sector NY, the team parsed-out, displayed data, and conducted an analysis for the following categories.

- Geographical area
- Incident Time Scale and Seasonality
- Impacts of COVID-19 on USCG operations in the Port of NY/Newark
- Predictive Analytics - Incident forecasting

Research Outcomes: At the culmination of the eight-week program, the student research team developed a working prototype of a dashboard visualization and trend analysis tool. In its current form, the tool is being transitioned for use by USCG Sector NY.

Additional details regarding the team's project can be found in their final research presentation slides, including a video recording of their presentation, and research poster located on the MSC website at https://www.stevens.edu/SummerResearchInstitute. Table 5 below identifies the student team members, their academic disciplines and their university affiliations.

Table 5. Risk Management Dashboard and Predictive Analytics Research Team.

Student	**Academic Discipline**	**School**
Gil Austria	Computer Engineering	Stevens Institute
Amy Seedhom	Mathematics and Computer Science	Boston University
Connor Smith	Engineering Management	Stevens Institute
Timothy Stephens	Computer Science	Stevens Institute
Faculty Mentor: Dr. Talmor Meir, Senior Lead Data Scientist, Verisk Analytics and Dr. Barry Bunin, Stevens Institute		

Research Team/Project: *Maritime Cyber Risk*

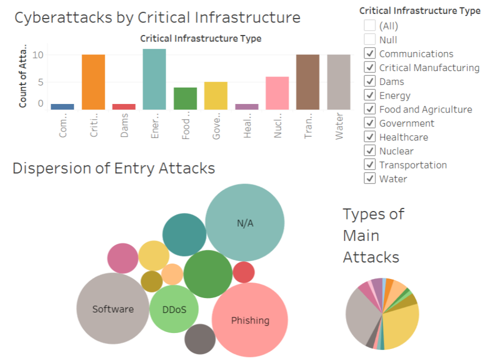

Figure 5. The Maritime Cyber Risk Team analyzed attack vectors of reported cyberattacks to critical infrastructure to develop mitigation strategies for the maritime domain.

Students on the Maritime Cyber Risk Team, shown above in Figure 5, were tasked with analyzing and cataloging cyber-attacks that have occurred within the maritime sector and to assess the methodologies used in these attacks to better understand vulnerabilities to maritime information technology (IT) and operational technology (OT) systems. Upon their initial literature review, the team decided to broaden their approach and examine attacks across all critical infrastructure sectors, given the more extensive availability of information and the common reliance of critical infrastructure sectors on supervisory control and data acquisition (SCADA) systems.

A synopsis of the student team's research, including the team's research question, importance to homeland security, methodology and outcomes are provided below in Table 6.

Table 6. SRI 2020 – Maritime Cyber Risk Project Overview.

Project Title: Cyber Risk Assessment and Trend Analysis across Critical Infrastructures
Research Question: *What cyberattack vectors have been used to attack the maritime and other critical infrastructures, what can be learned from those attacks, and what can be done to mitigate the consequences of those attacks happening again?*
Importance to Homeland Security: The goal of the research was to evaluate the current risks and vulnerabilities across different critical infrastructures, find patterns in different attacks, and create a general risk assessment and mitigation plan for the maritime sector.
Prospective End-User: U.S. Coast Guard and Maritime Enterprise
Project Abstract: The maritime cybersecurity team identified and cataloged entry and main cyberattacks across all critical infrastructures to analyze weaknesses and identify patterns in cybersecurity in the maritime domain and to create a mitigation plan to strengthen these weaknesses. An extensive catalog was created to identify the different types of entry and main attacks in the different critical infrastructures which were then followed by a risk assessment based on those attacks/threats. By identifying these flaws, the team developed a comprehensive mitigation plan and employee education program to protect the maritime domain from future attacks and can be applied to other critical infrastructures as well.
Methodology: The team conducted an extensive literature review of known cyberattacks across multiple critical infrastructures that commonly rely on SCADA systems. The team created an exploit catalog to categorize the cyberattacks. From that, the team used Tableau data software to visualize and analyze patterns in the data to then conduct a risk assessment as well as create generic mitigation plans for port facilities and vessels.
Research Outcomes: The team developed a catalog of cyberattack exploits across different critical infrastructure types and documented the points of entry in which the attacks occurred. The team also identified which critical infrastructure sectors were most attacked and the methodologies used by hackers to gain entry into IT/OT systems, and how the attack manifested. Based on their analysis, the team developed a risk assessment and a set of mitigation strategies, for both maritime port facilities and maritime vessels.

Additional details regarding the Maritime Cyber team's project can be found in their final research presentation slides, including a video recording of their presentation, and research poster located on the MSC website at https://www.stevens.edu/SummerResearchInstitute.

Table 7 below identifies the student team members, their academic disciplines and their university affiliation.

Table 7. Maritime Cyber Risk Student Research Team.

Student	**Academic Discipline**	**School**
Sebastian Churion	Computer Science	Stevens Institute of Technology
Grace Miguel	Software Engineering	Stevens Institute of Technology
Nisil Patel	Computer Science	Stevens Institute of Technology
Trey Robertson	Maritime Transportation	Texas Southern University (HBCU)
Faculty Mentor: Dr. Barry Bunin, Stevens Institute of Technology		

Research Team/Project: ***Sulfur Emission Detection***

Figure 6. The Sulfur Emission Detection team utilized nanotechnology applications to develop a prototype of a hand-held emission detection device for USCG marine inspectors.

The Sulfur Emission Detection team, shown above in Figure 6, was organized and coordinated as part of a DHS S&T Minority Serving Institution Summer Research Team Program (MSI SRTP). The MSI SRTP was held virtually in conjunction with the MSC's Summer Research Institute. Led by Dr. Bruce Kim, Associate Professor Electrical Engineering, City College of New York, the team included City College undergraduate student's Edhar Muradov and Satesh Ramnath, and Christine Huang and Amar Bindra of Stevens Institute of Technology. The team's ten-week summer research project focused on the development of a handheld sensor platform that can be used by U.S. Coast Guard marine inspectors to efficiently and effectively monitor compliance of the International Maritime Organization's (IMO) global cap on vessel sulfur emissions. The team utilized nanotechnology applications to develop a prototype and concept of operations for the handheld device. The team's work has been recommended for an invention disclosure and potential patent by Stevens Institute of Technology's Office of Technology Commercialization.

An overview of the student team's research including the team's research question, methodology and outcomes are provided below in Table 8.

Table 8. SRI 2020 – Sulfur Emission Detection Project Overview.

Project Title: Sulfur Emission Detection
Research Question: *How can we detect sulfur concentration in emissions to verify whether a ship is using an IMO compliant fuel or adequate scrubbing systems?*
Importance to Homeland Security: The IMO has reduced the maximum allowed sulfur content in fuel from 3.5% sulfur to 0.5% sulfur. The goal of the project is to create a hand-held device using high accuracy nanowire technology which can aid the USCG to monitor ship compliance to the IMO emissions standards at anchor points or at port.
Prospective End-users: U.S. Coast Guard
Abstract: Under the aegis of the United Nations International Maritime Organization (IMO), regulations have been developed to limit polluting emissions from ships. The United States Coast Guard (USCG) has the responsibility of enforcing these regulations in US waters. At the present time, USCG capabilities to measure these pollutants are inefficient. Furthermore, the IMO has recently implemented a global cap on sulfur emissions from 3.5% to 0.5% as of January 1, 2020. In this project, the sulfur detection team proposes to apply nanotechnology techniques to develop a sensor that can efficiently detect and measure sulfur content in ship emissions. This project aims to develop a Zinc Oxide (ZnO) nanowire array-based sensor platform capable of remote operation for sulfur dioxide (SO_2) detection. The faculty and student team leverages a number of online modeling, simulation, and software tools to develop a proof of concept for SO_2 emission detection. A prototype platform to host the nanowire sensor is assembled.
Methodology: The team utilized nano-technology applications to develop a hand-held sensor platform. The team organized themselves into three working groups. The Chemical team developed nanotechnology-based sensors, the Mechanical team conducted simulations of ship sulfur oxide emissions, and the Hardware team designed a measurement apparatus to detect and measure emissions.
Research Outcomes: The team developed a prototype and concept of operations for a hand-held sulfur emission detection sensor platform. The team has been encouraged by Stevens Institute of Technology's Office of Technology Commercialization to file for an invention disclosure and consider applying for a patent.

A copy of the Sulfur Emission Detection team's final research presentation slides, including a video recording of their presentation and research poster can be found on the MSC website at https://www.stevens.edu/SummerResearchInstitute.

Table 9 below identifies the Sulfur Emission Detection team members, their academic disciplines of study and their university affiliation.

Table 9. Sulfur Emission Detection Student Research Team.

Student	Academic Discipline	School
Amar Bindra	Chemical Engineering	Stevens Institute of Technology
Christine Huang	Mechanical Engineering	Stevens Institute of Technology
Edhar Muradov	Computer Engineering	City College of New York
Satesh Ramnath	Electrical Engineering and Systems Engineering	City College of New York
Faculty Mentors: Dr. Bruce Kim, Associate Professor, City College of NY and Dr. Barry Bunin, Stevens Institute of Technology with support by MSC Graduate Research Assistant, Jonathan Adamson		

Research Team/Project: _Offshore Windfarm Safety and Security_

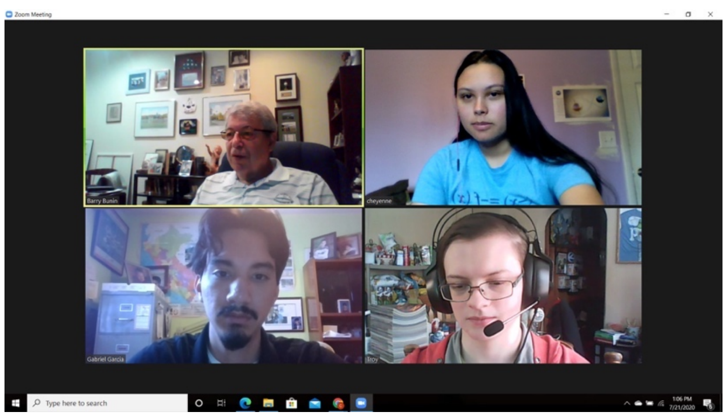

Figure 7. Dr. Barry Bunin (top left), met with the Offshore Windfarm student research team remotely via Zoom during the summer research program.

The emergence of offshore windfarms in U.S. coastal waters are creating new concerns for the U.S. Coast Guard. Students on the Offshore Windfarm summer research team, shown above in Figure 7, were tasked to conduct an extensive literature review and analysis of studies that have been conducted on the effects of windfarms on navigation, radio interference, ocean currents and other environmental considerations. The team was also tasked with identifying potential impacts on Coast Guard operations and to suggest mitigation strategies to minimize the potential impacts.

An overview of the student team's research including the team's research question, methodology and outcomes are provided below in Table 10.

Table 10. SRI 2020– Offshore Windfarm Project Overview.

Project Title: Offshore Windfarm Safety and Security
Research Questions: • *What impacts does the marine environment and human activities have on wind farm structures and what risks do compromised structures pose?* • *What are the impacts of the development of offshore wind farms on radio transmissions and radar and on hydrodynamic predictive models?* • *Do the impacts pose potential risks to coast guard operations? What are strategies to mitigate those risks?*
Importance to Homeland Security: Wind energy is necessary to help meet the nation's renewable energy needs. Offshore windfarm installations can interfere with radio transmissions and radar systems. The presence of hundreds of towers may alter ocean currents in terms of their direction and speed, and in turn, affect predictive ocean models and impair Coast Guard Search and Rescue operations in their vicinity.
Prospective End-users: U.S. Coast Guard
Abstract: This project identifies risks offshore windfarms pose in the areas of the marine environment and vessel safety, radio transmissions and radar systems, and hydrodynamic predictive models. Wind farm structures may be susceptible to harsh marine environments and damage caused by human activities. Compromised wind farm structures may have impacts on the marine environment, safety, and vessel traffic. Research also found that installations can interfere with radio transmissions and radar systems. The presence of offshore windfarms can create clutter in radar and navigational systems, which can potentially interfere with U.S. Coast Guard operations. After identifying the risks, the team proposed mitigation strategies for the Coast Guard to consider when assessing an offshore windfarm project.
Methodology: The team performed a comprehensive literature review and consulted subject matter experts to conduct their research and analysis.
Research Outcomes: Based on their extensive research and literature review, the team proposed mitigation strategies for Offshore Windfarm impairments as they pertain to predictive modeling, radio and radar communications, the protection of submarine cables, and the prevention of corroding structures and the control of biofouling.

A copy of the Offshore Windfarm team's final research presentation slides, including a recording of their presentation and research poster can be found on the MSC website at https://www.stevens.edu/SummerResearchInstitute.

Table 11 below identifies the student team, their academic majors and their university affiliations.

Table 11. Offshore Windfarm Student Research Team.

Student	Academic Discipline	School
Troy Chartier-Vignapiano	Physics	Stevens Institute of Technology

Gabriel Garcia	Electrical Engineering	Stevens Institute of Technology
Cheyenne Petzold	Mathematics	Montclair State University
Faculty Mentor: Dr. Barry Bunin, Stevens Institute of Technology		

Research Team/Project: _Wave Glider_

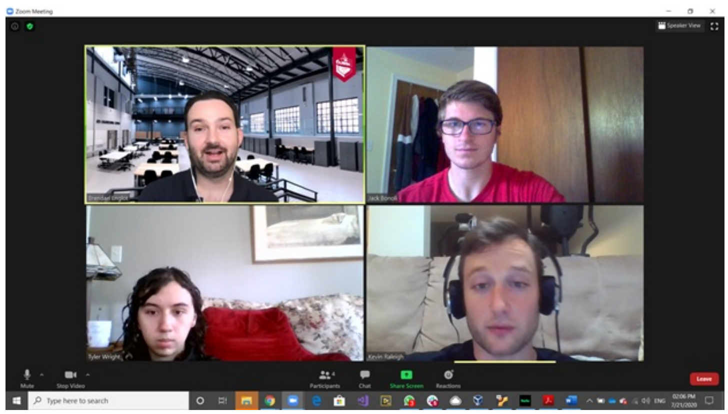

Figure 8. Students on the Wave Glider Team met with their faculty mentor, Dr. Brendan Englot (top left), virtually throughout the SRI 2020 program.

The Wave Glider student research team, pictured above in Figure 8, were challenged to provide a proof of concept for validating an AI-driven design process for maritime systems. This was done through the modification of the Virtual RobotX workspace.

An overview of the student team's research including the team's research question, methodology and outcomes are provided below in Table 12.

Table 12. SRI 2020 – Wave Glider Project Overview.

Project Title: Proof of Concept for Validating an Artificial Intelligence Driven Design Process for Maritime Systems
Research Question: *How can an unmanned surface vessel (USV) concept generated from an AI-driven design process be computationally validated?*
Importance to Homeland Security: USVs can be used for long, low cost voyages for surveillance/data collection, environmental monitoring, and sweeping for nefarious activity. Validation of an innovative design process in developing USVs can lead to rapid optimization and prototyping of USV capabilities and designs.
Prospective End-users: U.S. Coast Guard
Abstract: The purpose of this research was to provide a proof of concept for validating an AI-driven design process for maritime systems. This was done through the modification of the Virtual RobotX workspace. Four vessel designs were developed and tested in a task designed to evaluate their overall performance. The task involved

navigating a series of buoys amid wind and waves while trying to achieve the shortest completion time. The outcome of this process was a proof of concept which was capable of generating scores for vessel designs which autonomously completed a demonstrative task.
Methodology: The team utilized Virtual RobotX simulation software to compete in a virtual version of the RobotX Competition. The team was able to use existing codebases to give the virtual USV functionality. The team tested the USV simulation to assess performance and maneuverability USV hulls in varying wind and wave conditions. They were able to change and test hull parameters and create weather scenarios to test the impacts on the USVs performance and autonomous path planning capabilities.
Research Outcomes: Discrepancies in computer capabilities and how each team member scored the USV simulations, made it difficult to draw specific conclusions about how hull forms affect performance**.** The team was able to observe however, a significant difference in vehicle performance. Overall the Virtual RobotX software workspace showed great potential as a computational proof of concept for designs generated by an AI-driven design process.

A copy of the team's final research presentation slides, a video recording of their presentation and research poster can be found on the MSC website at https://www.stevens.edu/SummerResearchInstitute.

Table 13 below identifies the Wave Glider team members, their academic disciplines of study and university affiliations.

Table 13. Wave Glider – Student Research Team.

Student	**Academic Discipline**	**School**
Jack Bonoli	Naval Engineering	Stevens Institute of Technology
Kevin Raleigh	Ocean Engineering	Stevens Institute of Technology
Tyler Wright	Software Engineering	Stevens Institute of Technology
Faculty Mentor: Dr. Brendan Englot, Stevens Institute of Technology		

Research Team/Project: <u>BlueROV Underwater Robot</u>

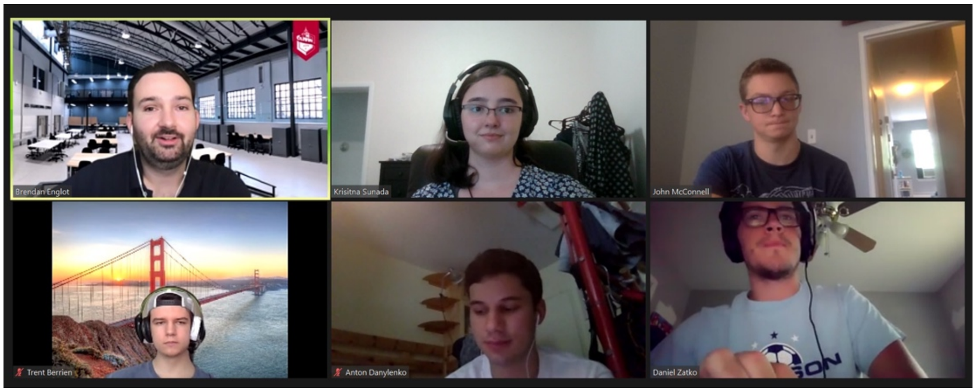

Figure 9. Students on the BlueROV team met with their faculty mentor, Dr. Brendan Englot (top left) via Zoom to discuss project details during the 2020 Summer Research Institute.

Students on the BlueROV team, pictured above in Figure 9, were tasked with creating a new and improved graphical user interface for enhanced ease of use by pilot operators. The team was also responsible for designing a deployment system to allow operators to easily and efficiently deploy and retrieve the ROV over pier railings and other obstacles without damaging the ROV. An overview of the student team's research including the team's research question, methodology and outcomes are provided below in Table 14.

Table 14. SRI 2020 – BlueROV Project Overview.

Project Title: BlueROV: Efficient Deployment and Monitoring of an Advanced Harbor Inspecting Underwater Robot
Research Objective: *Create a better user experience for operators of ROV's. Mechanically develop an easy and efficient deployment and retrieval mechanism for the ROV, and to enhance the software and user interface to improve the pilot's situational awareness and maneuverability during deployment.*
Importance to Homeland Security: Making ROVs more accessible and efficient to use can benefit agencies by allowing the increase of their use in practical situations ○ Scan for objects hidden on the underside of boats ○ Detect structural damage in piers and ports ○ Offshore oil inspection ○ Detect foreign objects attached to underwater structures
Prospective End-users: U.S. Coast Guard and Customs and Border Protection
Abstract: *The team's research involves increasing the efficiency and ease of use of the remotely operated underwater vehicle, BlueROV. The two main objectives were to improve the methods of deploying and retrieving the BlueROV, and to improve the user interface used by the pilot. These goals were met through the development of a mechanism to lift and lower the BlueROV into the water, and a graphical user interface that allows the pilot to view important sensor information in one window. The results of this research would be useful for many organizations and agencies that use underwater ROVs. Examples include U.S. Customs and Border Protection and the Coast Guard, both of which use ROVs for various types of inspections. By making the deployment and monitoring of the BlueROV more efficient, underwater vehicles similar to the BlueROV could potentially be used in more diverse situations.*

Methodology: The team organized themselves into two sub teams, the mechanical team and the software team. The mechanical team was responsible for developing designs for a new and efficient ROV deployment system and the software team developed new code to integrate the ROVs sensor data into an enhanced and improved graphical user interface. The mechanical team researched commercially available off the shelf deployment systems and used SolidWorks and modeling and simulation software to develop their own custom deployment mechanism designs. The software team used QT Framework, Tkinter Toolkit and RQT to build and optimize the user-interface for the BlueROV.
Research Outcomes: The mechanical team developed custom 3D designs for two ROV deployment systems. The Crane Arm Deployment design included an adjustable arm length and angle, a horizontal rotation, an electric winch and counterweights for stability, and the Swinging Arm design was shorter and smaller in profile, featured wheels for easy transport, swings arms that are capable of extending over pier railings and an electric winch. The software team developed a custom GUI design using the RQT framework. The GUI provides for enhanced sensor data visualization and integrated camera and sonar image displays, and recording capabilities.

Simulations of the mechanical and software teams designs can be found in a video recording of the team's final research presentation on the MSC website, together with a copy of the team's presentation slides and research poster (https://www.stevens.edu/SummerResearchInstitute).

Table 15 below identifies the student team, their academic majors and their university affiliations.

Table 15. BlueROV - Student Research Team.

Student	**Academic Discipline**	**School**
Trent Berrien	Mechanical Engineering	Stevens Institute of Technology
Anton Danylenko	Software Engineering	Stevens Institute of Technology
Kristina Sunada	Mechanical Engineering	Stevens Institute of Technology
Daniel Zatko	Computer Engineering	Stevens Institute of Technology
Faculty Mentor: Dr. Brendan Englot, Stevens Institute of Technology		

3.1.14. SRI 2020 Student Survey

An assessment of the virtual summer research program was conducted via a student survey (see Appendix E-1 for a copy of the student survey questions and format). Student participants were each asked to complete an online survey and to provide feedback on the virtual delivery of the summer research program, the students' learning gains, areas for program improvement and program impacts on student interest in advanced study and/or careers in homeland security. The survey was completed by all 22 student participants.

A majority of the student respondents rated the SRI Excellent in the following categories:

- Program Coordination/Administration (82%)
- Student Team Dynamics (64%)
- Use of Slack (64%)
- Faculty Mentorship (55%)
- Student Projects (50%)
- Research Project Outcomes (48%)
- Program Format (45%)
- Guest Speakers (45%)

73% of the survey respondents stated that the SRI enhanced their interest in advanced academic study and careers in the homeland security domain, and 100% of the students reported that they would recommend the program to their peers and colleagues at their respective schools.

When asked to what extent the SRI enhanced or improved their skills, a majority of the students reported "Significant Improvement" in the following areas:

- Ability to Conduct Research (55%)
- Professional Confidence (50%)
- Organizational Skills (41%)

When asked to describe their experience in the virtual SRI and identify their "top takeaways", the students commonly mentioned the following:

- Collaboration and communication with stakeholders, as well as across the student team.
- Ability to work efficiently and maintain motivation regardless that the program was held remotely.
- Holistic learning experience.

When asked to identify the strengths and weakness of the program, students frequently mentioned the following:

Strengths:

- Faculty mentorship and webinar speakers.
- Interactions with stakeholders.
- Program administration
- Relevant research projects.

Weaknesses:

- Weekly status update meetings should allow for breaks and team presentations should be kept to no more than 10 minutes per team.
- The virtual program should allow for more informal team building opportunities.

The students worked in collaboration with assigned researcher mentors and had the unique opportunity to interact and engage with homeland security practitioners throughout the eight-week program.   Through their experience in the summer research program, students gained a greater awareness of maritime and homeland security issues. Student survey responses show that participation in the SRI has effectively inspired student interest to pursue careers and academic study in the homeland security domain. Collectively, the SRI was effective in achieving the following outcomes:

- One student team was encouraged to submit an invention disclosure and to enter into discussions with Stevens Institute of Technology's Office of Technology Commercialization.
- MSC stakeholders requested briefings and materials on the student research team projects.
- Several of the student teams are considering publishing journal papers on their research.
- Each of the six student teams will submit their research posters for consideration to the 2020 Maritime Risk Symposium.
- Student presentations and research reports demonstrated that the students gained knowledge and understanding of the maritime security domain and their respective research projects.
- A majority of the students (73%) expressed enhanced interest in pursuing careers and/or advanced academic study in maritime/homeland security as a result of their participation in the SRI.

3.1.15. SRI Virtual Program Platforms

Figure 10. The MSC utilized several online platforms to host the SRI 2020 program.

MSC continuously strives to enhance the learning experiences of its students by modifying and tailoring the SRI program format. Due to the COVID-19 public health crisis, the SRI 2020 program was delivered remotely. The MSC leveraged several online platforms to coordinate and host the program. The platform logos are shown above in Figure 10. Slack served as the main communications tools across the student teams, faculty mentors and

Center administrators. Zoom was used for faculty, team and SRI group meetings, and Webex was utilized to engage the Center's stakeholders.

In lieu of the program's annual field-visits, the Center organized a series of homeland security webinar speakers to provide context and insight into the current of state of affairs in the field and allow for students and homeland practitioners to network.

If the program is held virtually in the future, the Center will leverage the same online platforms and will take into consideration the student requests for more informal interactions and better organized weekly status update meetings.

3.2. Graduate and Undergraduate Research Assistantship Programs

Milestones	Performance Metrics	Status/Discussion
1. Homeland Security Research Assistantships 7/1/19 – 5/30/20	Confer a minimum of two Graduate Research Assistantships.	Completed: MSC provided tuition and stipend support for three Master's degree students. The students conducted research into Offshore Windfarms, Fentanyl Detection and the Hydrodynamics of Waystations for UUVs and USVs.

3.2.1. MSC Research Students (2019/2020)

Seven students conducted research with the MSC throughout the 2019/2020 academic year (Year 6). The students included three graduate students who participated in the Center's Graduate Research Assistantship program and four undergraduate students who assisted with MSC research tasks as Research Support Assistants. The graduate students were provided funding support through the MSC and the undergraduate students were provided stipend support by Stevens Institute of Technology. Table 16 below provides an overview of the students and their research activities.

Table 16. MSC Research Students.

Student	Award / Program	Research /Activities
GRADUATE STUDENTS		
Jonathan Adamson	Graduate Research Assistantship / Chemistry and Nanotechnology	Conducted research in the area of fentanyl detection methods. Collaborated with CBP NY Laboratory.
Eric Isaksen	Graduate Research Assistantship / Ocean Engineering	Conducted research in the area of Offshore Windfarm impacts to USCG operations. Provided research

		briefings to Sector SE New England.
Kevin Raleigh	Graduate Research Assistantship / Ocean Engineering	Conducted research in the area of hydrodynamics of open-ocean waystations for UUV and USVs.
UNDERGRADUATE STUDENTS		
Domenico Albarella	Undergraduate Research Support Assistant/ Mechanical Engineering SRI 2018/SRI 2020 program alumni	Provided support to rebuild and operationalize an infrared camera as part of the Maritime Security Laboratory suite of assets.
Maria Manoussakis	Undergraduate Research Support Assistant/ Mechanical Engineering SRI 2019 program alumni	Provided support to rebuild and operationalize an infrared camera as part of the Maritime Security Laboratory suite of assets.
Mathew Seedhom	Undergraduate Research Support Assistant/ Computer Engineering SRI 2019 program alumni	Assisted in working with USCG Sector NY to further develop the Risk Management Dashboard developed during the SRI 2019 program.
Herb Zeiger	Undergraduate Research Support Assistant/ Mechanical Engineering SRI 2018/SRI 2019 program alumni	Provided support to rebuild and operationalize an infrared camera as part of the Maritime Security Laboratory suite of assets.

3.2.2. Graduate Research Assistantships

Figure 9. MSC awarded three Graduate Research Assistantships for the 2019/2020 academic year at Stevens Institute of Technology.

At the start of the 2019/2020 academic year, the MSC awarded Graduate Research Assistantships to Jonathan Adamson, Eric Isaksen and Kevin Raleigh. The students were competitively selected based on their academic qualifications, research interests and faculty recommendations. The Graduate Research Assistantships each received tuition and stipend support. Details regarding the student's research and assistantship activities are provided below.

<u>Jonathan Adamson – Graduate Research Assistant</u>

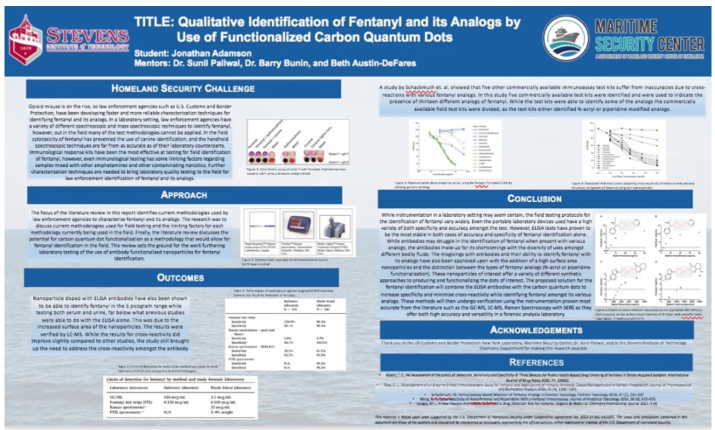

Figure 11. Jonathan Adamson's research poster showcases the work he completed during his MSC Research Assistantship.

Jonathan was awarded a place in the MSC research assistantship program following his admission into Stevens Institute of Technology's Chemistry department. He holds a Bachelor of Science degree from Central Washington University in Chemistry. Working under the mentorship of Dr. Sunil Paliwal and Dr. Barry Bunin, Jonathan conducted research to develop advanced methods to assist CBP and USCG personnel in their efforts to efficiently and effectively detect and identify fentanyl and its derivatives at U.S. Ports of Entry. Throughout his Assistantship program, Jonathan provided briefings and discussed his research with scientists from CBP's New York Laboratory located in Newark, NJ. See below for an abstract of Jonathan's research:

Abstract: Illicit use of fentanyl and its derivatives in the United States (US) has risen from 2012-2017. Of the 70,237 drug overdoses in 2017, 67.8% were related to opioids. Often fentanyl is a cheaper highly addictive analgesic that is combined with heroin in illicit drug manufacturing. Fentanyl alone is 80-100 times stronger than morphine, however fentanyl derivatives such as acrylfentanyl are 3,400 times stronger than morphine. While identifying these illicit drugs has been made possible with various analytical chemistry techniques/instruments such as Gas Chromatography/Mass Spectroscopy (GC/MS) and DART-MS (Direct Analysis in Real Time Mass Spectroscopy), they are time-consuming and require highly specialized instrumentation. Carbon Quantum Dots (CQDs) offer a faster, cheaper approach to identifying fentanyl and fentanyl derivatives. Quantum Dots have a variety of bioindicator applications in cancer and medicinal research as they fluoresce under UV light and are water soluble. The benefit of CQDs is a significant drop in the toxicity as compared

to the metallic quantum dots, and increased functionality with the ability to attach various substituents that bind to the fentanyl derivatives. CQDs offer a faster and more pH stable identification tool to help identify illicit drugs such as fentanyl and the host of fentanyl derivatives.

Over the course of the academic year, Jonathan completed 18 credits towards the balance of his Master's degree requirements and presented his research in a final presentation event for MSC research investigators and DHS stakeholders on May 19, 2020. During his Assistantship, Jonathan engaged in the following courses and fellowship/research activities.

Semester	Course Title	Credits
Fall 2019	CH 646 Natural Products	3
Fall 2019	CH 561 Instrumental Methods of Analysis	3
Fall 2019	Bio 687 Molecular Genetics	3
Spring 2020	CH 620: Advanced Inorganic and Bioinorganic Chemistry	3
Spring 2020	CH 610: Thermodynamics and Kinetics	3
Spring 2020	NANO 525: Surface and Nanostructure Characterization	3

Assistantship/Research Activities:

- Attended bimonthly meetings with MSC and Stevens faculty mentors.
- Provided monthly project briefings to CBP New York Laboratory Director and personnel.
- Presented research in a virtual presentation event held on May 19, 2020.
- Completed a final research report and poster (Figure 11).

Eric Isaksen – Graduate Research Assistant

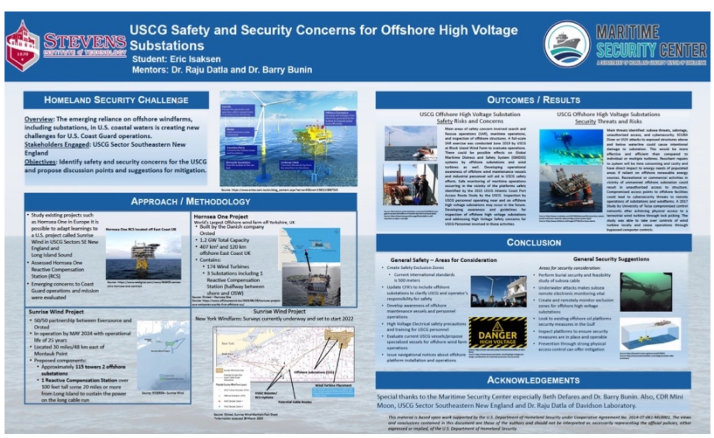

Figure 12. Eric Isaksen assessed the potential impacts of offshore windfarm and high-voltage booster stations on USCG operations.

Prior to joining Stevens Institute of Technology's Ocean Engineering Master's degree program, Eric worked as a subsea cable installation engineer for TE SubCom. He is a graduate of the SUNY Maritime College in Marine Transportation and was awarded an MSC Research Assistantship for the 2019/2020 academic year. During his Assistantship program, Eric conducted research in the area of Offshore High Voltage Booster Stations and their potential on USCG operations. See below for an abstract of his project:

Abstract: With the emerging construction of offshore wind farms in the United States, power generated from these installations will have to transmit electricity over distances that have not been sustainable in the marine environment in the past. This will become possible due to the development of offshore High Voltage Booster Stations. When high voltage booster stations are used in the transmission of the power from offshore wind turbines to shore-based locations, this may create the potential for vulnerabilities in which an exposed single-point offshore structure is responsible for supplying electricity to major metropolitan areas. Research must be conducted to understand and assess the potential risks and safety concerns inherent in the construction and operation of booster stations. In this study we will consider the safety and security implications, and environmental concerns these stations may pose to the U.S. Coast Guard and propose a risk management approach to address them.

Over the course of the Assistantship program, Eric completed 24 credits towards his Master's degree in Ocean Engineering and participated in the following research activities:

Semester	**Course Title**	**Credits**
Fall 2019	ME 511 Wind Energy-Theory & Application	3
Fall 2019	OE 511 Urban Oceanography	3
Fall 2019	OE 527 Naval Architecture Lab	3
Fall 2019	OE 630 Hydrodynamics	3
Spring 2020	ME 528 Computer Aided Ship Design	3
Spring 2020	ME 520 Design of Marine Structures	3
Spring 2020	ME 532 Total Ship Design II	3
Spring 2020	CE 565 Numerical Methods for Civil and Environmental Engineers	3

Assistantship/Research Activities:

- Conducted 20 hours per week of research as part of the Assistantship program.
- Participated in regularly scheduled faculty mentor meetings.
- Attended Offshore Wind Power Conference at SUNY Maritime
- Provided briefings of research progress to representatives from USCG SE New England.
- Completed a final research report and poster (Figure 12).

At the culmination of his Assistantship program, Eric presented his research outcomes in a final report and virtual presentation for MSC stakeholders and research investigators on May 19, 2020.

Kevin Raleigh – Graduate Research Assistant

Figure 13. Kevin Raleigh (R) stands next to his research poster with his faculty advisor, Dr. Mirjam Furth. His research poster was awarded Best Graduate Student Poster at the 2019 Maritime Risk Symposium.

Prior to joining the MSC Research Assistantship program, Kevin was employed as an engineer with the Naval Surface Warfare Center, Carderock Division and holds a Bachelor of Engineering degree in Naval Engineering from Stevens Institute of Technology. During his undergraduate degree program, Kevin was awarded a DoD-Science, Mathematics and Research for Transformation (SMART) Scholarship. In the Fall of 2019, he entered a master's degree program in Ocean Engineering at Stevens Institute of Technology and was competitively awarded an MSC Graduate Research Assistantship. Throughout his Assistantship, Kevin conducted research focused on the hydrodynamics of open-ocean waystations for UUVs and USVs. An abstract for his research project is provided below:

Abstract: In order to maintain surveillance over large areas of open ocean, systems of sensors are necessary. Such systems allow other resources and personnel to be diverted to more highly trafficked or more sensitive areas and can multiply the range of current security forces. Any offshore structure with sufficient power has the potential to be used as a sensor platform, providing a force multiplication on existing sensor networks. An autonomous platform primarily designed as a tethered sea farm could serve as a remote sensor platform or communication relay for agencies such as the US Coast Guard. Such a structure would have power generation in order to monitor its integrity remotely, meaning sensor power would not pose an additional design hurdle. With a group of buoys arrayed in a known pattern relative to one another, tracking of air, surface, and submerged targets can be more accurate through sensor netting. Additionally, a large enough group of platforms could represent a denied area by providing accurate location data on all traffic entering within a certain range of the platforms. This monitoring would be valuable in search and rescue efforts. The first step in developing this kind of sensor platform is understanding the motions of this type of system, particularly how said motions change with large fluctuations

in structure mass, due to marine growth. By testing motions on a scaled structure with varying amounts of simulated growth, the motions of the system can be better understood and from there the power generation options can be assessed. Finally, sensor types can be chosen based on the amount of power available to each buoy.

Over the course of the Assistantship program, Kevin completed 24 credits towards his Master's degree in Ocean Engineering and participated in the following research activities:

Semester	Course Title	Credits
Fall 2019	PEP 527 Math Methods for Scientists and Engineers	3
Fall 2019	OE 560 Fundamentals of Remote Sensing	3
Fall 2019	OE 657 Sustainable Transportation Systems	3
Fall 2019	OE 900 Thesis in Ocean Engineering	3
Spring 2020	CE 681 Intro to Finite Element Method	3
Spring 2020	EN 530 Intro to Sustainable Engineering	3
Spring 2020	OE 512 Intermediate Fluid Dynamics	3
Spring 2020	OE 585 Littoral Processes	3

Assistantship/Research Activities:

- Conducted 20 hours per week of research as part of the Assistantship program.
- Participated in regularly scheduled faculty mentor meetings.
- Attended Offshore Wind Power Conference at SUNY Maritime
- Presented Poster "Hydrodynamics of Waystations for Autonomous Drone Charging at the 2019 Maritime Risk Symposium (MRS) held at SUNY Maritime.
- Awarded Best Graduate Poster at the 2019 MRS (Figure 13).

At the culmination of his Assistantship program, Kevin presented his research outcomes in a final report and virtual presentation for MSC stakeholders and research investigators on May 19, 2020.

3.2.3. Graduate Research Assistantship - Final Presentations

Due to the COVID-19 pandemic, the Graduate Research Assistants presented their final research outcomes in a virtual presentation session held via Webex on May 19, 2020 for MSC stakeholders and research investigators. Stakeholder attendees included representatives from DHS S&T, USCG, CBP, among other Federal, state and local homeland security organizations.

Copies of the Graduate Research Assistants research posters can be found on the MSC website at https://www.stevens.edu/research-entrepreneurship/research-centers-labs/maritime-security-center/education-training/education-programs

3.2.4. Undergraduate Research Support Assistants

During Year 6, Stevens Institute of Technology provided funding support for four undergraduate students to provide research support to the Maritime Security Center. The four students were alumni of the MSC's Summer Research Institute program. The tasks and research activities of the MSC undergraduate research assistants were described above in Table 16.

3.3. Coordinated STEM Internship Program

#	Milestone	Performance Metric	Output
M1	Conduct outreach to DHS stakeholders to identify and confirm internship partners and student opportunities.	Contact and confirm a minimum of three DHS components/stakeholders to participate and host student interns.	Completed: MSC has confirmed three internship hosts for the inaugural internship program. (e.g. USCG RDC), CBP, and NUSTL)
M2	Recruit and admit students into the HS STEM Coordinated Internship Program	Award a minimum of four students in internships.	Completed: Four students were competitively awarded internship placements.
M3	Confirm internship projects, requirements and logistics.	Collaborate with DHS intern host to define internship project scope, coordinate internship logistics and suitability.	Completed: MSC in collaboration with the internship hosts, confirmed internship projects and tasks.
M4	Convene ten-week field-based internship assignments.	Student interns complete ten-week internship assignments and complete an internship summary report.	Completed with contingency plans: The ten-week internships were completed remotely due to the COVID-19 public health crisis. Therefore, no field-based placements or activities occurred. Completed: Four internship reports were prepared.

3.3.1. Program Overview

Figure 14. MSC placed four students in virtual internships with the USCG Research and Development Center, NUSTL and CBP New York Laboratory.

In Year 6, MSC established a coordinated internship program to place STEM-focused students in field-based internships with the U.S. Coast Guard and other DHS component agencies. The program was developed to connect students with quality field-based experiences and to cultivate long-term relationships between the DHS components and students to enhance the prospective homeland security workforce. The overarching objectives of the internship program are to:

- Match vetted student talent with DHS stakeholder human capital needs.
- Create opportunities for students to gain on-the-job experience within the maritime and homeland security operational environments.
- Increase the number of undergraduate and graduate-level STEM discipline students seeking careers and job placement in the private and public homeland security sectors.
- Create robust educational partnerships that facilitate accelerated experiential learning and professional development activities for students, and enhanced relationships with DHS stakeholders.
- Cultivate a network and pipeline of experienced and homeland security workforce ready STEM students.

MSC worked with its colleagues from the U.S. Coast Guard, Customs and Border Protection, and the National Urban Security Technology Laboratory (NUSTL) to host and identify internship opportunities for students during the months of June – August 2020. Following a competitive admission review process, the MSC selected four student candidates to participate in the inaugural 2020 internship program. The students applied and were selected from among the Center's Summer Research Institute (SRI) and Research Assistantship program networks.

Due to the COVID-19 pandemic, the student internships were held remotely throughout the ten-week program.

3.3.2. Students and Internship Projects

Table 17 provides a summary of the student interns, their host organization and internship projects for the ten-week program.

Table 17. MSC Coordinated STEM Interns.

Student	Internship Advisor	Internship Host	Project/Tasks
Jonathan Adamson	Dr. Jennifer Hayes, Forensic Scientist	CBP New York Laboratory	Analyzed methods for enhanced fentanyl detection at Ports of Entry. Attended virtual CBP Laboratory meetings and trainings. Due to restrictions caused by COVID-19, Jonathan was unable to perform any lab-based experiments.
Domenico Albarella	Teddy Damour, Program Manager	NUSTL	Provided assistance and conducted research in support of the C-UAS Air Domain Awareness (ADA) program.
Alice Huston	David Cote, IT Network Branch	USCG Research and Development Center	Provided project management and research support to the IT Network Branch in Maritime Operational Mobile Technology.
Matthew Kirby	Tyler Mackanin, Test Engineer	NUSTL	Provided research support and analysis for the System Assessment and Validation for Emergency Responders (SAVER) program. Prepared TechNotes assessing technology capabilities, limitations and measures for integration into existing systems.

3.3.3. Program Format and Outcomes

The recruitment and selection of STEM Internship candidates was held during the Fall 2019 academic semester. Student candidates were recruited from the MSC's Summer Research Institute and Research Assistantship current student and alumni networks. The goal of the admission review process was to have a minimum of four students selected and interviewed by the prospective internship host organizations by December 2019, to allow for sufficient time for the students to complete the suitability clearance process and onboarding prior to the start of the program in June. The five-month lead time between January and June, also gave the internship hosts and MSC administrators the opportunity to pivot to virtual internship projects late in the spring, when it became apparent that the COVID-19 public health crisis was going to negatively impact the ability to place students in operational environments.

While many of the objectives of the Coordinated STEM Internship were to expose students to the operational environments of homeland security organizations, the internship hosts developed contingency plans in which the students would engage in virtual meetings and trainings sessions on a regular basis throughout their internship program, and work on tasks and deliverables that held the students accountable for their time and work. In addition, the MSC organized bi-monthly status update meetings with the STEM Interns over the course of their ten- week summer placements to monitor engagement and troubleshoot any challenges the students may have working remotely.

MSC administrators also interacted with the internship host organizations to gather feedback on the program and the student's performance in carrying out their responsibilities.

Overall, the inaugural STEM Internship program was tremendously successful and the MSC received many positive comments on the student's engagement, performance and contributions to the organization's workload and operations. The NUSTL student interns, Domenico Albarella and Matthew Kirby each provided final presentations on their work in a virtual event organized for NUSTL employees.

3.4. Minority Serving institution (MSI) Engagement

Milestone	Performance Metrics	Status / Discussion
1. Minority and women student participation in the Center's annual Summer Research Institute. SRI 2020 – Outreach and recruitment (9/1/19 – 2/16/20)	Diversity in the SRI program will reflect a minimum of 50% of students from underrepresented communities. (e.g. minority students, women and MSI enrolled students.)	Partially Completed: The demographics for the 2020 SRI included 48% students from underrepresented communities and students from three MSIs.
2. MSI participation in MSC research activities/programs. Summer Research Team program YR 6 (6/1/20 – 8/7/20)	MSC will host a minimum of one MSI SRT team per summer. Outreach efforts to recruit MSI SRT participation will be measured by the number of targeted email distributions and personal conversations had with MSI representatives.	Completed: MSC hosted a faculty and student research team from City College of NY. The MSC contacted several MSIs leading up the MSI SRTP deadline to encourage as many project submissions as possible.
3. MSI Workshop	MSC will host a STEM-focused workshop tailored to MSI faculty and educators from underserved communities.	Completed: MSC developed and delivered a virtual Maritime Transportation System Cybersecurity MSI STEM Educator's workshop on May 29, 2020.

3.4.1. MSI Workshop – Maritime Transportation System Cybersecurity

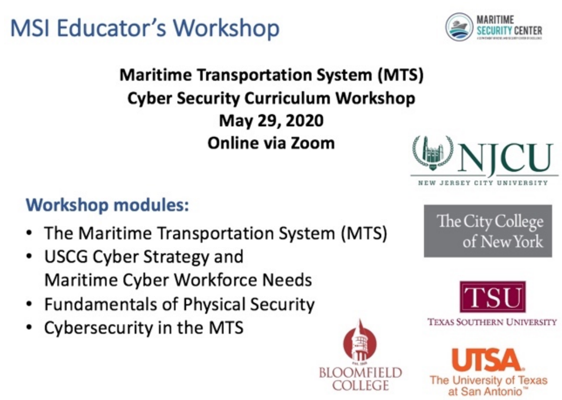

Figure 15. MSC's 2020 MSI Workshop was held virtually on May 29, 2020.

The MSC held a virtual workshop for faculty members from Minority Serving Institutions (MSI) on May 29, 2020. The Maritime Transportation System Cybersecurity curriculum development workshop had originally been planned to be held in April on-campus at Stevens Institute of Technology in Hoboken, NJ, however, due to the closing of campus-based activities at the start of the COVID-19 pandemic, the workshop was moved to the latter part of May and held remotely via Zoom.

The workshop was designed to bring attention to the Maritime Transportation System (MTS) as critical infrastructure and to assess emerging threats caused by cybersecurity vulnerabilities and attacks. The workshop leveraged curriculum developed by Stevens Institute of Technology and the Maritime Security Center to help build workforce capacity in the area of maritime cybersecurity.

The workshop was led by Dr. Barry Bunin, Research Professor at Stevens Institute of Technology and featured LCDR Alexander Kloo, from USCG Sector New York. LCDR Kloo provided the workshop participants with an overview of the MTS, a discussion on the U.S. Coast Guard's cyber initiatives and workforce imperatives.

Workshop attendees included faculty and program directors from Bloomfield College, City College of New York, New Jersey City University, Texas Southern University, and the University of Texas – San Antonio.

The curriculum for the virtual event included the following modules:

- The Maritime Transportation System (MTS)
    - Components of the MTS
- USCG Cyber Strategy and Workforce Imperatives
- Fundamentals of Physical Security
    - Physical Security in the MTS
- Cybersecurity in the MTS

    - Basic Concepts of Cybersecurity: Confidentiality, Integrity, Availability (C-I-A) Triad, Authentication, Nonrepudiation
    - Evolving Cyber Vulnerabilities
    - Common Attack Types (Phishing, Ransomware, Man-in-the-Middle, Denial of Service)
    - Recent Cyber Attacks - Saudi Aramco Attack, Maersk NotPetya Attack, Port of Antwerp Attack

- Risk Assessment and Decision Making
    - Risk Assessment, Vulnerability, and Consequences, Risk Management: Prioritizing Projects, Best Practices

Copies of the workshop presentation slides can be found on the MSC website at https://www.stevens.edu/STEM%20Educators%20Workshop.

To assess the effectiveness of the workshop in providing relevant and useful curriculum materials and information, the MSC asked the participants to complete a post-workshop survey. (see Appendix E-2 for copy of the survey instrument). When asked what inspired them to attend the workshop, the respondents commonly reported the relevance of the topic to their academic programs, the desire to learn new topics and incorporate new curriculum into their classrooms, and the opportunity to network with colleagues from other schools. When asked if the workshop content met their expectations, 60% said that the workshop "Exceeded My Expectations". The quality of the workshop was rated Excellent in the following categories:

- Quality of Workshop Curriculum
- Quality of Instruction
- Participation Engagement and Dialogue
- Quality of Workshop Administration

When asked how they would improve the workshop for future participants, a majority of the respondents said that they would increase the workshop format from three hours to four and would include more examples of best practices and more reference materials. MSC administrators have continued to communicate and engage with the workshop attendees by sharing relevant information on webinar events and other opportunities. In one case, a workshop attendee coordinated a guest lecture for the MSC's Summer Research Institute students.

3.4.2. MSI Summer Research Team Program

Dr. Bruce Kim, Associate Professor of Electrical Engineering at the City College of New York (CCNY) together with undergraduate students Edhar Muradov and Satesh Ramnath, conducted research in collaboration with the Maritime Security Center as part of the DHS Minority Serving Institution Summer Research Team Program (MSI SRTP). The team's research program was held virtually in conjunction with the MSC's Summer Research Institute.

Dr. Kim and his student team's research focused on the development of a handheld sensor platform that can be used by U.S. Coast Guard marine inspectors to efficiently and effectively monitor compliance of the International Maritime Organization's (IMO) global cap on vessel sulfur emissions. The team utilized nanotechnology applications to develop a prototype and concept of operations for the handheld device. The team's work has been recommended for an invention disclosure and potential patent by Stevens Institute of Technology's Office of Technology Commercialization. Details regarding the MSI Summer Research Team's research project and outcomes can be found in the Summer Research Institute section of this report, under 3.1.13. Student Research Projects, and copies of the team's final presentation slides and research poster can be found on the MSC website at www.stevens.edu/SummerResearchInstitute.

3.5. Maritime Cybersecurity Professional Development Course

#	Milestone	Performance Metric	Output
M1	Collaborate with USCG Cyber Command to identify maritime cyber education needs.	Develop a professional development short course tailored to the cybersecurity educational needs of the USCG Cyber Command. Engage in a minimum of three curriculum discussion and development meetings with USCG POC.	Complete: MSC, CG Cyber Command and CG Sector NY met monthly from September 2019 to June 2020 to create a tailored professional development course for CG marine inspectors.
M2	Adapt Stevens Maritime Cyber course into a professional development/short course format.		Completed: MSC in conjunction with CG Cyber Command and Sector NY created a course organized into six modules. The modules are based on topics covered in a graduate-level course offered by Stevens Institute of Technology.
M3	Develop course module in conjunction with USCG Cyber Command POC. (3/1/20 – 5/30/20)		Completed: The Cyber course planning committee has met more than 10 times and continues to meet monthly to finalize

			the course curriculum and delivery details.
	Confirm course date and location with USCG POC.	Deliver a minimum of one short course.	In process: The original course was scheduled to be held April 28 & 29, 2020 at USCG Sector New York. Due to COVID-19, the course has been postponed until early fall.
	Deliver course		In process: Due to COVID-19, the course has been postponed until early fall and will likely be held virtually.
	Gather course feedback in the form of a post-program survey.	A post-course survey will be used to assess the utility of the course to the USCG participants and for constructive feedback to improve future delivery of the course.	Incomplete: Dissemination of the course survey will occur at the end of the course delivery in early fall.

3.5.1. Maritime Cyber Pilot Course Overview

Figure 16. MSC and Coast Guard Cyber Command discussed the Maritime Cybersecurity course curriculum in a presentation during the MSC's annual review meeting.

Working in collaboration with Coast Guard Cyber Command and USCG Sector NY, the MSC developed a maritime cybersecurity professional development pilot course tailored to

Coast Guard marine inspectors. The course is designed to provide fundamental Cybersecurity knowledge to enable cyber risk awareness as part of routine vessel and facility security inspections.

The course draws upon maritime cybersecurity curriculum developed by Stevens Institute of Technology and includes practical insight into relevant information technology (IT) and operational technology (OT) cyber vulnerabilities and methodologies behind recent cyberattacks. The objectives of the course are to provide foundational knowledge and familiarity with cybersecurity concepts and terms, to allow marine inspectors to engage in informed conversations with facility security officers and chief information officers.

3.5.2. USCG Engagement

The impetus behind the professional development course, came from the MSC's participation on the USCG Sector New York Area Maritime Security Committee's Cybersecurity Subcommittee. Over the past five years, the MSC's Director of Education has assisted in co-chairing the subcommittee and has helped to facilitate and host maritime cybersecurity tabletop exercises, workshops and relationship building in the Port of NY/NJ.

It is through these engagements, that MSC's Director of Education began collaborations with LCDR Sarah Brennan and LT. Emily Miletello, USCG Sector NY, and LCDR Michael DeVolld, Coast Guard Cyber Command. Throughout the course development planning process, the above Coast Guard personnel provided invaluable boots on the ground perspective and considerable input into shaping the course curriculum.

Over the past year, the MSC, USCG Sector NY and Coast Guard Cyber Command met monthly to refine the course and plan for its delivery. The meetings occurred in person and remotely via Webex on the following dates: June 29, 2020, May 18, 2020, April 27, 2020, April 6, 2020, March 23, 2020, Feb. 28, 2020, Nov. 26, 2019, Sept. 25, 2019

3.5.3. Course Modules and Delivery Format:

The course is organized into a sequence of six modules. The modules are designed to provide fundamental cybersecurity knowledge within the context of the maritime domain and to build greater awareness of cyber vulnerabilities in IT and OT systems and maritime operations. The course modules include the following:

- Maritime Cyber - USCG Regulatory Overview and the Maritime Transportation System
- Fundamental Concepts in Cybersecurity
- Access Control, Biometrics and SMART cards
- GPS and its Vulnerabilities
- Operations Systems (SCADA, etc.)
- Risk Management and Decision Making

The course was scheduled to be delivered onsite at USCG Sector New York over a two-day period on April 28 and 29, 2020. Unfortunately, due to the COVID-19 pandemic, the course was not able to be held as planned. The MSC, CG Cyber Command and USCG Sector NY planning team continued to meet virtually and have developed new plans to host the course virtually via Microsoft Teams in the Fall.

4. Other Related Activities

This section describes additional activities related to MSC that occurred during the reporting period. These include the Center's activities for soliciting projects, stakeholder engagement, communications and outreach, management, and guidelines and policies.

4.1. Project Solicitation

In Year 6, the MSC continued to leverage its network to solicit new projects. MSC conducted multiple meetings with the USCG representatives from various organizations, mainly from the Acquisition Directorate (CG-9) and from the Capabilities Directorate (CG-7) and from Customs and Border Protection Air and Marine. These meetings resulted in identifying multiple projects of interest to the USCG and CBP (e.g., impact of wind farms on search and rescue operations, detection of non-compliant vessels with sulfur emissions, detection of illegal pleasure craft based on vessel weight, among others). Due to limited resources, previously identified projects of high interest to the USCG as well as these projects have not been funded yet. Also, due to the COVID-19 pandemic, travel was restricted starting in March of 2020 which further limited our ability to meet with key stakeholders and pursue additional funding.

4.2. Stakeholder Engagement, Communications, and Outreach

MSC continued to engage partners from various key stakeholder organizations in a range of activities (e.g., Meetings, COE Summit, and Workshops). MSC personnel participated in numerous activities and partnered with the USCG HQ, USCG RDC, USCG Sector NY, DHS S&T Borders and Maritime Division, Customs and Border Protection Field Operations, CBP New York Laboratory, National Urban Security Technology Lab, and others as described below.

USCG HQ

Through a coordinated effort with DHS OUP, representatives from MSC met several times with USCG representatives from the Acquisition and Capabilities Directorates as well as representatives from different areas in the USCG, including the Living Marine Resources Enforcement Policy, Sector Corpus Christi, and Office of Bridges Programs. The meetings were very productive and resulted in fruitful discussions of the USCG needs.

In addition, the MSC Director is serving as a member of the National Maritime Security Advisory Committee (NMSAC) that is chaired by USCG CG-FAC members to provide technical advice to the USCG Commandant. The NMSAC met once during Year 6 and discussed high priority issues to the USCG.

USCG RDC

The USCG RDC hosted an MSC summer research student in a virtual ten-week internship held from June 1, 2020 – August 7, 2020. MSC and USCG RDC worked collaboratively to vet prospective interns and to determine an internship project of mutual interest. Ms. Grace Python, Senior Operations Research Analyst and former MSC Master's Degree Fellow, participated in the Center's 2020 virtual Summer Research Institute, providing input and feedback into the Offshore Windfarm and Risk Management Dashboard summer research teams.

USCG Sector New York

MSC and the USCG Sector New York have developed a strong partnership over the years. Over the past year, MSC collaborated with USCG Sector NY personnel to develop a Maritime Cybersecurity Professional Development course in conjunction with Coast Guard Cyber Command. The two-day course was to be held at Sector NY on April 28 & 29, however, due to the COVID19 public health crisis, the course has been postponed until early fall 2020. MSC continues to meet regularly with Sector NY to plan for the course. Mr. John Hillin, Division Chief Safety and Security has also played a key role in the MSC's Summer Research Institute and has proposed and championed a number of student research projects. Over the past two summer's John has engaged with students to develop a Risk Management Dashboard that can be used to visualize and conduct trend analysis of incidents occurring in the Sector New York Area of Responsibility (AOR). The tool is continuing to be built out and will incorporate predictive analytic capabilities to allow for asset planning and allocation. John also provided input into the Sulfur Emission Detection student team project.

In another MSC event, LCDR Alexander Kloo, participated in the Center's Maritime Transportation Cybersecurity MSI STEM Educator's Workshop in May 2020. LCDR Kloo's engagement included a presentation on the Coast Guard's Cyber Strategy.

Throughout Year 6, MSC's Director of Education continued to serve as a co-Chair for the Sector NY Area Maritime Security Committee – Cybersecurity Subcommittee and participated with Sector New York personnel in a Maritime Cyber Risk Model (MCRAM) workshop led by MITRE.

S&T Tech Centers

MSC Director met on multiple occasions with DHS S&T Tech Center Subject Matter Experts to discuss sensors, unmanned platforms for maritime security, countering unmanned aerial systems, and Machine Learning applications in maritime and port security. These discussions led to an involvement with the US/UK Collaboration on Resiliency and Security (ColoRS) project and receiving funding to provide input to the team on the use of autonomous platforms for maritime security applications.

NUSTL

In addition to NUSTL's engagement in multiple Center's research projects, the Lab has played a significant role in the MSC's educational programs and in the placement of its students into internship and employment opportunities. Over the past year, the Center has collaborated with NUSTL to vet and place two students in internships with the Lab. Due to COVID-19 the ten-week internships were held virtually. The students engaged in projects in the areas of CUAS systems and TechNote preparation. One of the students was mentored by Tyler Mackanin, who is a former MSC Master's Degree Fellow and who is now a Test Engineer at NUSTL. Several NUSTL employees also participated in the Center's annual Summer Research Institute student research presentation event held virtually on July 23, 2020.

CBP

CBP's Office of Field Operations at the Port of NY/Newark confirmed an annual field visit for MSC Summer Research Institute (SRI) students to be held June 11, 2020. Unfortunately, due to COVID19 the field visit was not able to occur. In lieu of the annual visit however, Acting Branch Chief, Scott Rutledge, provided the students with a webinar on CBP Port Operations during the summer research program. The trip to Port would have marked the Center's nineth annual visit to CBP over the course of the summer research program. The Acting Branch Chief also attended the virtual SRI student research presentations.

CBP Laboratory and Scientific Services

CBP New York Laboratory has contributed greatly to the MSC's educational programs. This past year, CBP Lab scientists met in person and over conference call with an MSC MSC Graduate Research Assistant who was conducting research into improved methods for fentanyl detection at US ports of entry. In addition, CBP New York Laboratory provided an opportunity for the graduate student to participate in a virtual internship during the summer of 2020. The student was able to participate in meetings and attend virtual training sessions with the Lab's personnel.

PANYNJ

Michael Edgerton, Manager of Port Security for the Port Authority of New York and New Jersey (PANYNJ) provided a guest webinar for students in the MSC's 2020 Summer Research Institute. Michael's presentation discussed approaches to security risk assessment. He also attended student project briefings and provided input and subject matter expertise in support of the student team projects.

MSC and Stevens students also participated in a full-scale exercise coordinated by the PANYNJ Office of Emergency Management. The exercise included a hypothetical plane crash at Newark Liberty International Airport. The students roleplayed injured crash victims and were able to observe emergency personnel and law enforcement from multiple Federal, state and local entities as they responded to the simulated event.

Other Activities

In addition to the activities discussed above, MSC conducted many targeted communications efforts.

The MSC held its annual review meeting virtually this past year due to COVID-19. The meeting was attended by more than 50 DHS personnel, including representatives from USCG HQ, USCG RDC, USCG Sectors New York, Southeastern New England, and Corpus Christi, CBP Field Operations, CBP New York Laboratory, CBP AMOC, DHS S&T, and NUSTL, as well as MITRE, ABS, PANYNJ, and others.

The Center generated a monthly email newsletter that was distributed to the Center's stakeholders. These updates proved to be an effective way to communicate MSC's activities with its government partners and generate discussions among DHS components on areas of interest.

The monthly update contains relevant information regarding the Center's research, stakeholder engagements and student achievements. An archive of MSC's update newsletters can be found on the Center's website at: https://www.stevens.edu/research-entrepreneurship/research-centers-labs/maritime-security-center/center-newsletters.

4.3. Management Activities

The main COE management activities not discussed earlier in this report are summarized in this section. The Center Director worked with the COE's Principal Investigators (PIs) to develop project work plans and discussed project content that will benefit DHS and its stakeholders. The Director also worked closely with the DHS Program Manager and spoke with her on a regular basis to understand DHS expectations from the Center and bring up any issues of concern and to adjust operations based on additional OUP COE requirements. Based on these discussions and meetings, the Director held regular meetings with individual PIs as well as coordinated conference call meetings with the Center's PIs as needed. The purpose of these meetings was to ensure that the individual projects are progressing according to the work plans and continue to be aligned with DHS OUP's expectations. During the COVID-19 pandemic, MSC lead and partner universities closed and restricted all travel activities. To ensure that the projects were minimally impacted, MSC developed a contingency plan that took into account various potential re-opening dates and realigned the schedules to allow research activities to continue without having the need for face-to-face meetings and to change the project end dates. In addition to the contingency plans, the frequency of meetings with PIs was increased to weekly until the various projects were back on track.

Members of the Center Science and Education Advisory Committee (SEAC) have been engaged periodically throughout the year and were kept informed of the Center activities through phone conversations and Center email communications. In addition, they were invited to Center activities including the Summer Research Institute.

In addition to the above activities, the Center Director continued to reach out to many DHS stakeholders at various levels and in different capacities to discuss their projects and how the Center can be a resource to them. These meetings included discussions with representatives from DHS Countering Weapons of Mass Destruction, NUSTL, CBP Air and Marine Office, and various USCG key people. Also, MSC worked closely with the USCG RDC and NUSTL regarding research in the area of counter-UAS systems, such as developing requirements, testing, and quantifying their performance. The Director also discussed transition ideas with CBP Air and Marine personnel to understand their needs and their limitations in preparation for transitioning projects when they are ready. In particular, many discussions were focused on current sensors for detecting and tracking underwater and water surface threats.

As part of its transition efforts, the MSC management has continued to conduct project evaluations and tracking of post-project developments. Discussions and meetings were conducted with the Stevens Office of Innovation and Entrepreneurship to discuss potential patents and licensing of research Intellectual Property that is expected to result from the MSC projects.

In addition, MSC management continued to work closely with ICE, DHS Intelligence and Analysis Directorate, DHS CWMD, and National Maritime Security Advisory Committee (NMSAC). With ICE, many discussions were conducted regarding the use of multiple sensors to protect against illegal smuggling of humans and illicit material in the Caribbean. Finally, MSC's Director attended NMSAC calls/meetings.

4.4. Center Guidelines and Policies

During Year 1, MSC administrators created a document for the Center's academic partners and research PIs containing general orientation information (e.g. partner contact information, reporting requirements, and DHS acknowledgement and disclaimer statements), and copies of the Center's policy and security requirements for handling sensitive material, as well as student safety and security guidelines. The MSC General Information and Guidelines for Academic Partners document was updated in Year 6 and shared with each of the MSC partner schools, with the requirement that they acknowledge receipt and confirm that they have reviewed and understand the policy and security requirements for handling sensitive material and the student safety and security guidelines.

5. Budget

The budget breakdown is being provided separately as part of the Stevens financial reporting requirements. The accompanying Excel file provides a summary of the funds (actual and budget) per project and per object code (e.g., salary, fringe, travel, overhead, supplies, etc.). Please note that the numbers included are based on numbers available in the financial reporting system at the time this document was prepared. Some expenses and credits may not have posted when this report was prepared and will consequently be reflected in future financial reporting.

APPENDIX E-1 SRI 2020 Student Survey

MARITIME SECURITY CENTER
A DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE

Summer Research Institute

2020 - Student Survey

Your feedback is very important and will help us assess the impact of the SRI on your learning gains and professional development, and will help us improve the summer research program for future participants.

Please take the time to provide us with as much detailed information as possible in the open-ended questions. <u>All responses are anonymous.</u> Thank you in advance for your time and feedback!

* 1. How would you describe your knowledge of the maritime domain/enterprise prior to the start of the SRI?

- 1=No prior knowledge
- 2=Minimal knowledge
- 3=Working knowledge
- 4=Advanced knowledge

* 2. Prior to the SRI had you taken any classes online? (via remote learning?)

- Yes
- No

* 3. To what extent has the SRI enhanced or improved your skills in the following areas?

	1=Not at all	2=Some Improvement from when I started the SRI	3=Significant improvement from when I started the SRI
Ability to Conduct Research	○	○	○
Communication Skills	○	○	○
Leadership Skills	○	○	○
Networking	○	○	○
Oral Presentations	○	○	○
Professional Confidence	○	○	○
Teamwork/Collaboration	○	○	○
Organizational Skills	○	○	○
Self-Motivation	○	○	○

Other (please specify)

* 4. Which of the skills above did you improve the most and what SRI activities helped you improve them?

* 5. What skills have you developed or enhanced during the SRI that you feel will be of most use to you in your academic program and future career?

* 6. Rate the SRI in regards to the following items:

	1= Not good	2= Good	3= Very Good	4= Excellent
Faculty Mentor Guidance and Support	◯	◯	◯	◯
Program Coordination/Administration	◯	◯	◯	◯
Program Format	◯	◯	◯	◯
Guest Speakers	◯	◯	◯	◯
Teamwork/Collaboration	◯	◯	◯	◯
Stakeholder Engagement in Projects	◯	◯	◯	◯
Research Project Outcomes	◯	◯	◯	◯
Use of Slack	◯	◯	◯	◯
Weekly Status Update Meetings	◯	◯	◯	◯
Student Projects (How did you feel about the project you were assigned?)	◯	◯	◯	◯
Student Team Dynamics. (Did the members of your team collaborate and contribute equally to your research project?)	◯	◯	◯	◯

* 7. How would you best describe your experience in the SRI and what are your top takeaways from the program?

* 8. What would you say are the strengths of the SRI?

* 9. What would you say are the program weaknesses and what can the MSC do to improve the program if it is held remotely again next summer?

* 10. Has the SRI enhanced your interest in pursuing a career and/or further academic study in the field of maritime/homeland security?

◯ Yes

◯ No

* 11. Would you recommend the SRI to your friends and colleagues at your university/school?

◯ Yes

◯ No

APPENDIX E-2 Maritime Transportation Cybersecurity MSI Workshop Survey

MARITIME SECURITY CENTER
A DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE

Maritime Cybersecurity MSI Educator's Workshop

Workshop Feedback Form

Dear Colleague,
The Maritime Security Center would like to request your feedback on your recent participation in the Center's Maritime Cybersecurity Educator's Workshop. Your feedback is important to us and will help shape and guide how we deliver the program in the future. We appreciate your constructive comments and thank you for your time.

* 1. What best describes you?

- ○ Higher Education (College-level) Faculty Member
- ○ Higher Education Administrator
- ○ Other (please specify)

* 2. What inspired you to attend the Workshop? (Check all that apply.)

- ☐ The topic is relevant to my job/academic program.
- ☐ I was hoping to learn new information that will assist me in my classroom.
- ☐ I am looking for new curriculum materials to include in my classes.
- ☐ I am interested in creating a new program in Maritime Cybersecurity.
- ☐ This was an opportunity to network with fellow colleagues.
- ☐ Other (please specify)

* 3. Did the Workshop content meet your expectations?

Did not meet my expectations.	Met my expectations.	Exceeded my expectations.
○	○	○

Other (please specify)

* 4. What aspects of the Workshop were of most interest and relevance to you? (check all that apply.)

- [ ] USCG Perspectives on Maritime Cyber and the MTS.
- [ ] Introduction to the Maritime Transportation System.
- [ ] Discussion on IT and OT Systems and Vulnerabilities.
- [ ] Other (please specify)

* 5. Rate the Workshop in regards to the following items:

	Not good at all	Good	Very Good	Excellent
Quality of the Workshop Curriculum	○	○	○	○
Quality of Instruction	○	○	○	○
Quality of Workshop Coordination/Administration	○	○	○	○
Ease of the Online Platform (Zoom)	○	○	○	○
Participant Engagement and Dialogue	○	○	○	○

* 6. Prior to attending the Workshop, had you discussed or incorporated examples of maritime cybersecurity concerns in your curriculum plans or programs of study?

- [ ] Yes
- [ ] I have not up until this point, but I will now consider incorporating discussion into my curriculum.
- [ ] No and I am unlikely to include mention or examples of this in my curriculum.
- [ ] Other (please specify)

* 7. What were your top takeaways from the Workshop? (Check all that apply.)

- [ ] Curriculum discussion
- [ ] Discussions and networking
- [ ] Inclusion of the U.S. Coast Guard

8. What can the Maritime Security Center do to improve the Workshop for future participants? (Please provide as much detail as possible.)

9. Would you be interested in collaborating with the MSC/Stevens Institute of Technology to host future workshops or engage in collaborative research projects?

- [ ] Yes
- [ ] Not at this time, but maybe in the future
- [ ] No
- [ ] If yes, please let us know how you would like to collaborate.:

10. Additional feedback/comments regarding your experience in the Workshop. (optional)