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National Center of Excellence
Center for Secure and Resilient Maritime Commerce (CSR)

YEAR THREE REPORT

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Center for Secure and Resilient Maritime Commerce (CSR)

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Nansen Environmental Remote Sensing Center
Pacific Basin Development Council
Port Authority of New York and New Jersey

Affiliated Institution
Global Maritime and Transportation School at the US Merchant Marine Academy
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YEAR THREE EXECUTIVE SUMMARY

The Center for Secure and Resilient Maritime Commerce (CSR), along with the University of Hawaii’s National Center for Islands, Maritime, and Extreme Environments Security (CIMES), are the U.S. Department of Homeland Security’s (DHS) National Center of Excellence for Maritime, Island and Extreme/Remote Environment Security (MIREES). The Center supports DHS efforts under NSPD-41 / HSPD-13 to provide for the safe and secure use of our nation’s maritime domain (including island and extreme environments and inland waterways), and a resilient MTS, through advancement of the relevant sciences and development of the new workforce.

The CSR brings together a unique group of academic institutions and public and private partners that is led by Stevens Institute of Technology, Hoboken, New Jersey. Besides Stevens Institute, the partnership includes the following academic institutions: Rutgers University, University of Miami, University of Puerto Rico, Massachusetts Institute of Technology, Monmouth University and the U.S. Merchant Marine Academy’s Global Maritime and Transportation School. The non-university partners in the CSR include the Port Authority of New York and New Jersey, the Mattingley Group, the Pacific Basin Development Council, and Nansen Environmental Remote Sensing Center.

The CSR strategy to succeed in its mission relies on the creation and sustainment of a truly collaborative research and education enterprise that draws on the discipline-specific strengths of each partner, their intellectual and physical infrastructure assets, and their leveraged relevant DHS and non-DHS research and education activities. The Center, now in its 4th year of operation, possesses extraordinarily diverse expertise and significant experience in developing new knowledge, models, tools, policies and procedures, and education/training methodologies related to maritime security and safety.

In order to ensure alignment of the CSR research and education activities with the implementation plans under NSPD-41/HSPD-13, while also ensuring both the relevance and agility needed to support the DHS member agencies, we have developed a set of metrics that serve both to guide the Center’s activities and to facilitate the performance assessment of those activities. Fundamentally, these activities center on supporting the safety and security of our nation’s Marine Transportation System (MTS) and coastal and offshore resources. To address these goals, CSR’s research and education efforts are divided into two basic areas: Maritime Domain Awareness (MDA), and Topics in Global Policies influencing MTS Security, including Design for Resiliency.

Maritime Domain Awareness: The Maritime Domain is defined as "all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances.” The MDA projects examine the basic science issues and emerging technologies to support the use of a layered approach to the problem. The layers include satellite-based wide area surveillance; HF Radar systems providing over-the-horizon surveillance; and nearshore and harbor surveillance systems centered on
underwater acoustic technologies. Integration of these systems is aimed at achieving vessel detection, classification, identification, and tracking. The new knowledge and new and improved technologies and algorithms developed under this research area are aimed at achieving real-time, all-weather, day/night, multi-layer maritime surveillance from the open ocean to estuaries, harbors and inland waterways, all at high-resolution. One of the fundamental questions yet to be answered is the limit of resolution of each of the component sensor technologies (e.g., space-based, HF Radar, and underwater acoustic); or in other words: “how small is too small?” or “how far is too far?” This issue of resolution is driven by the concern for threats associated with small surface vessels, UUVs, and divers. Ultimately, this layered surveillance capability should provide the means to enable adequate surveillance-based understanding of our waterways so that we can accurately define “the normal”, with all of its variability. Only then can we accurately define and detect the “departures from the normal,” or anomalies that can in concert with decision-support systems trigger a response.

The University of Miami’s Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) leads the space-base applications and is developing new understanding and new processes for receiving and analyzing large maritime area data from multi-satellite and multi-frequency sensors such as Synthetic Aperture Radar (SAR) and electro-optical (EO) sensors. Algorithms continue to be developed to employ the data to detect vessels, including small ships, in harbors, inland waterways, the coastal ocean and the high seas. Algorithms are also being developed to integrate this vessel detection information with ground-based systems such as Automatic Identification System (AIS). The Deepwater Horizon oil spill response demonstrated the path to transitioning satellite imagery products to operational use in the field. The success of the CSTARS team in providing near real-time analyzed imagery to the first responders during this catastrophic event was a dramatic illustration of the utility of the sensors and algorithms, and was a primary reason for the CSR receiving the DHS S&T Impact Award for the second time in our three years of existence.

Rutgers University’s High-Frequency Surface Wave Radar (HF Radar) team is developing robust detection algorithms that recognize ship-associated HF Radar signals above the background noise (e.g., surface waves). Algorithms continue to be developed to support vessel detection and tracking capabilities using compact HF Radars, demonstrating that ships, including small ships, can be detected and tracked by multi-static HF Radar in a multi-ship environment, while simultaneously mapping ocean currents. Further, Rutgers has been developing novel algorithms for improved ship position detection based on the use of multiple radar detection images. Hardware systems and software developed and tested in the CSR New York Harbor test-bed and at the Port of Miami are being transferred to the University of Puerto Rico for testing in Caribbean waters. The University of Puerto Rico at Mayagüez (UPRM) is focused on the installation and operation of HF Radar in remote areas such as the Mona Passage for the dual use applications of ship detection & tracking, and surface current mapping.
Stevens Institute of Technology leads the nearshore and harbor surveillance system portion of the MDA project. Much of the Stevens effort has been devoted to the development of a passive acoustic array that can provide low-cost, highly portable acoustic surveillance capability. The signal processing is based on the cross-correlation of signals received by several hydrophones. The system has been applied to measuring the travel direction and acoustic signature characteristics of vessels in the heavy traffic of NY Harbor as well in the Port of Miami, where many types of vessels (from jet skis to cruise ships) are typically present.

Stevens researchers are also conducting investigations of emergency response decision-making. We have found that emergencies can demonstrate both the strengths and weaknesses in human decision-making. When pushed to their cognitive limits, decision makers often fall back on overly simple reasoning strategies. It was found that common cultural practices can help overcome human weaknesses while supporting human strengths. Simply discussing a decision with a collaborator can help decision makers better see and understand complex relationships between decision variables and the consequences of various decisions. The researchers believe that decision technologies can fill the need for greater computational power and extended memory.

**Topics in Global Policies influencing MTS Security, including Design for Resiliency:**
This element of the CSR research activities takes a broad view of the MTS and relevant global policies and procedures. Vulnerabilities within the global supply chain are being examined via a collaborative effort to strengthen maritime resiliency and the resiliency of extended enterprises, as well as improving the recovery and continuity of operations. CSR researchers are developing the essential tools and processes necessary to create a capability to "design for resilience" for MTS resiliency.

There are three separate but integrated research activities under this research area, including **Enterprise Resiliency Modeling – Architecting Strategic Intent, Resilient and Cognitive Port Infrastructure Systems and Enterprises** and the **Port Resilience Project**.

The **Enterprise Resiliency Modeling – Architecting Strategic Intent** project is employing systemic diagram modeling, i.e. Systemigrams, to capture systemic intent of port enterprise resilience in a unique fashion. The graphical representation allows convergent values to be identified that can serve as a basis for the establishment of a common culture across diverse stakeholders. The common culture provides the context for improved cooperation and emergent leadership of the entire system. The Systemigram models expressed as a CONOPS are then actualized in an agent-based modeling and simulation environment in order to capture the temporal and special dimensions of port enterprise resilience.

The **Resilient and Cognitive Port Infrastructure Systems and Enterprises** project seeks to model the marine transportation system as a network where the ports are the nodes and the links are the waterways that connect the ports. Using the network model,
the network resiliency is measured from a multi metric perspective; the metrics reflect the impact of a disruption on the system’s value delivery levels that are defined by the performance measures. Resiliency metrics are being defined and, using a network model along with a System Dynamics model, the effect of port collaboration on the above mentioned resiliency metrics are being measured. An Enterprise Architecture approach is being used to develop an architecture for a Cognitive Port System.

The **Port Resilience Project** is aimed at developing a more detailed MTS capacity study that takes into consideration daily volumes (rather than annual volumes). Prior analysis conducted by the CSR researchers, while providing some insights about port capacities to handle various volumes, is limited in a variety of ways and can only consider annual volumes. The Year 3 study took daily variations into consideration. The effort also included the development of a set of recommended resilience practices based on insights drawn from field visits, qualitative and quantitative survey input, and assessment of port case studies.

The three activities outlined here are all directed at better understanding the national MTS and its level of resiliency. They also aim to provide the modeling framework, visualization tools, and data that will enable an assessment of the present state of the US MTS in terms of vulnerability, capacity, and ultimately, resilience, as well as the preliminary tools necessary for an eventual capability to design for resilience.

**Education Activities:** Central to CSR’s mission is the transfer of its research and expertise into highly relevant, innovative educational programs designed to enhance maritime domain awareness and the knowledge, technical skills and leadership capabilities of our nation’s current and future maritime security workforce. Since the Center’s inception in 2008, CSR, via collaboration with its academic partners, Stevens Institute of Technology, Rutgers University, University of Miami, University of Puerto Rico, Massachusetts Institute of Technology and Monmouth University, have worked together to develop a comprehensive portfolio of maritime security-centric educational programs. These programs include:

- Science, technology, engineering and mathematics (STEM) K-12 teacher workshops,
- Curriculum development in MDA for undergraduate education,
- Professional development courses in port security sensing technologies tailored to maritime industry and homeland security practitioners, and
- A four-course Graduate Certificate in Maritime Security delivered online via Stevens Institute of Technology’s WebCampus.

In June 2011, CSR conducted the second installment of its primary educational initiative - the Summer Research Institute (SRI) - a multi-disciplinary, intensive summer research program designed to provide qualified undergraduate and graduate-level students with the unique opportunity to engage in rigorous hands-on research in collaboration with CSR faculty to address critical issues in MDA, the MTS, emergency response and preparedness, and maritime system resilience.
I. INTRODUCTION

Mission
The National Center of Excellence for Maritime, Island & Remote/Extreme Environment Security supports DHS efforts under NSPD-41 / HSPD-13 (National Maritime Security Strategy, 21 December, 2004) to provide for the safe and secure use of our nation’s maritime domain (including island and extreme environments, and inland waterways), and a resilient Marine Transportation System (MTS), through advancement of the relevant sciences and development of the new workforce. These efforts are specifically aligned to assist in the successful implementation of the elements of NSPD-41 / HSPD-13:

• **Maritime Domain Awareness** - the effective understanding of anything associated with the Maritime Domain that could impact the security, safety, economy, or environment of the United States.
• **Global Maritime Intelligence Integration** - uses existing capabilities to integrate all available intelligence regarding potential threats to U.S. interests in the Maritime Domain.
• **International Outreach and Coordination** - provides a framework to coordinate all maritime security initiatives undertaken with foreign governments and international organizations, and solicits international support for enhanced maritime security.
• **Maritime Infrastructure Recovery** - recommends procedures and standards for the recovery of the maritime infrastructure following attack or similar disruption.
• **MTS Security** - responds to the President’s call for recommendations to improve the national and international regulatory framework regarding the maritime domain.
• **Maritime Commerce Security** - establishes a comprehensive plan to secure the maritime supply chain.
• **Domestic Outreach** - engages non-Federal input to assist with the development and implementation of maritime security policies resulting from NSPD-41/HSPD-13.

The Maritime Domain is defined as "All areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances."

In order to accomplish its research and educational goals, the Center for Secure and Resilient Maritime Commerce (CSR) brings together a unique group of academic institutions and public and private partners that is led by Stevens Institute of Technology, Hoboken, New Jersey. Besides Stevens, the partnership includes the following academic institutions: Rutgers University, University of Miami, University of Puerto Rico at Mayagüez, Massachusetts Institute of Technology, Monmouth University and the U.S. Merchant Marine Academy’s Global Maritime and Transportation School. The non-
university partners in the CSR include the Port Authority of New York and New Jersey, the Mattingley Group, the Pacific Basin Development Council, and Nansen Environmental Remote Sensing Center.

**Strategy**

The CSR strategy to achieve its mission centers on the creation and sustainment of a truly collaborative research and education enterprise that draws on the strengths of each partner, as well as their leveraged relevant DHS and non-DHS research and education activities. We believe that these unique attributes – collaborative; integrated research & education; and leveraged relationships with Federal, State, local government, and industry stakeholders – positions the CSR for continued long-term success and impact. Going forward, the CSR research and educational activities will continue to be built around two primary areas of interest:

1. **Maritime Domain Awareness (MDA)** – the development of sensor technologies, analysis tools, and decision aides that can enable an effective understanding of anything associated with the Maritime Domain that could impact the security, safety, economy, or environment of the United States.

2. **MTS Resiliency** – the development of models, tools, and decision aides that can assist policy makers and decision-makers responsible for making organizational changes and resource allocations to enhance resiliency in our nation’s MTS.

Through the first 3 years of operation, the CSR efforts related to technology development in support of MDA have been guided by a Spiral Development approach to solving the complex issues facing the MTS. This approach, illustrated in Figure 1, has required that the individual research projects – in satellite, radar, and underwater acoustics sensors - achieve the necessary fidelity to provide improved understanding and capabilities, as well as technology products that can be examined via field experiments in the real-world environment. These activities have led to the transitioning of new technologies to beneficial use in the field by the US Coast Guard, US Navy, NOAA, NGA, and the City of New York, among others. They have resulted in the CSR being awarded the DHS S&T Impact Award in two of its first three years of existence.

Port resiliency research is a highly complex and interdisciplinary research area that is quite novel in academia as well as in industry. Currently there are no accepted quantitative methodologies to assess resiliency benefits in a systematic manner, much less a means to formulate an optimal resiliency investment strategy for a port or terminal. Assessment methodologies are needed to evaluate the efficacy of security investments among alternative security plans to provide resiliency benefits and to quantitatively assess the value of such investments to enhance service recovery processes following a disruptive shock. The work of our researchers to-date has established the conceptual foundation and baseline data for the successful conduct of our resiliency research in the years ahead. Ultimately, the Resiliency research will take on the same Spiral Development characteristics that have thus far successfully guided the MDA research.
Ensuring Impact
The CSR researchers and educators are committed to ensuring that our new knowledge, technology products, tools, and educational programs are responsive to the wide range of stakeholders that we serve. Success in this endeavor requires that we:

- Partner with the end users to understand their needs;
- Partner with industry, as well as government and university laboratories, to understand technology gaps and to work toward filling those gaps.

In any port development, there is an interaction of public and private entities. Public entities are federal, state or city agencies. Usually, public agencies own the land on
which the port development is planned. The land is either developed by the public entity or given on lease to the private entity for development. Private entities can be terminal operators who develop a terminal and then operate the terminal. Port authorities often own the land or lease the land from the other public entities and then sub-lease to terminal operators for development.

Table 1 gives an overview of the preferences that different entities have in a port development project. Agencies such as the Department of Transportation (DOT) and Department of Commerce (DOC) are more interested in annual throughput of a port. Port authorities and terminal operators, on the other hand, are not just concerned about throughput but also the flow of the cargo. Just-in-time inventory management policy by the shippers has made them focus on the reliability of the cargo delivery. Security is of utmost importance for the Department of Homeland Security, as a primary aim of the agency is to protect the homeland against any avoidable disruption. These entities will select the methods that are suitable to their needs. After Katrina, numerous companies began using advance sourcing technology to plan their reactions to unexpected supply chain disruptions, increased the number of their suppliers, and analyzed the cost impacts of mode capacity on different routes. Individual shippers have developed their own contingency plans. The multiple disasters that recently struck Japan illustrate how vital contingency and resiliency planning are to supply chain continuity. Moving from private to public stakeholders, the risk analyses and consequence management approaches become far more complex than those faced by an individual shipper.

<table>
<thead>
<tr>
<th>Entity</th>
<th>Agencies</th>
<th>Preference</th>
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</thead>
<tbody>
<tr>
<td>Public</td>
<td>Department of Transportation</td>
<td>Annual throughput</td>
</tr>
<tr>
<td></td>
<td>Department of Commerce</td>
<td>Annual throughput</td>
</tr>
<tr>
<td></td>
<td>Department of Homeland Security</td>
<td>Port security</td>
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<td></td>
<td>Department of Defense</td>
<td>National security</td>
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<td></td>
<td>State and City</td>
<td>Jobs and tax revenues</td>
</tr>
<tr>
<td></td>
<td>Port Authorities</td>
<td>Annual throughput, cargo flow, new development</td>
</tr>
<tr>
<td>Private</td>
<td>Terminal Operators</td>
<td>Annual throughput and cargo flow</td>
</tr>
<tr>
<td></td>
<td>Shipping Companies</td>
<td>Cargo flow</td>
</tr>
<tr>
<td></td>
<td>Shippers</td>
<td>Reliability of cargo delivery and expense</td>
</tr>
</tbody>
</table>

Table 1 – Preferences for different maritime stakeholder entities

We have already established strong ties with many of these entities. We have visited numerous ports, agencies, and laboratories, including US Coast Guard Headquarters in DC; US Coast Guard Sectors New York; Miami; San Juan; Honolulu; and San Francisco; the Port of Los Angeles, Port of Long Beach, Port of Hueneme, Port of Seattle, Port of Tacoma, Port of New York/New Jersey, Port of Houston, Port of Miami, and the Port of
San Juan; NYC Office of Emergency Management; NYPD; NJ Office of Homeland Security and Preparedness; the Regional Catastrophic Planning Team in Manhattan; the Naval Research Laboratory, DC; National Maritime Intelligence Center; Naval Undersea Warfare Center, Newport, RI; Naval Surface Warfare Center, Panama City FL; Naval Research Laboratory, Stennis MS; SPAWAR, San Diego, CA; USCG R & D Center, Groton CT; CBP Air and Marine, Miami, FL; JIATFS, Key West, FL; Navy TENCAP; NGA; DIA; Air Force TENCAP; ARSTRAT; STRATCOM; NORTHCOM; Office of Naval Research, Arlington, VA; and US SOUTHCOM, Miami. Our challenge in the coming years is to take advantage of the relationships that we have initiated, and to expand these relationships by reaching out to additional stakeholders.

**Transitioning**

Successful transitioning of Intellectual Property begins with reaching out to the end user, understanding their needs, and building the trust necessary to enable the “productization” of a prototype device, model, tool, or algorithm. It was this sort of outreach in fact that led to the adoption of CSR-developed technologies and algorithms by end users that include the US Coast Guard (Search and Rescue, oil spill response); the US Navy (NUWC, Swimmer Detection System); and the NGA (oil spill response).

**Performance Metrics**

In order to ensure alignment of the CSR research and education activities with the implementation plans under NSPD-41/HSPD-13, our strategy incorporates a set of metrics that serve both to guide the Center’s activities and to facilitate the performance assessment of those activities. Table 2 illustrates how the CSR (MIREES) mission and associated research and education activities align with the implementation plans under NSPD-41/HSPD-13. Table 2 also lists the measurable outcomes – Performance Metrics - associated with the specific CSR activities that are used to assess progress in supporting DHS efforts under NSPD-41/HSPD-13.
<table>
<thead>
<tr>
<th>NSPD-41/ HSPD-13 Goals</th>
<th>MIREES Vision Statement</th>
<th>CSR Activities</th>
<th>Performance Metrics</th>
</tr>
</thead>
</table>
| MDA | “...safe and secure use of our nation’s maritime domain.” | MDA sensor technology development | 1. # of patent or copyright filings  
2. # of partnerships with external sensor developers and integrators  
3. # of partnerships with relevant DHS agencies and other Federal, State, and Local departments/agencies.  
4. # of field evaluations and exercises  
5. # of major publications  
6. # of technical conference presentations |
| Global Maritime Intelligence Integration | “...advancement of the relevant sciences..” | Information fusion. Human factors, including hostile intent assessment and decision-making | 7. # of new algorithms for sensor and information display/fusion.  
8. # of new algorithms for assessment of hostile intent; anomaly detection.  
Performance Metrics 3, 4, 5, & 6 |
| Maritime Operational Threat Response | “...safe and secure use of our nation’s maritime domain..” | Development of systems and algorithms to support real-time Situational Awareness/COP | 9. # of new delivery systems to provide for real-time delivery of sensor data, including space-based, land-based, and underwater sensor information.  
Performance Metrics 3, 4, 5, & 6 |
| International Outreach and Coordination | “...through advancement of the relevant sciences and development of the new workforce.” | Development of research and educational programs with international partners | 10. # of new research collaborations with approved international partners, as evidenced by MOUs, MOAs, and NDAs.  
11. # of new educational programs with approved international partners. |
| Maritime Infrastructure Recovery | “...safe and secure use of our nation’s maritime domain..” | Development of models and tools to support the design of a | 12. # of partnerships with the MTS community, including the port industry, shippers, carriers, etc. |
| MTS Security | “and a resilient MTS...” | “through advancement of the relevant sciences and development of the new workforce” | Examine the national and international policies and regulations that impact maritime security. | 17. New data regarding relevant national and international policies and regulations that impact maritime security. Performance Metrics 3, 5 and 6 |
| Maritime Commerce Security | “and a resilient MTS...” | “through advancement of the relevant sciences and development of the new workforce” | Develop models and tools for the analysis of the US supply chain, including vulnerabilities to disruption. | 18. New data to populate a US supply chain database. 19. # of new risk and vulnerability models of the supply chain, e.g., failure analyses. Performance Metrics 3, 5, 6, 12, 13, 14, 17 |
| Domestic Outreach | “development of the new workforce” | Develop/ conduct educational programs and materials for use in K-12, university, public outreach, and professional education. | 20. # of new undergraduate courses and programs at the member universities. 21. # of new graduate courses and programs at the member universities. 22. # of new professional education programs. 23. # of new K-12 programs and materials 24. # of new public outreach programs and materials | Performance Metric 11 |

Table 2 – Alignment of CSR Research and Education Activities with NSPD-41/HSPD-13 Goals; and Project Performance Metrics
In addition to these performance metrics, the CSR partners agree that an essential metric of success of the overall Center of Excellence effort is the degree to which the CSR functions as a cohesive, collaborative consortium. To that end, we have also adopted performance metrics that measure the **degree of collaboration** – by examining the following:

- Performance Metric 25: the number of multi-author papers, presentations, and reports
- Performance Metric 26: the number of multi-partner papers, presentations, and reports
- Performance Metric 27: the number of multi-partner educational programs and materials

We will remain flexible as we develop and refine the research plan, with the agility to respond quickly to new and emerging threats and national needs. Throughout, the member universities will involve undergraduate and graduate students, and will develop new courses, new curricula, and professional education and outreach tools to facilitate the training of the next generation of maritime security professionals, including students and professionals from historically underrepresented groups and minority serving institutions.
II. DESCRIPTION OF THE CSR

The National Center for Secure and Resilient Maritime Commerce (CSR) brings together a unique set of academic institutions, public organizations, and private sector partners. The Center was created to possess both diverse expertise and significant experience in developing new knowledge, models, tools, policies and procedures, and education/training methodologies related to global maritime security. CSR’s Director is Dr. Michael Bruno, Dean of the School of Engineering and Science at Stevens Institute of Technology. The Center is physically located on the Stevens Institute of Technology campus in Hoboken, New Jersey, which is adjacent to the Hudson River and the surrounding New York Harbor.

a. CSR Team Members

The CSR team consists of academic, public and private sector partners that collectively can address all key areas for DHS. The CSR Team academic members, in alphabetical order, and current principal investigators (PI) are listed below. When there is more than one PI for a school, each current PI’s primary research area or organization is shown in the associated parentheses.

Massachusetts Institute of Technology  Mr. James B. Rice, Jr.
Monmouth University  Dr. Barbara T. Reagor (RRI)
                    Mr. Anthony Macdonald, Esq. (UCI)
Rutgers University  Dr. Scott Glenn
Stevens Institute of Technology  Dr. Jeff Nickerson (Decision-making)
                                Dr. Roshanak Nilchiani (Infrastructure Resilience)
                                Dr. Brian Sauser (Resilience Modeling)
                                Dr. Alexander Sutin (Acoustics)
University of Miami  Dr. Hans C. Graber
University of Puerto Rico  Dr. Jorge E. Corredor

The non-academic partners include:

The Mattingley Group  Mr. Matt Mattingley
Nansen Envir. Remote Sensing Center  Dr. Johnny Johannessen
Pacific Basin Development Council  Ms. Carolyn K. Imamura
Port Authority of New York & New Jersey  Ms. Bethann Rooney

The Global Maritime and Transportation School at the U.S. Merchant Marine Academy, is an affiliated institution, which is funded by the federal government through other appropriation mechanisms outside of the CSR grant. The current CSR point of contact is Captain (ret) Fred Evans.
As stated above, the CSR team was assembled to take advantage of the strengths of each partner to address all aspects of maritime security as defined by our Stakeholders. Several of the partners have worked together for years in numerous U.S. and international projects related to the safe, secure and environmentally responsible transit of maritime cargo and passengers as well as the short and long-term impacts of coastal hazards on socio-economic systems, ecosystems and living marine resources.

The academic partners also have ongoing projects with relevant Federal and State agencies that have resulted in significant related capabilities. Many of these activities have been performed in collaboration, e.g., partnering with national intelligence agencies, and partnering on the NOAA-led Integrated Ocean Observing System (IOOS) initiative. These existing relationships ensure close coordination of the Center’s efforts among a diverse and yet highly complementary group of researchers. In addition to these partners, the CSR Team works with the existing and the other newly formed DHS Centers of Excellence as well as with related institutions, including the Naval Postgraduate School and the US Coast Guard Academy.

b. Advisory Board
Science and Education Advisory Committee
The Science and Education Advisory Committee (SEAC) consists of representatives from the maritime industry, relevant state and local agencies, academia, and national labs. The SEAC advises the CSR on present and future research projects and educational programs from the perspective of the current state-of-the-art in relevant science and technology, and present and future needs of the stakeholder communities. SEAC Members are listed here:

- Admiral James Loy (USCG ret), Chair
- Ms. Lilliane Borrone, former Director of the Port of New York and New Jersey
- Mr. Steven Carmel, VP, Maersk Sealand
- Dr. John Montgomery, Director, Naval Research Laboratory
- Ms. Sidonie Sansom, Director of Security, Port of San Francisco
- Ms. Bethann Rooney, Director of Port Security, Port Authority of NY and NJ
- Dr. Martha Grabowski, Professor, RPI

c. Cooperating Programs
There are several existing programs that are being leveraged through active cooperation with the CSR. From its Hoboken location, the Center has the opportunity to leverage a significant array of existing sensor and forecasting capabilities in the New York Harbor and its approaches. These facilities and associated equipment are operated by Stevens and Rutgers. Much of the system was funded by the U.S. Office of Naval Research and is currently being entrained by the NOAA Integrated Ocean Observing System (IOOS).

The Stevens New York Harbor Observing and Prediction System (NYHOPS) was established in 2002 to permit an assessment of ocean, weather, environmental, and vessel
traffic conditions throughout the New York Harbor region. NYHOPS is the most extensive estuary monitoring and forecasting system in the world, providing real-time observations and 48-hour predictions of ocean and weather conditions throughout the Hudson-Raritan Estuary. The system is used extensively by the maritime community, including the US Coast Guard, NOAA, the Sandy Hook Pilots, the State of New Jersey DOT, and the Port Authority of NY and NJ. The first responder community and emergency management agencies also utilize the real-time observations and the computer model simulations. These agencies include FEMA, DHS, the US Coast Guard, The New Jersey OEM, and New York City OEM. Resource management agencies are also active partners in the program. Some, including the New Jersey DOT and DEP, the New York City DEP, and the National Weather Service, have contributed both funding and guidance in the continuing expansion and enhancement of the program.

On the Atlantic Ocean, Rutgers University’s Coastal Ocean Observation Lab (RU COOL) operates the nation’s most extensive network of High-Frequency Surface Wave Radar (HF Radar) systems. These systems have been extremely successful in providing high-resolution, real-time synoptic information regarding coastal ocean currents along the New Jersey and New York coastal regions. The network is now employed in the USCG search and rescue operations algorithms (SAROPS) in the mid-Atlantic region. Stevens’ New Jersey Coastal Monitoring Network provides real-time observations of weather and ocean conditions on the beach and in the surf zone along the entire New Jersey shoreline.

The University of Miami, Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) is one of the nation’s leading organizations in the development and application of satellite-based tools and products to support various government agencies. CSTARS completed the Foreign SAR Evaluation Project for NGA using RadarSat-2, TerraSAR-X and Cosmo-SkyMed. They have participated extensively in the Foreign SAR Evaluation Project for the National Geospatial-Intelligence Agency (NGA), providing analysis and inter-comparison of targets and AOIs collected with all three sensors. CSTARS also participated in the Tandem Project in support of the USAF Space Missile System Center, acting as an advisor to the USAF in evaluating the usefulness of a tandem mission RadarSat-2 project. As a direct partner with the Defense Intelligence Agency, CSTARS hosted the installation and implementation of the Italian four satellite X-band SAR system COSMO-SkyMed. CSTARS is currently the only foreign ground station with full tasking and reception capabilities for global and local near-real time acquisitions.

To complement the programs cited above and under sponsorship from the U.S. Office of Naval Research, Stevens established the Maritime Security Laboratory (MSL) in 2004. The MSL is viewed as a primary existing facility that can be leveraged to support the CSR goal of establishing a real-world “laboratory” for test and evaluation and experiments and exercises. The MSL provides harbor-wide, coordinated, in-water environment sensors, weather stations, and video cameras (including IR) with pattern recognition software to enable automated surface ship detection and tracking. The MSL
also possesses a fully-equipped data fusion and visualization center. Over the past 7 years, MSL researchers have performed experiments related to:

- SCUBA diver detection using passive acoustic arrays; for both open-circuit and closed circuit SCUBA;
- The acoustic transmission parameters of the estuarine environment;
- The surface traffic acoustic signal characteristics and variability;
- Computer forecast model – assisted UUV operations for persistent underwater surveillance;
- Behavioral analysis of hostile intent; analysis of evasive behavior; and
- Optimization of sensor placement

d. **Collaboration with co-lead CIMES**

The leadership and researchers at the co-lead institutions - the National Center for Island, Maritime, and Extreme Environment Security (CIMES) and the CSR - believe that collaboration between the two centers is essential to meet DHS’s objectives. To that end, the two Centers set up an initial meeting at the University of Hawaii in November 2008 to share information about the research and education activities at the partner universities from both centers. This meeting was very productive in that there was an open discussion among the participants regarding various activities, and the key researchers for each activity were identified for follow up discussions. This led to another meeting in January 2009 that was hosted by the University of Miami and was used to discuss research collaboration among participants, and several meetings with the Director of CIMES (Dr. Roy Wilkens until the end of 2010 and Dr. Margo Edwards starting January 2011), in August of 2009, and January of 2010 (two separate meetings) to discuss ongoing joint activities and ensure continued partnering. The first full joint meeting of the two centers occurred in January, 2011 on the campus of the University of Hawaii.

The collaboration is strong and ongoing between the two Centers. The following areas are examples of collaboration during the first 3 years of operation:

- Passive acoustics: Researchers from Stevens and the University of Hawaii shared data and information from the work they have been performing in passive acoustics, and discussed ways for improving passive acoustic methods of port protection, including detection, classification and localization of surface ships, divers and UUVs. Several meetings have been held between the two universities’ acoustic research teams, with the notable result that the Stevens team provided the Hawaii team with the detailed technical specifications and design guidance for a passive acoustic system, and the Hawaii team has provided algorithms and signal processing guidance to the Stevens team in order to improve the performance of the existing Stevens systems. We are confident that this joint effort will prove remarkably successful in the coming years in terms of providing the community with a passive acoustic surveillance capability that does not presently exist.
- Non-Linear Acoustics: Researchers from the University of Hawaii and Stevens discussed their research in Time Reversal Acoustics and its application to port security (e.g., the use of the technology for non-lethal deterrence).
• HF Radar Surveillance: The HF Radar teams at Rutgers University and the University of Hawaii and the University of Alaska (CIMES partner) have met and are discussing collaboration in terms of comparing the vessel detection and tracking capabilities using their two different RADAR systems and supporting algorithms. It is anticipated that future collaborative activities will include comparative tests in field experiments under different environmental conditions. This information will be employed in the ongoing planning and installation of an HF Radar system along the western coast of Puerto Rico.

• Power Systems for Extreme Environments: Researchers from the University of Alaska and Stevens have discussed various battery technologies and the requirements for robust and efficient means to provide power and back-up power in extremely cold and isolated environments, such as Alaska.

• Multi-Sensor Integration: Stevens and the University of Hawaii discussed teaming on a DHS proposal for Multi-Sensor Integration that combines the strengths of all of the partners from CSR and CIMES.

• The directors as well as members of CSR and CIMES worked together to contribute technical articles and provide guest editorial to a special Maritime Security issue of the Marine Technology Society journal, one of the key refereed journals in the industry.

e. Communications and Outreach
Collectively, CSR and CIMES represent a unique consortium of academic institutions, working in close collaboration and partnership with several industry and government partners. It is MIREES’ shared vision to function as a key national resource to DHS in all areas of maritime security and coastal, island, and inland waterway maritime domain awareness, through innovative research and relevant educational programs. To that end, MIREES strives to reach its vision through the combined strength and capabilities of its partnerships and through efficient and effective communications and outreach to its stakeholders, end-users and the general public.

Since MIREES’s inception in 2008, CSR and CIMES have largely developed their own communications and outreach initiatives and have maintained separate websites. However, the centers have collaborated to prepare joint marketing material and have exhibited together at the USCG Innovation Expo, at the fourth and fifth annual DHS University Network Summits, and at the DHS Career Development Fair. While both centers have been successful in establishing their respective identities and engaging their local and regional stakeholders, the centers realize that if MIREES is to be recognized as a national “go-to” resource, they must combine their communications and outreach strategies and promote the totality of the centers’ research and education capabilities and accomplishments.

f. Collaboration with other COEs
The CSR is partnering with the COE co-led by Rutgers University and Purdue University, the Command, Control, and Interoperability Center for Advanced Data Analysis (CCICADA). This collaboration is aimed at enabling new techniques and
algorithms for the analysis of multi-sensor data being gathered by the CSR researchers, including space-based, HF Radar, and passive acoustic data. The collaboration may also include researchers at CSR and CCICADA working together on decision-making, particularly in the study of decision-making in complex (data-rich) environments. CSR researchers are also partnering with researchers from CREATE in the area of maritime risk assessment and port system resilience.
III. RESEARCH PROJECT REPORTS

a. Description of Research Areas
As mentioned earlier, CSR, along with the University of Hawaii’s National Center for Islands, Maritime, and Extreme Environments Security (CIMES), support DHS efforts under NSPD-41 / HSPD-13 to provide for the safe and secure use of our nation’s maritime domain (including island and extreme environments and inland waterways), and a resilient MTS, through advancement of the relevant sciences and development of the new workforce. The CSR research efforts have been divided into two basic areas: Maritime Domain Awareness (MDA), and Topics in Global Policies influencing MTS Security and Coastal Safety. These research areas, and their associated tasks (projects) can be summarized as follows:

1. Maritime Domain Awareness (MDA):
   - Task 1.1 Space-Based Wide Area Surveillance
   - Task 1.2 Investigation of HF Radar for Multiple Applications: Over-The-Horizon Vessel Detection and Tracking, Search and Rescue, and Environmental Monitoring
   - Task 1.3 Nearshore and Harbor Maritime Domain Awareness Via Layered Technologies
   - Task 1.4 Decision-Support Systems

2. Topics in Global Policies influencing MTS Security, including Design for Resiliency
   - Task 2.1 Resiliency Modeling
   - Task 2.2 Resilient and Cognitive Port Infrastructure Systems and Enterprises
   - Task 2.3 Port Resilience Project

In the following, we provide a summary of the research efforts and results associated with each of these projects.
1. Maritime Domain Awareness

Task 1.1 Space-Based Wide Area Surveillance, University of Miami (H. Graber, PI)
TRL 8

Project Objectives and Significance to Stakeholders

CSTARS continues to explore the use of space assets such as high-resolution electro-optical (EO) and synthetic aperture radar (SAR) for detecting and classifying small boats to large vessels. Also SAR data is extensively applied to monitoring of environmental pollutants such as oil spills or algae blooms that potentially can have negative impacts on port and maritime commerce as well as pose health threats to coastal communities. Ongoing studies and exercises with DOD agencies show that wakes from small, fast moving boats can be detected and large vessels can be tracked across ocean basins. In collaboration with one of the primary companies operating a network of spaced-based Automatic Identification System (AIS) transponders, we have made tests of monitoring large ocean basins with space-based AIS. CSTARS is employing the “Commercial SAR Architecture” developed under the NGA funded CSTARS Pilot Project in a new funded Joint Capabilities Technical Demonstration project called CROSS – Commercial Radar Operational Support for SouthCom which incorporates the high resolution SAR sensors such as Cosmo-SkyMed, TerraSAR-X, TanDEM-X and RadarSat-2 to support SouthCom in Human Assistance Disaster Response (HADR) to small vessel detections. As part of the CSTARS Pilot project satellite-based monitoring of vessel traffic will be demonstrated to better understand what is needed to implement a comprehensive end-to-end surveillance of the global maritime domain which currently does not exist and must be tied to direct access of multiple satellite sensors to maintain persistence. Also CSTARS demonstrated its capability to rapidly respond and deliver large volumes of images for the DeepWater Horizon oil spill in the Gulf of Mexico. Specifically, CSTARS will continue to participate in port and maritime security exercises and leverage other resources in achieving secure operations within the global and national maritime domain. Additional project objectives include exploring the use of polarimetry in vessel and wake detection, and the use of complex image data to extract information on vessel behavior. We will examine Radon Transform for detection of linear features such as wakes and look at new high resolution and different frequency satellite radar sensors for detection of vessels and estimation of vessel movement. We will continue to seek to apply our techniques to the monitoring of maritime disruptive events such as an oil spill.

Milestones Met

1. Provided acquisition with different satellite sensors for the Port of Miami test. On 09 - 12 April 2011 we provided near real time collects of high resolution satellite data from the COSMO-SkyMed constellation, TerraSAR-X, RadarSat-2 and EROS-B in support of a small boat detection exercise in the Port of Miami by the CSR. The Port of Miami has one major entrance/exit which is used by most vessels including cargo and
container ships, cruise ships and recreational boats to enter the port to dock or for smaller vessels to continue inside the coastal waterway. The goal of this exercise was to detect all types of vessels with multiple surveillance systems such as satellites, HF radar and acoustic sensors and unambiguously identify each vessel with each surveillance system.

Figure 1 shows an overview of the Port of Miami from EROS-B, a high-resolution panchromatic satellite, on 11 April 2011. Numerous vessels of all sizes are visible and readily identified as to type.

![Figure 1: EROS-B panchromatic image (70 cm resolution) collected on 11 April 2011 at 19:16:57 UTC.](image)

Figure 2 shows a zoomed in cloud-free, EROS-B optical image on 12 April 2011 with numerous vessel of all sizes and types clearly visible in the main channel to the Port of Miami. All vessels visible in this image were clearly identified by acoustic sensors, while the larger vessels were also tracked by HF radar. Both systems were set up on Fisher Island (center land at bottom), which was not ideal for unrestricted tracking by both systems.
Figure 2: EROS-B panchromatic image (70 cm resolution) collected on 12 April 2011 at 19:03:49 UTC.

Figure 3 shows a summary of the detected vessels by all sensors including AIS. The photos were taken from the Fisher Island, the location of the acoustic sensor, which shows the vessels (container ship, cargo ship and catamaran). The full resolution EROS-B image provides enough details to identify vessel type and even shows the cargo and or make-up of the ship.

Figure 4 provides an example of a high resolution SAR image of the Port of Miami. The SpotLight TerraSAR-X radar image shows a great deal of details of the vessels and their wakes. Also other surface features are visible in the radar image such as surfactants and possible oil slicks. Figure 5 shows a RadarSat-2 SpotLight image of the vicinity of the port with numerous vessels anchored outside the entrance waiting for docking space. Figure 6 is one of several Cosmo-SkyMed SpotLight images during the experiment delineating the location of channel markers, vessels and their wakes as well as wakes from ships that have passed the area some time ago.
Figure 3: Top: EROS-B panchromatic image (70 cm resolution) collected on 12 April 2011 at 19:03:49 UTC. Bottom: Zoomed cut-out of port entrance showing with high detail three vessels: the containership Stadt München, a cargo ship and a catamaran.

Figure 4: SpotLight high resolution TerraSAR-X image of vessels and wakes in the vicinity of the Port of Miami. The image was taken on 9 April 2011 at 23:13 UTC.
Figure 5: SpotLight high resolution RadarSat-2 image of vessels waiting to enter the Port of Miami. The image was taken on 12 April 2011 at 23:23 UTC.

Figure 6: SpotLight high resolution Cosmo-SkyMed-1 image of vessel approaching and waiting outside the Port of Miami. The 1 m resolution image shows great details including the channel markers to the port entrance/exit. Fast moving ships and their wakes are also visible, as well as historic wakes from vessels already outside the image. The image was taken on 10 April 2011 at 23:18 UTC.
Table 1 shows a list of collected satellite images during the CSR Miami experiment according to sensor, type, image mode and date and time. Even for the short exercise period, a certain amount of persistence can be achieved with satellite sensors monitoring the approaches to ports and harbors. A comprehensive description of the experiment is included as an appendix to this report.

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<th>Date &amp; Time (UTC)</th>
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<td>SpotLight</td>
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<td>SpotLight</td>
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<td>SpotLight</td>
<td>2011-04-10 23:18:14</td>
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<td>SpotLight</td>
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<td>SpotLight</td>
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<tr>
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<td>SpotLight</td>
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<td>EROS-B</td>
<td>Optical Sensor</td>
<td>Panchromatic</td>
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<td>Cosmo-Skymed 2</td>
<td>Radar</td>
<td>SpotLight</td>
<td>2011-04-12 23:06:12</td>
</tr>
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</table>

Table 1: List of satellite sensors utilized by CSTARS for the CSR Miami experiment.

2. Developing new algorithms for wake detection (work in progress)

The Radon Transform (RT) maps the spatial domain of an image into the two dimensional Euclidean space (Radon, 1917). It is defined as

\[ f(\rho, \theta) = \int_{-\infty}^{\infty} g(x, y) \delta(\rho - x \cos \theta - y \sin \theta) dx \, dy \]

where \( g(x,y) \) represents the intensity level of the image at position \((x,y)\), \( \delta \) denotes the Dirac delta function, \( \rho \) the length of the normal from the origin to a straight line, and \( \theta \) represents the angle between the normal and the x-axis. The Dirac delta function forces the integration of \( g(x,y) \) along the line \( \rho = x \cos \theta + y \sin \theta \). Consequently, the RT yields the integrals across the image at varying orientations \( \theta \) and offsets \( \rho \) relative to the image center (Murphy, 1986). The main advantage of this operation is that it maps a straight line in the image space into a single point in the transform space. Detection of dark
(bright) linear features in an image thus becomes detection of dark (bright) points in the Radon domain.

We have been experimenting with the RT to detecting wakes in radar images. In particular we are interested in extracting wakes from radar images with more speckle noise. Below are some results from applying the RT to simulated radar images with different speckle noise levels to mask the presence of a linear feature, i.e., a ship wake. Figure 7 shows a simulated 4-look radar image with a linear “wake” feature approximately 256 pixels long and 2 pixels wide. The background normalized radar cross-section $\sigma_o$ is 2 dB and the foreground $\sigma_o$, or “wake” feature is 6 dB. This provides a contrast of 2.61.

In Figure 8 we successively degraded the linear “wake” feature to test if the RT is still capable of extracting a wake from a noisy background. The radar cross-section is reduced from 6 dB to 3 dB which is 1 dB above the noise.

![Figure 7: Simulated 4-look radar image chip with a linear “wake” feature 256 pixels long and 2 pixels wide. Contrast between the background and “wake” feature is 2.61.](image)

![Figure 8: Successive degradation of linear feature, reducing the contrast, to less than 1.5. The “wake” feature (right image) is barely visible.](image)
Figure 9 shows the RT for the severely degraded “wake” feature in Figure 8. The “wake” feature is still detectable as a point location in the Radon domain providing its orientation (angle) and location in the image domain. Other small artifacts arise due to the low contrast and short random linear features.

Figure 9: RT for severely degraded “wake” feature in noisy background.

3. Maritime & Port Security Sensing Technologies Course in Washington, DC on October 20, 2010
Presented three lectures on satellite remote sensing. The following lectures were presented to attendees from USCG and DHS:
Lecture 1: “Synthetic Aperture Radar (SAR)”
Lecture 2: “SAR Applications and Techniques”
Lecture 3: “Vessel Detection Exercise”

4. GEOINT Symposium in New Orleans, LA on 2-4 November, 2010
Attended USGIF Workshop on Commercial SAR Familiarization.

5. MIREES Joint Annual Meeting in Honolulu, Hawaii on January 10 - 12, 2011
Attended the “MIREES Joint Meeting” at the University of Hawaii in Honolulu, HI in January 2011.

Attended the “CSR Midterm Review” in Washington, DC.
Presented three lectures on satellite remote sensing. The following lectures were presented to attendees from USCG and DHS:
Lecture 1: “Synthetic Aperture Radar (SAR)”
Lecture 2: “SAR Applications and Techniques”
Lecture 3: “Vessel Detection Exercise”

Attended the Annual DHS S&T University Network Summit in Washington.

9. Congressional Brief to Senate and House Staffers, Washington, DC on 2 May 2011
Presented an overview on the satellite component of the CSR to congressional staffers in the Congressional Meeting Room South CVC, Rm 217.

10. DHS Summer Institute at Stevens Institute of Technology, Hoboken, NJ on 13 – 16 June, 2011
Presented lectures on satellite remote sensing and worked with the Satellite Team to develop an image collection plan for several days to monitor the vessel traffic in the morning and evening along the Hudson River.

Collaborations
Contributed with Stevens Institute of Technology to the development of the DHS Summer Institute and participated in the teaching and exercises in June 2011. Two additional faculty from the University of Miami provided lectures and experimental support in June and July to the Satellite Team.

CSTARS:
Working partnership with NGA on the commercial radar support for the U.S. Southern Command.

Working with PACOM on providing satellite imagery support in Southeast Asia.

Working with JIATFS and Navy TENCAP to develop an end-to-end vessel detection and classification program.

Working with Office of Naval Research on various maritime domain issues.

European Collaborations - continue
- MARISS – GEMES MAritime Security Services
- NATO La Spezia – remote ground station operation
- Visiting EUCOM in Stuttgart, Germany
- Visiting AFRICOM in Stuttgart, Germany
**Ongoing Projects and Future Plans**

Space-based AIS evaluation in three areas of interest was postponed in order to:
1. Wait for launch of additional space-based AIS microsatellites
2. Leverage test with JCTD CROSS in support of SouthCom, JIATFS and 4th Fleet
3. Ensure support from satellite vendors to maximize collects
4. Finalize agreements and licenses for raw AIS data in place
Test to take place for 1 month commencing in January/February 2012

The impact of polarimetric data on detection and discrimination of targets shows promise from testing done to date. A larger parameter space for different imaging modes, vessel sizes and sea state and environmental conditions are needed. These tests will continue in year 4 and also include results from tests of opportunity leveraging other DoD projects.

Sub-aperture stacking for ship speed and course is on-going research.

**Commercial SAR Architecture Center**
- Project successfully completed.
- Numerous automated image production processes implemented.

**Data analysis**
1. Wake detection - continuing
   - Radon transform approach
   - Examining dual and quad polarization data
   - Pattern analysis of elementary shapes
   - Speckle noise reduction

2. Innovative antenna configuration
   - Explore squinting algorithm for moving targets such as dynamic imaging or sub-aperture stacking
   - Develop new methodologies using phase history data to better detect targets in background noise

**Documentation**
1. Numerous presentations to NGA senior staff of CSTARS capabilities including DHS CSR project goals.
2. Visit by the Director of NRO, GEN Bruce Carlson (22 October 2010).
3. Visit to USCG Sector Miami (13 December 2010)
5. Visit by Director of MSD, Dr. Pedro Rustan, from the NRO (3 January 2011).
6. Visit by DD for Intelligence Integration from the ODNI (25 March 2011).
7. Visit by Director of NGA’s CIDAP (31 March 2011).

**Other Resources Leveraged**
1. NGA’s CSTARS Commercial SAR Pilot Project
2. NGA’s Crisis Support Project
3. NGA’s JCTD CROSS
4. Cooperative maritime support from JIATFS, ICE and USCG
5. ONR projects on relevant maritime problems

Table 2 presents a summary of presentations given during the year:

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<tr>
<td>Briefing to General Carlson, Director,</td>
<td>CSTARS, Miami, FL</td>
<td>Oct 22, 2010</td>
<td>CSTARS Brief Presented to General Bruce Carlson</td>
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<td>National Reconnaissance Office</td>
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<td>Briefing to Intel Representatives from the</td>
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<td>Nov 16, 2010</td>
<td>CSTARS Brief Presented to Commonwealth Nations</td>
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<td>Zealand and United Kingdom)</td>
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<td>Briefing to Deputy Director for National</td>
<td>CSTARS, Miami, FL</td>
<td>Mar 25, 2011</td>
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<td>Briefing to Director of CIDAP, Ms. Patricia</td>
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References
**Task 1.2 Investigation of HF Radar for Multiple Applications: Over-The-Horizon Vessel Detection and Tracking, Search and Rescue, and Environmental Monitoring (Note: there are two PIs on Task 1.2, S. Glenn, Rutgers; and J Corredor, UPRM) TRL 8**

*Task 1.2, Project 1, Rutgers University (Dr. Scott Glenn, PI)*

**Project Objectives and Significance to Stakeholders**

Our work examines the HF Radar data processing sensitivities in the approaches to the New York Harbor Mid-Latitude Testbed to determine the desired range of settings for real-time operations for vessel detection and tracking. Goals include implementing a real-time mono-static HF Radar vessel detection capability in the approaches to New York Harbor Mid-Latitude Testbed where the vessel detections are calculated in real time at a remote shore site and transferred to a data aggregation center. We participated in the annual CSR coordinated field exercise held this year in Miami and worked with the University of Puerto Rico to develop the multi-static HF Radar capability in the Puerto Rico Tropical Island Testbed. We continue to collaborate with CIMES to design an Arctic High-Latitude Testbed for HF Radar vessel detection. And we leverage DoD efforts to develop the multi-static HF Radar capability in the Approaches to NY Harbor Mid-Latitude Testbed.

Our work is highly relevant to Border Security in tracking, and classifying of all threats along the terrestrial and maritime border and in improving the analysis and decision-making tools that will ensure the development and implementation of border security initiatives. In the Maritime Security domain, our work facilitates wide-area surveillance from the coast to beyond the horizon, including port and inland waterways, for detection, ID, & tracking. In particular, our work permits the detection of vessels between the port region and beyond the horizon, especially small vessels with the capability to geo-reference the images. Improved radar performance for detection and tracking of large and small vessels in the port and coastal regions — in particular, through the use of more advanced signal processing will benefit the Coast Guard.

**Milestones Met**

- Conducted a full sensitivity matrix study of HF Radar vessel detection parameters for a range of test cases.
- Demonstrated a real time vessel detection capability outside New York Harbor
- Participated in the CSR experiment that took place at the Port of Miami from April 8-12, 2011.
- Participated in the COE review meeting in Honolulu, HI January 11, 2011, gave presentations, and met with CIMES partners to develop plans for the Arctic testbed.
• Conducted annual maintenance and performed antenna pattern measurements on the University of Puerto Rico HF Radar sites. Helped install bistatic transmitter for 2011-2012 tests.
• Attended the DHS University Summit on April 1, 2011. Received S&T impact award for our role in the Gulf Oil Spill.
• Gave Module 6 – High Frequency Radar of the Port Security Sensing Technologies course offered by Stevens Institute.
• Worked with Tom Tomaiko (DHS S&T) to construct a plan for the implementation of a real-time bi-static vessel tracking capability in the New York Harbor testbed that will be implemented in the fall of 2011.
• Worked with Tom Weingartner, Univ of Alaska (a CIMES PI) to develop a successful proposal to implement the Arctic HF Radar testbed.
• Led the High Frequency Radar group, one of three research groups within the Summer Research Institute, which focused on the detection of vessels in the approaches to New York Harbor.
• Conducted year long noise measurements in New Jersey and Puerto Rico at the 13 MHz HF band.

The work in year 3 of the Center of Excellence focused on building a capability to generate real time vessel detections. Up to this point, all vessel detection was performed via post processing. Several tools were constructed to bring this capability to fruition. First, the offline Matlab vessel detection code was converted to a C tool that could run on the SeaSonde shore station. This tool was installed on the Sea Bright shore station and has been running since April 5, 2011. The most recent version of the software is PeakPicker 2.1.0.

A test was conducted to compare the results of the offline Matlab code with the real time PeakPicker. The test was conducted on June 14, 2011 from 11:00 to 16:00 GMT. The code was run with the settings shown in

**Table 1.** The improvements to the PeakPicker code outperformed the offline Matlab code, with the number of false alarms was reduced with the real time code.

A graphical user interface (see, e.g., Figure 13) was constructed to view the real time data originating from the shore station.

A 24/7 data feed of the real time vessel detection was provided to the Naval Research Laboratory. A warning script was written to notify the operators if the detection feed became dormant.
Table 1: Threshold settings used for the vessel detection comparison between the offline Matlab code and real time PeakPicker code.

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</tbody>
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The work on the DHS COE project is leveraging the work performed under the NAVSEA Littoral Expeditionary Autonomous PowerBuoy (LEAP) program. This program started in September 2009. We were able to purchase a second 13 MHz combined transmit/receive HF Radar system. This system was first installed as part of the Miami field experiment. It was then moved to Belmar, NJ to pair with the 13 MHz SeaSondes at Seaside Park and Sea Bright, NJ. On August 11, 2011, Ocean Power Technologies (OPT) along with Rutgers personnel deployed the LEAP buoy (Figure 1), containing a bistatic transmitter off the coast of Brielle, NJ at a water depth of 37m (Figure 2). An image of the spectra from the three shore stations and the buoy transmitter is shown in Figure 3.

![Figure 1: NAVSEA Littoral Expeditionary Autonomous PowerBuoy (LEAP Buoy) in front of Coast Guard Buoy tender.](image)
Figure 2: Google Earth KMZ image showing the three bistatically linked 13 MHz SeaSonde sites along with the LEAP Buoy. The buoy lies in between two shipping lanes off of Brielle, NJ.

Figure 3: Spectra Map showing three bistatic signals (top three) and one monostatic signal (bottom).

YM Los Angeles Sensitivity Study
As noted in the 2009-2010 Annual Report, we participated in the coordinated field experiments on November 9, 2009. Rutgers was able to detect several vessels from the 13 MHz SeaSonde located at Sea Bright, NJ. One of those vessels was the Los Angeles. We conducted a sensitivity study on this test case. As you lower the detection threshold, you increase the number of false alarms and if you increase the detection threshold, you
decrease the number of false alarms but also risk rejecting potentially valid vessel
detection. Where do you strike the balance? Figure 4 presents the results from a
sensitivity study that we conducted using the data from the YM Los Angeles. The Los
Angeles was heading north along the Barnegat shipping lane on November 9, 2009.
Position information (from AIS) of the vessel was collected between 06:30 and 07:45
GMT, a 75-minute window. All the detections for the full test matrix were averaged per
unit time and are shown on the left of Figure 4. The percentages of valid detections
(verified via AIS) are shown on the right of Figure 4.

The panels on the left represent the number of detections per minute based on length of
the integration time and threshold level. The top panel is for IIR background and the
bottom panel is for the Median background. Longer integration times and lower
threshold levels result in more detections. Keeping integration time and threshold
constant, we can look at the influence of the background on the number of detections.
For instance, using an integration time of 256 seconds (512 point FFT) and threshold of 9
dB results in an average of 0.2 detections (aka peppers) per minute for the IIR
background and 1.0 detections per minute for the Median background. This is a 5-fold
increase in the number of detections per unit time for the Median compared with the IIR
background. Not all of these detections are valid, some are false alarms.

The panels on the right show the percentage of valid detections. Lower thresholds lead to
more detections. However, longer integration times do not lead to better detections. For
both the Median and IIR background the 128 or 256 point FFT gives the best results. The
number of detections drop for the 512 or 1024 point FFT. Using the same integration
time and threshold level from before (512, 9dB) the IIR background gives a probability
of detection of 42% while the Median background gives a probability of detection of
47%.

From Figure 4, look at the second tick from the left on all plots (for consistency); this is 7
dB threshold for IIR and 9 dB for Median. Best probability of detection (right panels of
Figure 4) is about 57% for IIR and 66% for Median. In both cases, the best FFT length is
between 128 & 256. At the second (threshold) tick of the left figure, this gives a false
alarm rate (per minute) of about 0.2 for IIR and 0.6 for Median. So in summary of the
difference between IIR and Median, for a difference in detection probability of 9% (57%
for IIR vs. 66% for Median), you triple the false alarm rate for Median over IIR. This
will be valuable information as we begin providing this data to end-users. As we develop
the Association Algorithms in this program this will enable us to use both IIR & Median,
and different FFTs and thresholds simultaneously, allowing us to increase probability of
detection somewhat (you never get to 100%), while drastically reducing false alarm rate.
It is well known from Gaussian target detection theory going back 60 years, that small
percent changes in detection probability by adjusting threshold and FFT parameters lead
to much larger changes in false alarm rate, as affirmed here.
Median Sensitivity Study - In this study as shown in Figure 5, the best detection rates were from a window that was 5 range cells and 7 Doppler cells wide. Increasing either type of cell or both above this amount gives negligible change that is not statistically significant. Below this, we can see a definite decrease in detection probability.
Figure 5: YM Los Angeles Median Sensitivity Study. Varying the number of Doppler bins and sizes yields different results.

Vessel Detection Software Improvements

- Created C program foundation for real-time peak detection -- based on CSPro, the SeaSonde's real time application that averages raw cross spectra.
- Verified that the original MATLAB code was operating correctly and simplified its operation for offline processing.
- Converted output target detection files to a format similar to the SeaSonde tabular output files so the same output format is generated by both MATLAB and the C version.
- Prepared the pepper-plot MATLAB program to read and display detections from both the MATLAB and C versions.
- Configured the C output file folders to be compatible with the SeaSonde system.
- Designed key components of the real time C code: i.e., input parameters allowing any number of FFT sizes with the two background methods (IIR and Median); and for the range file buffering algorithm (which is important in order to feed the proper number of range points to each of the FFTs).
- For best response to user and minimum computation time, the processing of the FFTs and methods of detections were designed as 'open' loops that could be exited and reentered without loss of processing continuity. Input parameters were allowed to change on-the-fly.
- For fastest execution speed, the MATLAB code was profiled to determine areas of most intensive computation. Surprisingly, it was not in the FFT computation but in the Median background computation. This happened because the median method requires the data to be sorted to find its median values. Sorting is a classic time-consuming computer problem. The volume of data processed and the number of median calculations are very high.
• Programming was adjusted to utilize array processing methods built into the Mac OS system using the native array sorting and the eigen-vectors/values computations effectively. FFT calculations built into the Mac OS were actually slower than the code transferred from the SeaSonde. This is probably because the built-ins are DFTs made for graphic processing and not true FFTs.
• Redo calculation of ideal antenna-pattern outputs to include amplitude and phase factors.
• Added key-coded ITAR-related security protection.
• Tested with multiple data sets run through both the MATLAB and C versions - HOMR, SEAB, and BRNT.
• Preparation, monitoring, and bug repair for real-time field-testing.

CSR Miami Experiment - April 11, 2011
(See Appendix C for additional details.)
Rutgers personnel set up and tended to a 13 MHz SeaSonde at the entrance of the Port of Miami on Fisher Island in Miami, Fl. In order to ensure that the SeaSonde was operating properly, Rutgers personnel were on site to make adjustments and observations of the ship signals in the HF Radar data. Range series data files were collected and brought back to campus for processing. These files were then run through the ship detect Matlab code to produce possible ship detections. From April 8th, 2011 until April 12th, 2011, the Fisher Island site was able to detect 79 vessels transiting into or out of the Port of Miami and many more passing by. Of these 79 vessels, four Class-B AIS, pleasure craft were detected. See Figures 6 through 11. The detection rate results from the April 11, 2011 exercise are summarized in Table 2. The results from the highest detection rate are shown in Figure 10 (range, range rate and bearing) and Figure 11 (detections placed on a map). These detections were made on the Seaboard Caribe, which is shown in Figure 8.

Table 2: List of ships detected during the April 11, 2011 exercise

<table>
<thead>
<tr>
<th>Ship</th>
<th>MMSI</th>
<th>Time</th>
<th>Length</th>
<th>Width</th>
<th>IIR Detection (%)</th>
<th>Median Detection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Celebrity Century</td>
<td>2490540000</td>
<td>7:00 – 9:00</td>
<td>250</td>
<td>32</td>
<td>15.0</td>
<td>17.1</td>
</tr>
<tr>
<td>2 Celebrity Century</td>
<td>2490540000</td>
<td>20:30 – 22:30</td>
<td>250</td>
<td>32</td>
<td>27.7</td>
<td>27.7</td>
</tr>
<tr>
<td>3 Seaboard Caribe</td>
<td>305300000</td>
<td>11:30 – 13:30</td>
<td>139</td>
<td>22</td>
<td>35.0</td>
<td>37.3</td>
</tr>
<tr>
<td>4 Westerhaven</td>
<td>305625000</td>
<td>11:00 – 12:30</td>
<td>127</td>
<td>29</td>
<td>30.0</td>
<td>15.0</td>
</tr>
<tr>
<td>5 Westerhaven</td>
<td>305625000</td>
<td>18:30 – 19:30</td>
<td>127</td>
<td>29</td>
<td>19.0</td>
<td>14.9</td>
</tr>
<tr>
<td>6 Norwegian Sky</td>
<td>308865000</td>
<td>8:00 – 9:30</td>
<td>258</td>
<td>36</td>
<td>13.3</td>
<td>13.3</td>
</tr>
<tr>
<td>7 Norwegian Sky</td>
<td>308865000</td>
<td>21:00 – 23:30</td>
<td>258</td>
<td>36</td>
<td>18.3</td>
<td>28.3</td>
</tr>
<tr>
<td>8 Majesty Of The Seas</td>
<td>311734000</td>
<td>8:30 – 10:00</td>
<td>268</td>
<td>32</td>
<td>23.8</td>
<td>21.5</td>
</tr>
<tr>
<td>9 Majesty Of The Seas</td>
<td>311734000</td>
<td>21:30 – 22:30</td>
<td>268</td>
<td>32</td>
<td>11.8</td>
<td>10.9</td>
</tr>
<tr>
<td>10 Ahrnschoop</td>
<td>341400000</td>
<td>0:00 – 3:00</td>
<td>76</td>
<td>11</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>11 MOL Encore</td>
<td>357249000</td>
<td>1:30 – 3:00</td>
<td>298</td>
<td>32</td>
<td>20.2</td>
<td>15.9</td>
</tr>
<tr>
<td>12 Yorktown Express</td>
<td>367168650</td>
<td>8:30 – 10:30</td>
<td>243</td>
<td>32</td>
<td>25.5</td>
<td>19.4</td>
</tr>
<tr>
<td>13 Yorktown Express</td>
<td>367168650</td>
<td>17:30 – 19:30</td>
<td>243</td>
<td>32</td>
<td>11.1</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Figure 6: AIS data in the vicinity of the Port of Miami for the April 11, 2011 exercise. This data only includes vessels transiting into or out of the harbor during the day.
Figure 7: Picture of combined transmit and receive 13 MHz antenna at Fisher Island, Miami, FL.

Figure 8: Picture of Seaboard Caribe from www.digital-seas.com
Figure 9: Pepper plot of Seaboard Caribe at an FFT of 256 and Threshold of 10 dB.
Figure 10: Range (top), range rate (middle), and bearing (bottom) of the Seaboard Caribe as it approaches the FISH 13 MHz SeaSonde site at Fisher Island, Miami, FL. The ship GPS data is the aqua line and the radar detections are the dark blue squares. The signal peaks were detected using the IIR Method at an FFT of 256 and a threshold of 10 dB.
Figure 11: Detections made by the 13 MHz SeaSonde radar placed on a map showing the detections (dark blue circles), GPS track (aqua line), location of the Fisher Island HF Radar (center of radial grid) and the time of the track (green text). The signal peaks were detected using the IIR Method at an FFT of 256 and a threshold of 10 dB.

In this environment, a busy shipping port in a major sub-tropical city, IIR was found to be a more reliable method of detecting ships. Longer-time FFTs seem to detect vessels better, probably due to the fact that there are many big vessels and they are not changing their radial velocities much during an FFT period. When running Ship Detect using the Median background, many horizontal lines appeared on the radial velocity plots, which interfere with positive ship detections. Median also adds many false-alarm peppers that may be falsely assumed to be part of a vessels track.
Real Time Vessel Detection
On July 11, 2011, the Summer Research Institute (SRI) conducted a controlled, real-time port security test. The test called for the boat, Savitsky (Figure 12), to transit from out front of the Sea Bright, NJ 13 MHz SeaSonde site at the base of New York Harbor all the way up into the Hudson River in the vicinity of the Stevens Institute of Technology. SRI students worked from 6:00 AM until approximately 7:00 PM trying to detect and identify the vessel. One of the technologies they used was the real-time vessel detection software, PeakPicker, which was recently installed at the Sea Bright, NJ SeaSonde site. In combination with underwater acoustics, SeaSonde data, and satellite fly-overs, the SRI interns were able to track the ship periodically until it reached the Hudson River.

![Savitsky](image)

*Figure 12: Savitsky: This vessel acted as a potential terrorist threat during the July 11, 2011 SRI port-security test.*

Due to the small size of the Savitsky, it was decided to decrease the threshold to 6 dB in order to increase the likelihood that the SeaSonde would be able to detect the Savitsky with its PeakPicker software. In Figure 13, you can see that the total number of potential detections was 2,120. If the threshold was increased to 11 dB, as in Figure 14, you can see that the total number of potential detections decrease to 707. This decrease in potential detections is a good example of the tradeoff of choosing high or low thresholds. Lower thresholds will have many more potential detections but also many more false alarms compared to higher thresholds.
Figure 13: Real-time Vessel Detection GUI – The threshold was set to 6 dB in order to find the most amount of signals for the SRI experiment.

Figure 14: Real-time Vessel Detection GUI - The threshold was increased to 11 dB in order to remove potential false detections.

Puerto Rico 2011

- Two weeklong trips by Rutgers personnel to work with partners at the University of Puerto Rico – Mayaguez
• Performed boat-based antenna pattern measurements at both the CDDO and FURA SeaSonde sites in January 2011.
• Performed a second set of pattern measurements in May 2011. Comparison of pattern measurements taken in January and again in May found similar environmental effects.
• Antenna patterns at both sites showed stability and insignificant distortion. This indicates that the effect of electromagnetic interference has a negligible effect on the ideal pattern of the receive loops.
• Installed a bistatic Transmitter at El Combate, Puerto Rico.
• Both CDDO and FURA sites are operating bistatically and can currently see the bistatic transmitter signal.
• Installed two USB cell modems to the computers at CDDO and FURA. This has allowed for increase communication uptime allowing the ability to transfer files at defined intervals.
• The dock at the FURA SeaSonde site was re-built and the antenna was remounted with new cables after a storm damaged the previous dock and destroyed the SeaSonde cables.
• New receive cables were installed at CDDO.

Collaborations
University of Puerto Rico Mayaguez
CODAR Ocean Sensors

Future Plans
Please see the outline of Year-4 plans in the Appendices, and the Year 4 Workplan for Rutgers University.

Documentation
Here is a summary of presentations given during the year and papers published on this research:

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Location</th>
<th>Date</th>
<th>Title of Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Homeland</td>
<td>Hoboken,</td>
<td>July 16, 2010</td>
<td>National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)</td>
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<tr>
<td>Security, Summer Institute</td>
<td>NJ</td>
<td></td>
<td></td>
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<tr>
<td>SRI, Briefing to Pacific</td>
<td>Hoboken,</td>
<td>July 29, 2010</td>
<td>Small Vessel Detection with UHF Radar in the Hudson River</td>
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<td>Northwest National</td>
<td>NJ</td>
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<td>Laboratory</td>
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Mid Atlantic Bight Physical Oceanography and Meteorology

Hoboken, NJ

October 26, 2011

Utilizing UHF Radar in the Hudson River

DHS Briefing to Great Lakes Partners

Hoboken, NJ

November 30, 2010

National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)

CSR Advisory Committee

Hoboken, NJ

December 7, 2010

National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)

MIREES Annual Meeting

Honolulu, HI

January 11, 2011

The Center for Secure and Resilient Maritime Commerce (CSR)

Aquatic Sciences Meeting

San Juan, Puerto Rico

February 13, 2011

Validation of an Ultra High Frequency Radar for Current Mapping and Vessel Tracking in the Urbanized Hudson River Estuary

Radiowave Operators Working Group Meeting

Santa Barbara, CA

April 26, 2011

Application of 13 MHz SeaSonde Systems for Vessel Detection

Independent Study Program, Blake Cignarella, 2010 CSR Summer Institute Graduate, Exploring the Potential Effects of Oceanographic Environment on Port Security in the Mid Atlantic


Resources Leveraged

<p>| Mid Atlantic Regional Coastal Ocean Observing System | Admin Assistance, electronic data processing, web support, technical support for the 30 site, operational, regional HF Radar network |
| NOAA IOOS Program National Surface Current | CODAR loan brokering, data coordination with the U.S. National Network, operating frequency permissions |</p>
<table>
<thead>
<tr>
<th>Mapping Plan</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>UCSD Coastal Observing Research and Development Center</strong></td>
<td>Web hosting, Data quality control for the national HF Radar network.</td>
</tr>
<tr>
<td><strong>NAVSEA LEAP Program</strong></td>
<td>13 MHz SeaSonde deployed in NJ, 13 MHz bistatic transmitter deployed on shore and at sea</td>
</tr>
<tr>
<td><strong>CIT</strong></td>
<td>Additional support for vessel tracking test in Norfolk to evaluate the system for a Navy port.</td>
</tr>
<tr>
<td><strong>DHS S&amp;T</strong></td>
<td>Development and demonstration of real-time bistatic software for vessel detection.</td>
</tr>
<tr>
<td><strong>NJ Board of Public Utilities</strong></td>
<td>Proposal approved to Install Four 13 MHz CODAR SeaSondes along the south Jersey coast, extending the range of the NY Harbor testbed.</td>
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</table>
Task 1.2, Project 2, University of Puerto Rico Mayaguez (Dr. Jorge E. Corredor, PI)

Objectives and Significance to Stakeholders

A main objective is to provide a testbed for ship detection and tracking in the Mona Passage using High Frequency radar for tracking and Automatic Identification System (AIS) for validation. In addition, we aim to provide operational surface current maps of the Mona Passage and AIS data on ships transiting the Mona Passage for dissemination by the Caribbean Coastal Ocean Observing System (CariCOOS). Our efforts include providing a testbed for HFR system augmentation using a bistatic transmitter, and site surveys to support the deployment of a bistatic transmitter on Mona Island. We also train scientists in technologies pertinent to maritime security, and support the CSR Summer Research Institute.

In terms of stakeholder significance, our work to develop and disseminate operational surface current and ship traffic maps and other products for the Mona Passage as a contribution to the US Integrated Ocean Observing System through the Caribbean Integrated Coastal Ocean Observing System – CarICOOS supports Coast Guard Search & Rescue and NOAA HazMat spill response in the region.

Milestones Met

Antenna Pattern Measurements:
Antenna pattern tests were twice repeated at FURA aboard a police go-fast boat and at CDDO (Club Deportivo del Oeste) aboard UPRM’s R/V SULTANA. Antenna patterns were largely consistent through time although somewhat more variable at CDDO than at FURA. An important conclusion, referred in the publication noted below, is that: “Repeated measurements showed limited temporal variability of antenna distortion patterns demonstrating that these are in large part the product of the surrounding environment.”

Field validation experiment:
A large part of the work completed was in data analysis of the surface current validation experiment implemented jointly with CarICOOS in July 2010, and subsequent manuscript preparation. Significant input was provided by both the PR team (professors and students) and the Rutgers - COOL team who were responsible for the antenna pattern measurements and subsequent parameterization. This work culminated in the publication cited below.

AIS:
Seeking better coverage of the northern reaches of the Mona Passage, a second AIS unit was installed at FURA in Añasco and then at the UPRM campus in Mayaguez. Surprisingly, coverage from the original AIS antenna emplaced in the PIs laboratory at La Parguera on the SW coast of PR continues to provide better coverage than the Mayaguez antenna! (Reception of signal varies, so siting matters.)
Bistatic Transmitter Deployment:
A bistatic transmitter, custom-built by CODAR Ocean Sensors for Rutgers COOL, was deployed at 17.985086° -67.214593°. This site, about 8 miles south of the CDDO site is at a beach resort named Mojacásabe. This deployment constituted a pilot test for eventual deployment of the equipment on Mona Island.

Mona Island Survey:
A survey of the east coast of Mona Island was implemented on May 12 2011 to locate sites for bistatic transmitter emplacement. This survey was intended to identify sites for deployment of a bistatic High Frequency radar transmitter to supplement and enhance the existing network comprised of transmit/receive (Tx/Rx) stations at the PR Police FURA station at Añasco Beach in Añasco and the Club Deportivo del Oeste in Joyuda, Cabo Rojo. The added vantage-point provided by the installation of a Transmit (Tx) signal generator GPS-synchronous with the existing network will increase and enhance HFR coverage (see figures below). Air transportation and logistic were generously provided by PR Department of Natural Resources and the Environment (PR-DNRE) upon authorization by the Secretary, the Honorable Daniel Galán-Kercadó.

Sites considered were the dock at Playa de Pájaros the clifftop at Pájaros and the old lighthouse. (See map, table and photos) attached. Concerns about the dock at Pájaros were the lack of clearance towards the north, the difficulty of carrying out the installation on the dock without obstructing use of the dock, and the possibility of vandalism. The old light house site was too far removed from the cliff edge which would impede signal propagation. The clifftop at Pájaros thus seems to be the best site with road access, proximity to the coast and a clearer view to the northeast.
**Left to right: Dock at Pájaros, Clifftop at Pájaros, and Old Lighthouse sites.**

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dock at Pájaros</td>
<td>18.063784°</td>
<td>-67.869647°</td>
</tr>
<tr>
<td>Clifftop at Pájaros</td>
<td>18.062924°</td>
<td>-67.871816°</td>
</tr>
<tr>
<td>Old Lighthouse</td>
<td>18.084755°</td>
<td>-67.851266°</td>
</tr>
</tbody>
</table>

**Table 1. Coordinates for sites surveyed**

The figures above, produced by Mr. Lilliboe of CODAR Ocean Sensors, depict current coverage and expected coverage of the Mona array when supplemented with the bistatic transmitter at Mona Island.

**Scientific party for the Mona Survey:**
Jorge E. Corredor - UPRM
Julio M. Morell – UPRM
Ethan Handel – Rutgers University
Peter Lilliboe – Chief Engineer, CODAR Ocean Sensors

**Summer Research Institute:**
In June 2011, Dr. Canals attended the DHS Summer Research Institute at Stevens for 2 weeks, during which he lectured on MDA activities in the US Caribbean region. Three students from UPRM participated in the SRI, and one of these students has already expressed interest in continuing to work with HF Radar in Puerto Rico. He is one of three undergraduate students funded by the DHS-SLA project to work with Dr. Canals and Dr. Corredor in Fall 2011 on the UPRM / Rutgers HF Radar system.

Dr. Jorge Corredor served as Faculty Lead for the week of July 5-8. He lectured on
maritime awareness with specific emphasis on the role of meso-scale phenomena (internal waves, eddies, river plumes, upwelling), on progress in the development of the Mona Testbed facility and on the Caribbean Coastal Ocean Observing System. Dr. Corredor attended the field visit to the New York Emergency Management.

**DOCUMENTATION**

**Products served currently through the CarICOOS web page:**
Surface currents in the Mona Passage: [http://www.caricoos.org/drupal/node/141](http://www.caricoos.org/drupal/node/141)

**Publications:**


**COLLABORATIONS AND RESOURCES LEVERAGED:**

<table>
<thead>
<tr>
<th>Rutgers University – Coastal Ocean Observing Laboratory</th>
<th>Technical support in HF Radar operation and maintenance 12 MHz CODAR system loan Bistatic transmitter</th>
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<tbody>
<tr>
<td>Caribbean Integrated Coastal Ocean Observing System - CarICOOS</td>
<td>Admin Assistance, electronic data processing, web support, technical support, Site ID, site selection &amp; permitting</td>
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<tr>
<td>Texas A&amp;M University</td>
<td>12 MHz CODAR system loan</td>
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<tr>
<td>Fuerza Unida de Rápida Acción – Policía de Puerto Rico</td>
<td>CODAR site</td>
</tr>
<tr>
<td>Club Deportivo del Oeste, Inc Joyuda, Cabo Rojo</td>
<td>CODAR site</td>
</tr>
<tr>
<td>PR DNRE</td>
<td>Air and land transportation to and at Mona Island.</td>
</tr>
<tr>
<td>Mojacasabe Beach Resort</td>
<td>Bistatic Transmitter site</td>
</tr>
<tr>
<td>NOAA IOOS HFR Plan</td>
<td>Radio Frequency operator’s license</td>
</tr>
</tbody>
</table>

Further to the above, in spring 2011 a DHS Scientific Leadership Award (DHS-SLA) was awarded to Dr. Miguel Canals (CSR Co-PI) and to two other junior faculty members from CIMES (Dr. Vidya Mania, PI and Dr. Hector Carlo, Co-PI) for their project entitled "Education and training of students on maritime domain awareness and port security at
UPRM”. This joint CSR-CIMES proposal will provide ten scholarships to engineering students at UPRM interested in maritime security related careers.

Year 3 Challenges:
As noted previously we have been working with old equipment on loan from other institutions and as a result, have encountered significant downtime due to equipment failure. The Rutgers owned CODAR unit deployed at the CDDO site spent 5 months at the manufacturer’s plant undergoing repair. Moreover, we suffered cable partings at both sites which increased our downtime. To top things off, the police at FURA decided to tear down and reconstruct their dock which necessitated our tearing down the antenna until the completion of the dock. Repeated equipment failure or down-time due to other causes as noted above precluded implementation of two programmed activities: HF Radar vessel tracking experiments focusing on AIS-equipped vessels transiting the Passage and SLMDB buoy deployment in collaboration with the USCG. Barring further equipment malfunction, we intend to continue providing support to our Rutgers collaborators in experimental ship tracking in the Mona Passage and in assessing performance of the bistatic Tx installation at Mojacasabe. Current funding reductions preclude further work on the bistatic Tx installation at Mona Island.
Task 1.3 Nearshore and Harbor Maritime Domain Awareness Via Layered Technologies

Task 1.3, Stevens Institute of Technology (A. Sutin, PI) TRL 7

Project Objectives and Significance to Stakeholders

The acoustic component of the CSR research is aimed at the application of passive acoustic methods for surface and underwater threat detection, classification and tracking. The ability to safeguard domestic shipping and waterside facilities from threats associated with surface and underwater vessels and divers is critical to ensuring a viable Maritime Domain Awareness. Small surface vessels and divers have already been employed as weapon delivery vehicles elsewhere in the world. The Report to the Committee on Homeland Security, House of Representatives stated [1]: “The systems used in U.S. coastal areas, inland waterways, and ports - AIS, radar, and video cameras - have more difficulty tracking smaller and noncommercial vessels because they are not required to carry AIS equipment and because of the technical limitations of radar and cameras.” Intensive attention is being paid to unmanned surface and underwater vehicles as a new emerging threat to waterside security [2]. There is some information that terrorist organizations trained divers for possible nefarious missions [3].

A number of technologies have been developed for MDA [4-8] and many of them are combined in an integrated system. Examples of similar systems include a European system for enhanced operational maritime border control and maritime domain awareness [6] and the Joint Harbor Operations Center (JHOC), an experimental fusion center organized by the US Coast Guard and Navy for the protection of ports where the Navy has a large fleet presence [4,7]. Inside the center, homeland security personnel capture radar and sonar signals, track video and vehicle data, take phone calls from the field, listen to radio traffic from patrols and commercial ships at sea, and break down classified intelligence information--all in an effort to prevent a terrorist strike or assist in maritime rescues [7].

The research being conducted in the National Center for Secure and Resilient Maritime Commerce (CSR), a DHS S&T National Center of Excellence for Port Security examines basic science issues and emerging technologies to improve the security of ports as well as coastal and offshore operations. The CSR work relies on a layered approach utilizing above water and underwater surveillance techniques. The investigated layers include satellite-based wide area surveillance; HF Radar systems providing over-the-horizon monitoring; and nearshore and harbor passive acoustic surveillance. Integration of these systems is aimed at achieving surface and underwater threat detection, classification, identification, and tracking at various scales.

Milestones Met
1. During year 3 of the project, researchers from Stevens continued to gather information regarding the characteristics and variability of acoustic signatures from surface and underwater vessels and divers, under a variety of ocean and weather conditions. These measurements formed an invaluable database for use in the characterization of threat signatures, and eventually in decision-support algorithms. The new tests conducted in the port of Miami, Den Helder (Holland), the Hudson River, and NY Harbor allows for the registration of several hundred boat acoustic signatures. A large library of diver signatures was collected in joint tests with TNO (Holland) in Den Helder.

2. Stevens Passive Acoustic Detection System (SPADES) was permanently deployed in the Hudson River in Summer 2011. Joint data from SPADES, radar, AIS and video surveillance were analyzed by students from the CSR Summer Research Institute. The students collected more than 100 acoustic signatures and have found the acoustic detection distances of various vessels for different environmental conditions.

3. The detailed acoustic signature of the Stevens R/V Savitsky was measured in combination with engine RPM and distance. The conducted test demonstrated correlation of RPM with radiated frequencies. The boat engine gear ratio was determined from the acoustic measurements, demonstrating that it can be used as one of the classification parameters.

4. Novel algorithms for ship signature extraction based on a joint signal processing of DEMON signals from several hydrophones was developed. The suggested method requires 1000 times less data rate for communication between hydrophones and can serve as a basis for signal processing of signals from a network of autonomous passive acoustic buoys.

5. A joint Satellite–Radar-Acoustic test conducted in the Port of Miami demonstrated persistence and tip-and-queue functionality. This test confirmed the feasibility of passive acoustic ship classification observed by satellite and radar. The smallest target detected by satellite and acoustics was a Jet Ski. The acoustic detection distance of jet skis was about 1.7 km.

6. Information about Transmission Loss and Ambient Noise in various test areas was collected and systemized. Ambient noise acoustic measurement showed high level of acoustic noise in the Miami port channel and much less noise level offshore. Strong noise on the shelf and in the channel is probably due to snapping shrimp. The reduced offshore noise level allows acoustics to detect much longer distances than in the channel.

7. The diver detection test conducted in the Dutch Harbor Den Helder demonstrated that passive acoustic open circuit scuba diver detection in this type of environment can be conducted at distances of at least 400m. The first test with
two separated pairs of hydrophones also demonstrated the feasibility of diver localization.

8. A palm-sized portable underwater recording system was built and tested. The new SPADES-2 passive acoustic system that is several times lighter than the current system was developed. It is under testing and will be available for taking measurements in the field in a few months.

Laboratory Capabilities
Acoustic research at Stevens is conducted in the Maritime Security Laboratory, or MSL, that provides the capabilities of experimental research of physical phenomenon connected with acoustic wave generation and propagation in the realistic environment of the Hudson River Estuary. Initially, the focus of MSL was on threats posed by surface and subsurface intruders including SCUBA divers [9-10] and later was extended to small boats by using passive acoustic techniques [11-12]. Part of the uniqueness of Stevens’ Maritime Security Laboratory is its location on the Hudson River tidal estuary, which is a key waterway that defines the Port of New York/New Jersey, one of the busiest harbors in the U.S. From a scientific perspective, this harbor embodies a high degree of complexity due to variability of currents, salinity, temperature, winds, turbidity, as well as man-made factors including ambient noise due to surface and air traffic, construction noise, and various forms of electromagnetic radiation. All of these enter into the analysis of above and below surface threats. Hence, the estuary itself is an integral part of the laboratory. The estuary is equipped with instrumentation to collect weather and environmental data, and through modeling, to predict their characteristics. The MSL research vessels, UUVs and other assets are shown in Figure 1. The larger boat is the RV Savitsky (Fig.1a). It is specially constructed and fitted out for maritime research purposes. Towards the stern, is an A-frame for loading large and heavy items onto and off of the boat. Two smaller boats (Fig.1a and b) are used for support and experiments. Small boats are also used to deploy remote instrumentation, divers, and provide for safety. In addition, they are used as additional points of radiation or reception in experiments involving acoustic propagation between several points and measurements of temporal variability of acoustic field.

The Stevens research is supported by several UUVs iRobot Ranger (Fig.1e) and iRobot Transphibian (Fig.1d). The iRobot Transphibian, a fin-powered vehicle is both a mobile UUV and a bottom crawler. The fins enable the robot to navigate with 6 degrees of freedom.

The surface water traffic surveillance is conducted by several video cameras, Infrared system (Fig.1c), AIS system and two radars (Fig1.f,i). Information about these systems is presented in section 2.1. The majority of the acoustic tests were conducted using Stevens Passive Acoustic Detection System (SPADES) shown in Fig. 1g and h. SPADES allows the passive
acoustic detection, tracking and classification of various surface and underwater sources of sound including surface vessels, swimmers, various types of divers, and unmanned underwater vehicles [10,11]. The system components include a land-based computer and an in-water system. The two sub-systems are connected via an underwater cable that provides power and communication between the two sub-systems. The central mooring houses the electronic components required for signal conditioning, data acquisition, pre-processing, storage, and transmission. The four hydrophones are mounted on stands. Usually the stands provide the hydrophone placement at a height of 60 cm above the bottom.

In addition to SPADES, we built a small portable recording system having a very small weight of less than 1 pound (Fig.1j). This system records acoustic signals using two inexpensive hydrophones. It can be placed in any area of the waterside and has been tested for recording diver and small boat acoustic signatures. The description of this system in more detail and test results is presented in section 2.2.

Figure 1. Stevens assets used for acoustic research.

2.1. New capabilities of surface surveillance
Several lab improvements were part of a separate effort that was effectively leveraged this year to enhance CSR work on MDA.

To improve the capabilities of vessel detection, observation and tracking, MSL has installed several new sensors and integrated them with already existing and working systems. The new sensors include:

- CO10 observation system of video and infrared cameras;
- AIS receiver with antenna;
- separate AIS data feed from internet source;
- MR2020 – Pulse Doppler Radar;
- BridgeMaster – Pulse Radar.

**CO10 observation system.**

![CO10 observation system of video and infrared cameras](image)

**Figure 2. CO10 observation system of video and infrared cameras;**

- Compact day/night long-range observation system;
- Thermal imaging camera channel – IR sensor with a x36 zoom lens;
- Daylight channel - High resolution color CCD camera with a x20 zoom lens;
The Automatic Identification System receives data that is transmitted by AIS equipped vessels:

- Vessel Data
- Cargo Data
- Voyage Data
- Status

A software system was developed to process, analyze and display AIS data that MSL is receiving from US Coast Guard data feed. This system is capable of:

- Acquire AIS messages from internet port;
- Decode AIS messages;
- Display positions and history of all detected vessels on Google Earth.
- Record all acquired data;
- Playback recorded data.

An example of the AIS system data presentation for a portion of the Hudson River is shown in Figure 4.
Figure 4. Example of the AIS system data presentation.

MR2020 – Pulse Doppler Radar
The Pulse Doppler radar installed on the roof of the Babbio building has the following parameters:

- X band coherent Pulse Compression Radar
- Operates at 8.85 GHz, narrow 3.8-degree horizontal beamwidth and a 5.35-degree vertical beamwidth.
- Automatically detects moving targets, such as walking persons, vehicles and flying objects (gliders and helicopters) at ranges of up to 30km.
- Range
  - Walking Person- 10km
  - Light Vehicle - 17 km
  - Heavy Vehicle – 30 km
- >100 Tracked targets
- Integrated into multi-sensor systems at border and critical assets.
BridgeMaster – Pulse Radar

![BridgeMaster – Pulse Radar](image)

*Figure 5. BridgeMaster – Pulse Radar.*

The radar has the following parameters:
- X Band Radar
- 9.4-GHz pulse radar with a very narrow 1-degree horizontal beamwidth and a 24-degree vertical beamwidth
- 8 foot antenna
- Surface Target Detection and Tracking
- Long range
- Interface to AIS for 2nd radar simulated tracks

**Display**

Google Earth is used as a platform for displaying data from AIS, radar and acoustic sensors. In Figure 6, a section of the Hudson River next to Stevens Institute of Technology is displayed with two vessels moving and multiple vessels docked at the piers.
- Blue boats represent targets detected by Coast Guard AIS;
- Green boats represent targets detected by installed AIS antenna;
- Red boats represent targets detected by radar;
- Circle on the western side of Hudson river shows the location where the SPADES system (system of hydrophones) is deployed;
- Green lines from the circle depict bearings from hydrophones to the moving vessels emitting acoustic noise;
- Numbers on green lines are angles in degrees from North;
- Red boats detected by radar show distances in meters to the SPADES system;
- Boats detected by AIS have their names shown.

This visualization overlay is a real-time capability continuously displayed in the lab.
Long-wave infrared camera
The camera provides night vision of water traffic and a number of recordings were conducted to compare visual and infrared videos. In Figure 7, one can see such comparisons done on the evening of July 4th, 2011.

![Figure 7. Comparison of frames of visual and infrared videos conducted on the evening of July 4th, 2011. Small vessels without lights are apparent in the IR frame (left) but disappear in the visual frame (right).](image)

Development of the new lightweight Stevens Passive Acoustic Detection System (SPADES-2)
The original Stevens Passive Acoustic Detection System was described in previous reports and demonstrated good performance. But the large size and weight of the
underwater box make the deployment and recovery of the system in real conditions somewhat challenging. The second version of SPADES was developed with this problem in mind.

As before, the system is divided into two parts (see Figure 8): underwater equipment and shore equipment. The underwater equipment consists of a set of hydrophones, ITC 6050, placed on metal stands and connected to a mooring via 15ft long cables.

![Figure 8. The schema of the SPADES-2.](image)

The mooring (see Figures 9 and 10) houses:
- custom made 4-channel signal conditioner
- Data Acquisition Board
- USB 2.0 to fiber media converter
- Custom made DC-DC converter to supply power for components.

The mooring has a diameter of 8 inches and is 13 inches long. The weight is about 25 pounds.
Figure 9. The schema of the underwater mooring of the SPADES-2.

Figure 10. The central mooring of SPADES-2.

The underwater equipment is connected to the shore equipment using a combined fiber-optic/electrical cable. This cable contains one copper pair used for powering of the mooring and four fibers, two of which are used for data transmission, a third which is used for the PPS signal from the GPS unit for precise signal timing, and a fourth which is reserved. The overall length of the fiber optics cable is 250 meters.
The dry end of the cable is connected to the Data Storage Computer. This part of the shore equipment contains not only the computer itself but also a Fiber Optics to USB 2.0 converter, and a GPS receiver, enclosed in a waterproof Pelican briefcase (see Figure 11).

![Figure 11. Shore Data Storage](image)

The data storage computer is equipped with two high capacity, 4TB or more, removable hard drives. One of them is used to record the data stream received from the underwater equipment while the second one is in reserve. If the first hard drive is full, the reserve hard drive takes on its function. Another duty of the Data Storage Computer is to transfer all data to the Signal Processing Computer (Figure 8). This computer is able to perform all operations including FFT transform, frequency domain filtering, multi-pair cross correlation, target tracking and visualization.

2.3 Improved Prerecorded Signal Emitter (PSE)

During hydroacoustic field tests, we need to check the deployed equipment by simulated signals before actual measurements are made. For this purpose, a Prerecorded Signal Emitter (PSE) was designed. See Figures 12 and 13. The PSE is controlled by software developed by Stevens. The package allows play back of virtually any type of prerecorded or simulated signals in the frequency range up to 100kHz. Two hydrophone channels allow us to record underwater sounds, analyze the signal via a FFT analyzer and prepare the signals for play back.
2.4. Portable Underwater Sound Recorder. First tests results.
During the April – May 2011 Lake Hopatcong test, the Portable Underwater Sound Recorder (PUSR) was tested. This instrument is based on the inexpensive handheld sound recorder ZOOM-H1. The device is capable of recording two channels of signals with resolution 16 bit or 24 bit and 44.1 kHz, 48kHz and 96 kHz sampling rate uncompressed WAV or MP3 format to microSD flash card. Use of a 32GB microSDHC...
card allows over 50 hours of recording time at 16-bit/44.1 kHz. For MP3 format, the recording time may reach 500 hours. H1 is a low power device, so single AA size battery allows 10 hours of operation.

![Figure 14. Portable Underwater Sound Recorder.](image163x504to448x629)

To build a underwater sound recorder, the existing microphones were removed and two hydrophones were installed. Also the capacity of the battery was increased. The recorder and the battery were enclosed in a watertight box. The system provides a sensitivity of -180dB re 1V/uPa in frequency range 20Hz-4kHz with reduced sensitivity up to 100 kHz. The overall weight of this small system does not exceed 2lb. See Figure 14.

Presented below are results of comparison of processing signals received by SPADES and the Portable Underwater Sound Recorder. Figure 15 shows examples of cross-correlation tracking of a small boat moving at a distance of approximately 220 m. It was standard path A that we used for acoustic signature measurements. As seen from this figure, the results are similar, but angular resolution is less for the portable system due to the relatively small separation between hydrophones (approx. 10 ft). Increasing the distance between hydrophones will lead to improvement of the PUSR angular resolution.
Figure 15. Cross-correlograms of Panga tracking recorded by SPADES (upper panel) and PUSR (lower panel).

Figure 16 presents spectra of test signal received by SPADES and the Stevens Portable Underwater Sound Recorder. This signal consists of a set of simultaneously generated sine waves with a start frequency of 222 Hz and every following is 1.11 times higher than the previous. Physical separation between the two systems was about 50 m and the Stevens boat carried the source of sound at a distance of about 200 m from SPADES. The figures demonstrate a similar level of signal for both systems and similar level of noise floor. It should be noted the specified level of noise is the ambient noise and systems self noise is below this level.
Figure 16. Spectra of the PSE signals received by the new portable system and SPADES.

The advantages of the Portable Underwater Sound Recorder are:

- Small size;
- Light weight;
- Easy deployment and recovery;
- Long recording time without battery replacement;
- Low cost;
- Autonomous

This kind of device is very suitable for long term research of ambient and shipping noise, as well as marine life, in ports, rivers, bays and coastal area. The disadvantage is the inability to provide signals for real time processing.
The SPADES system was continuously deployed on June 7, 2011 for a long-term test conducted by the Summer Research Institute (SRI). Figure 17 shows the hydrophone positions that had the following coordinates:

<table>
<thead>
<tr>
<th>Hydrophone #</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>-74.0244994</td>
<td>40.7418589</td>
</tr>
<tr>
<td>#2</td>
<td>-74.0244316</td>
<td>40.7417797</td>
</tr>
<tr>
<td>#3</td>
<td>-74.0245520</td>
<td>40.7417269</td>
</tr>
<tr>
<td>#4</td>
<td>-74.0246233</td>
<td>40.7418189</td>
</tr>
</tbody>
</table>

*Table 1. Deployed hydrophone positions.*

The improved abilities of MSL allowed measurements of clear acoustic signatures of various boats, measurements of accuracy of the acoustic ship bearings and their comparison with radar and AIS data, and finding correlation between radiated frequencies and engine RPM. Below we present results of tests conducted using the research vessel Savitsky in the Hudson River close to the waterfront of Stevens Institute of Technology. During the vessel runs, the acoustical signals of the vessel were recorded by underwater acoustic system SPADES and at the same time the rate of the vessel’s crankshaft rotations was recorded by an onboard data acquisition system. GPS coordinates from the vessel’s GPS receiver were also recorded for all runs.

The problem of clear measurements of the acoustic signatures in the urban environment is connected with intensive water traffic and acoustic signals from many boats that can come to the hydrophones at the same time. The main tool for choosing a time frame for
clear boat signature is Cross-correlation signal processing providing bearing to an acoustic source and its intensity. Figure 18 shows the Cross-correlogram for R/V Savitsky moving from South to North during the test conducted on June 30, 2011. This cross-correlogam allows choosing of the time when the boat is at the Closest Point of Approach (CPA) and the acoustic signal has maximum. This time is marked with a red line in Figure 18.

![Figure 18. Cross-correlogram and a frame of video during the run of R/V Savitsky. Video frame shows Savitsky moving in proximity of the SPADES system.](image1)

In many cases the acoustic system recorded signals from many boats at the same time and separation of the boat signatures could not be done in a simple way. Figure 19 shows an example of the recorded Cross-correlogram during the test with R/V Savitsky when the signal separation was not possible.

![Figure 19. Cross-correlogram and frame of video during the run of R/V Savitsky. The acoustic signals from three boats are mixed and the signatures cannot be separated.](image2)

For the case presented in Figure 18 the boat acoustic signature was measured at the CPA and it is shown in Figure 20. Savitsky was equipped with GPS and its track during this test is shown in Figure 21. The comparison of the R/V Savisky’s bearing measured by GPS with the bearing measured by acoustic method (Figure 18) shows good agreement.
Figure 20. Acoustic signatures of R/V Savitsky: a) the spectrum of low frequency part of the recorded noise, b) DEMON spectrum.

Figure 21. GPS track of R/V Savitsky during its run. Green squares show positions of hydrophones.
Measurements of vessel’s RPM were conducted by optical RPM sensor. A small piece of reflecting tape was attached to the engine’s shaft on the boat, and an optical sensor was placed next to it. This sensor’s output was in volts with 1 volt corresponding to 2500 RPM. Results of these measurements were converted to Hertz and displayed as a white plot on Figure 22. This figure also presents results of the boat speed calculation. We have calculated its speed as a simple function of distance between two subsequent GPS coordinates and time between them. Speeds for all runs are shown on Figure 22 as a red plot. Corresponding scale is on the right side of the graph. We can see that when R/V Savitsky was moving South its speed was higher for the same RPM comparing to moving North. From this observation we can conclude that at the time of runs there was a surface current to the south in the Hudson River of about 1.5 m/s or 3 knots.

![Figure 22. Frequency of rotations of crankshaft (RPM/60, white) and vessel’s speed in m/s. (red).](image)

We have confirmed our observation of river current with the Stevens New York Harbor Observation and Prediction System (NYHOPS) (Figure 23) that can be found at http://hudson.dl.stevens-tech.edu/maritimeforecast/maincontrol.shtml. These data-driven mathematical models have been developed by Stevens and are used to predict oceanic and atmospheric environmental factors.
The comparison between rotations of crankshaft and the measured DEMON frequencies is presented in Table 2.

<table>
<thead>
<tr>
<th>Time</th>
<th>Distance (m)</th>
<th>Direction</th>
<th>Current 1.5m/s, South</th>
<th>#of boats</th>
<th>Speed (m/s)</th>
<th>Engine Rotations (Hz)</th>
<th>DEMON Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:04:15</td>
<td>265</td>
<td>South</td>
<td>With</td>
<td>1</td>
<td>6</td>
<td>23</td>
<td>36.9</td>
</tr>
<tr>
<td>18:18:43</td>
<td>115</td>
<td>North</td>
<td>Against</td>
<td>1</td>
<td>4.5</td>
<td>31</td>
<td>49.8</td>
</tr>
<tr>
<td>18:26:54</td>
<td>270</td>
<td>South</td>
<td>With</td>
<td>2</td>
<td>8</td>
<td>34</td>
<td>54.2</td>
</tr>
<tr>
<td>18:32:45</td>
<td>155</td>
<td>North</td>
<td>Against</td>
<td>1</td>
<td>5.5</td>
<td>34</td>
<td>54.2</td>
</tr>
<tr>
<td>19:09:44</td>
<td>160</td>
<td>North</td>
<td>Against</td>
<td>2</td>
<td>4.5</td>
<td>30</td>
<td>47.6</td>
</tr>
</tbody>
</table>

Table 2. The comparison between rotations of crankshaft and the measured DEMON frequencies.

It is seen that the DEMON frequency is directly proportional to the RPM.

It is known that the blades frequency
\[ F_{\text{Blade}} = N F_{\text{prop}} \]

Where \( N \) is number of blades and \( F_{\text{prop}} \) is the frequency of the propeller rotation.

The frequency of the propeller rotation is connected with the crankshaft RPM through the gear ratio \( G \)

\[ F_{\text{prop}} = \frac{\text{RPM}}{G} \]

Substituting measured frequencies \( F_{\text{prop}} = 54.2 \text{Hz} \), \( F_{\text{Blade}} = 34 \text{Hz} \), \( N = 4 \) we received that the Savitsky gear ratio \( G = 2.51 \). The engine manual gives the ratio \( G = 2.54 \), which is very close to the ratio determined by acoustics. This example shows that measured acoustic signatures allow finding of the boat engine gear ratio that can be used for vessel classification.

**Ambient acoustic noise in various areas**

Ambient acoustic noise level is an important factor that affects the performance of both passive and active acoustic systems. During the previous years a number of field tests involving SPADES were conducted. In all tests, we performed measurements of the level of environmental underwater acoustic noise in wide frequency band spanning from 20Hz to 100kHz. The places where measurements were made include:

- Newport, RA
- Lake Hopatcong, NJ
- New York Harbor, NY
- Hudson River near New York City
- Key West, FL
- Panama City, FL
- Den Helder, Netherlands

To estimate the level of natural noise in the tests we selected periods of time when there were no nearby moving vessels and no other manifestations of human activities. All recorded data were recalculated to the ambient noise level in the band of 1 Hz and presented in dB re 1 mPa/\( \sqrt{\text{Hz}} \). The ambient noise data are presented together in Figure 24. It is seen that noise level may vary significantly depending on environmental conditions. The lowest level of noise was observed during a test on Lake Hopatcong in April 2011.
Figure 24. Ambient noise level measured at different sites

On Figure 25, highlighted are graphs obtained from places with a snapping shrimp population. Shrimp produce very short and very powerful acoustic pulses, “clicks”, which resulted in a high level of noise from low to high frequencies. Figure 26 presents an example of a snapshot of acoustic signal received in the port of Miami where the pulses generated by snapping shrimp are clearly seen.
Figure 25. Ambient noise level measured at different sites. Measurements conducted in areas with high levels of noise produced by snapping shrimp are shown in bold.

Figure 26. Example of the snapshot of acoustic signal received in the Port of Miami with strong pulses generated by snapping shrimp.
Phase measurements in DEMON algorithm for source bearing funding
An important feature of the passive acoustic system is its applicability for vessel classification based on vessel acoustic signatures [13-18]. The noise radiated by a ship is modulated at a rate dictated by some parameters of the propeller and engine (number of blades, rotational speed). Evaluation of that modulation provides information on the ship, such as the shaft rotation frequency and number of blades, that can be used for ship classification. The method for estimation of the high frequency envelope modulation is known as DEMON (Detection of Envelope Modulation on Noise) [16-18]. The DEMON spectra are the basis for various algorithms of ship classification. The DEMON algorithm utilizes the acoustic signal in a relatively high frequency band (above several kHz) where the ambient noise is much less than in the low frequency band.

Stevens Institute of Technology developed the simple passive hydroacoustic system with four hydrophones for underwater detection and tracking of divers and surface vessel detection and classification. Application of the cross-correlation method allows separation of the DEMON spectra when several vessels are present in an area of surveillance [11-12]. This method is based on measurements of time variation of cross-correlation signals coming from definite Direction of Arrival (DOA). The cross-correlation method of DEMON signature extraction utilizes relatively short time windows that are required for measurements of the cross-correlation, with repetition frequency of at least 200 Hz. However, the short time window of the cross-correlation calculation does not provide a high Signal/Noise Ratio (SNR), and so we considered another method of DEMON signal separation. This method is based on the measurements of the phase difference of line components in the DEMON spectra, in which case we can use a relatively long processing time interval (up to tens of second) that increases the SNR. A similar phase method can be also used for the measurement of DOA of low frequency line components.

Phase DEMON method for measurements of Direction of Arrival
The most common method for determining DOA using a simple acoustic system is based on the cross correlation of signals recorded by two or more hydrophones. Let us consider the signals received by two hydrophones separated by a distance $L$ (see Figure 27).

![Figure 27. The hydrophone positioning in relation to the acoustic source.](Image)
The noise radiated by a source whose direction makes an angle, $\alpha$, with the normal to the line between the hydrophones is recorded. The distance between the source and the hydrophones is much larger than $L$. The noise radiated from the vessel reaches the two hydrophones with a delay $\Delta T$ between them:

$$\Delta T = \frac{L \sin \alpha}{c}$$  \hspace{1cm} (1)

where $c$ is the speed of sound in water. The time delay can be used to find DOA:

$$\alpha = \arcsin \left( \frac{c \Delta T}{L} \right)$$  \hspace{1cm} (2)

If the vessel noise is modulated with frequency $F$ the envelope of the signal received by the two hydrophones will have the phase difference

$$\Delta \varphi = 2\pi \Delta TF$$  \hspace{1cm} (3)

This means that the measurements of the phase of the DEMON spectral component can be used for DOA finding. In order to avoid ambiguities in the DOA finding we used the hydrophone setting with distance between hydrophone $L$ less than the wavelength of the frequency $F$. For tests in NY Harbor with distance between hydrophones at 70 m it limits frequency to 20 Hz. For tests in the Hudson River with distances between hydrophone at 8 m the upper frequency limit was 188 Hz.

The block-diagram of the single channel DEMON signal processing is presented in Figure 28. Figure 29 shows how the combination of two DEMON processing units is used for the determination of the phase difference between two DEMON spectral components.

*Figure 28. The block-diagram of the single channel DEMON signal processing*
The PhDEMON algorithm can be described as follows.

The acoustic wave arriving at the hydrophone is transferred to the electrical analog signal $x(t)$. This signal is digitized with a sampling rate $f_s$ so that the sampled signal is given by $x[i] = x(iT)$ where $i = 0, 1, 2, \ldots$ and $T = 1/f_s$ is a sampling interval. In our experiments, the sampling rate was 200 kHz. The signal is band pass filtered (BPF) in the frequency band 10-90 kHz. This filtering allows us to suppress high ambient noise in the low frequency band.

The next step is the calculation of the envelope of the digitized filtered signal $\hat{x}[i]$ that is calculated using a Hilbert transform. The real part of the Hilbert transform function is then averaged in the time window, $T_D$. This time window contains $N = T_D f_s$ samples and the averaged envelope is calculated by the formula:

$$z[i] = \sqrt{\frac{1}{N} \sum_{i=N}^{(i+1)N-1} \hat{x}^2[i]}.$$

We computed the averaged signal envelope (DEMON signal) with the sampling rate $f_{Ds}=1/T_D$. In the results presented below, the sampling rate of the DEMON signal was 2kHz.

The application of the PhDEMON method for the determination of vessel bearing requires the comparison of the phases of the DEMON signals from two hydrophones. First, we choose the frequency $f$ in the DEMON spectra for the phase comparison. The phase of the chosen spectral component is found by using the Goertzel algorithm [19] and the phase difference between the two hydrophone signals is calculated. The phase difference $\varphi$ is recalculated to the time delay $\Delta T$ between two signals:

$$\Delta T = \frac{\varphi}{2\pi f}.$$

The phase difference $\varphi$ is then used for the calculation of DOA, using Eq. (2) and Eq. (5).
\[ \alpha = \arcsin \left( \frac{c \varphi}{2 \pi f L} \right) \] 

(6)

The PhDEMON algorithm allows tracking of various vessels using line components in the spectra of their DEMON signatures. Several examples of the application of this method are shown below.

**Examples of PhDEMON application in experiments**

The experiments were conducted in the Hudson River using the Stevens Passive Acoustic Detection System (SPADES) with 4 hydrophones [10]. The system uses hydrophones manufactured by International Transducer Corporation - Model ITC-6050C. They are sensitive in the band up to 100 kHz and provide -157 dB re 1V/1mPa midband open circuit receiving response. The hydrophones are connected to the central mooring via underwater cables and can be deployed at distances up to 50 m from the central mooring.

The acoustic data from the hydrophones are acquired and recorded on the in-water system. There, it simultaneously undergoes pre-processing and is transmitted digitally to the land-based computer. The land-based computer further processes the data and displays the results in real time.

The exact locations of the hydrophones were determined using a specially developed hydrophone positioning procedure. The procedure utilizes a supporting boat with GPS receiver, signal generator and acoustical emitter. The vessel moves slowly and makes at least one full circle around the acoustic system, while emitting noise signals in the water and recording GPS coordinates along the way. The SPADES system software calculates the correlograms for various pairs of hydrophones and provides information about the time delay between the acoustic signals arriving at the hydrophones. A specially developed program calculates the hydrophone positions that provide the least squares root deviation of the calculated time delays to the measured values.

**Experiments in NY Harbor**

In this experiment, we tested the hydrophone configuration setup with relatively long distance between hydrophones (up to 80m). The large distance between hydrophones provides better angular resolution than the setup with shorter distance. The hydrophones were placed at Latitude 40.032.596' and Longitude -74.000.116'. The depth at the point of measurements was approximately 10 m. Hydrophones #0 and #2 were oriented at -20° from the North – South axis and hydrophones #1 and #3 were oriented at 47°. The distance between hydrophones #0 and #2 was 78m and the distance between the other pair was 62m (see Figure 30). The accuracy of the hydrophone acoustic localization was approximately 4m.
There were several vessels in the area at the time of the measurements. The recorded signal was generated by the NJ Ferry SeaStreak shown in Figure 31a. This was confirmed by the DOA calculated using the cross-correlation method [20]. Figure 31c shows the spectrogram of the DEMON signature that demonstrates observation of the vessel during nearly 7 minutes when the SeaStreak moved to the distance of 7 km. Figure 31d shows the changing of the main DEMON frequency, and Figure 31e provides the DOA. The accuracy of SeaStreak tracking was confirmed by AIS data that were in range of the DOA deviation. The Doppler variation of the frequency shown in Figure 31d allows estimation of the vessel speed \( V \) according to the formula

\[
V = \frac{\Delta F}{F} c \cos(\theta)
\]

(7)

Where \( c \) is sound speed in the water, \( F \) is the frequency, \( DF \) is the Doppler shift and \( \theta \) is the angle between the direction of vessel movement and the direction between the center of hydrophone system and the vessel. The estimated vessel speed according to this formula was approximately 35 knots, while the AIS data showed that the speed of ferry in this area varied from 32 to 37 knots.
Figure 31. The DEMON spectrum (b) and the SeaStreak Ferry (a), spectrogram of the DEMON signal (c), tracking frequency variation in the DEMON spectra (d) and DOA tracking by the phase method (e).

Experiments in the Hudson River
In the Hudson River experiment, the hydrophones were placed closer together than in the NY Harbor experiment. Hydrophones #1 and #3 were oriented at -9° from the North – South axis and hydrophones #2 and #4 were oriented at 76°. The distance between hydrophones #1 and #3 was 8m and the distance between the other pair was 7m (see Figure 32).
Figure 32. Map of the experimental site and hydrophone positioning.

Figure 33 presents results of the spectral analysis of acoustic signals in the Hudson River recorded on July 3, 2010 from 15:00 to 15:10 (GMT). During this time, three ships (a Fast Ferry, the Stevens research vessel Savitsky and a NY DEP vessel) moved along the river. This figure shows the DEMON spectrogram (a) and cross-correlogram (b) for signals recorded for the sensors #1 and #3. The cross-correlogram is a floated chart similar to a spectrogram, a graph with two geometric dimensions: the horizontal axis represents time, the vertical axis is the delay between two hydrophone signals; a third dimension indicates the amplitude of the cross-correlation function. Figure 34 shows the DEMON spectra of the three vessels.

Figure 35 presents comparison of the DOA measured by the Phase DEMON and cross-correlation methods. It is seen that the both method give the similar DOA but the Phase DEMON permits tracking ships with definite frequencies.
Figure 33. DEMON spectrogram (a) and cross-correlgram (b) for the time window from 15:00 to 15:10 (GMT) when three ships moved along the Hudson River. Photos of the ships are shown in the upper panel of the Figure. The arrows on the top of the figure show the times when the DEMON spectra of the boats were taken.
Figure 34. The DEMON spectra of the three vessels shown in Figure 33. The line components used for vessel tacking by the Phase DEMON method are marked by arrows.
Figure 35. DOA tacking for the 3 vessels shown in Figure 33. The red line shows the ferry DOA using DEMON frequency between 14 Hz and 15 Hz; the green line is the DOA for R/V Savitsky using the signal in the band between 48 Hz to 50; and the purple line shows the DEP vessel DOA using the frequency band 10-12 Hz. For comparison, the blue line shows the DOA calculated using the cross-correlation method.

We have shown how the DEMON vessel signatures recorded by several hydrophones can be used for vessel bearing tracking. The PhDEMON method allows us to track several vessels at the same time using different line components in vessel signatures. The conducted experiments confirmed the feasibility of the suggested algorithm. The Doppler shift of the recorded signal allows estimation of vessel speed. The similar phase method can also be used for measurements of DOA of low frequency line components.
Passive acoustic diver detection conducted in a Dutch port (related project funded by TNO)
Potential threats from the waterside may be caused by intruders including divers with or without delivery vehicles, swimmers, small submarines, small vessels or unmanned underwater vehicles.

To increase the level of readiness for underwater harbor security, the Netherlands Organization for Applied Scientific Research (TNO) sponsored Stevens Institute of Technology (Stevens) in a collaboration to plan and carry out a field study of acoustic methods in an operational environment. In October 2010, TNO and Stevens conducted joint experiments in a Dutch harbor, where passive acoustic systems from both parties were investigated. The aim of these experiments was twofold: testing the acoustic detection and localization capabilities for well known types of targets, and gathering acoustic data for targets for which the current knowledge is limited.

Stevens Institute of Technology started to investigate passive diver detection in 2006. The research dealt with aspects such as characterizing the sound emission of the diver [9], evaluating how the acoustic signal is altered during propagation in shallow water [16], designing ways to detect such signal in the ambient noise and the design of a prototype [10]. The Stevens Passive Acoustic Detection System (SPADES) consists of four hydrophones that can be placed in arbitrary geometry and that can record signals of frequency as high as 100 kHz [10]. It has been used previously to demonstrate automated diver detection using a single hydrophone and, using several hydrophones, to determine and track the direction of a diver.

The 2010 experiment was held in the Royal Netherlands Navy harbor of Den Helder (Figure 36). The military harbor presents a central area that is about half a kilometer wide and 10 meter deep on average. Besides allowing access between the sea and the various military facilities, this area also serves as the entrance to the civil harbor.
During the trial, the harbor was following its activity as usual. Care was taken to ensure the safety of the personal involved during the trial, the divers in particular, but no effort was made to make the test site a quieter place, which would constitute more favorable conditions for passive acoustic detection. The picture of the SPADES system prepared for deployment is shown in Figure 37. Two deployments of the SPADES hydrophones were carried out (Figure 38). In the first deployment the SPADES hydrophones were deployed in a cross-configuration, with the hydrophones less than 10 m away from each other. In the second deployment, the SPADES was organized as a much wider array (max separation: 72 meters) that was placed farther away from the pier in order to test diver localization.
Examples of diver detection and tracking

Diver run #2 was conducted for the SPADES system hydrophones placed in configuration 1. The detection distance of the diver was 440 m in this case. The diver bearing was determined for first time at a distance of 340m. The acoustically measured bearing and its comparison with ground truth from a GPS device showed excellent agreement. The automated diver detection took place at the diver distance of 350m.

The second setup of the SPADES system was aimed to demonstrate a proof-of-concept approach to diver localization using cross-correlation. The hydrophones were divided in 2 spatially separated pairs. It is assumed that the targets stay on the same side of both hydrophone pairs for the duration of a test and also that the divers will be at least 55 degrees from the lines connecting the pairs, to guarantee highest resolution. The hydrophone pairs had distances of 29m and 17m, with 56.7 meters between the centers of the pairs.

The mechanism for localization in this proof-of-concept setup is based on user input: by examining the flowing cross-correlation chart mapped to angles, the user determines the direction to acoustic events and manually moves the cursors to match the bearing of the event. The bearing are mapped into lines on a 2D geographical map and intersected to produce geographical position of the target. Figure 39 shows the display of the SPADES system for diver tracking. Two examples of the diver tracking are shown in Figures 40 and 41. For the diver run presented in Figure 41 one of the divers stays outside of the operational area for the whole duration which consequently reduces the effectiveness of tracking. However a coarse position was determined even in this difficult case.
Figure 39. Display for the diver tracking during the tests.
Figure 40. Tracking of a diver; shaded area indicates low-resolution zone. White line is acoustic tracking and yellow line shows ground truth from GPS carried by a diver.

Figure 41. Tracking of two divers during Run 13, shaded area indicates low-resolution zone. Thin lines show acoustic tracking and thick lines present ground truth from GPS carried by divers.

Conclusions
- The test in Den Helder allowed us to extend collection of diver acoustic signatures.
• The conducted test demonstrated that passive acoustic open circuit scuba diver detection can be conducted at distances of at least 400m in that operational setting.

• The first test with two separated pairs of hydrophones demonstrated the feasibility of diver localization. This localization in future systems can be conducted using bearing info from multiple nodes. And we have plans to automate localization.

References


Leverage
• The effort described here employs the facilities of the Maritime Security Lab. The passive acoustic system was initially supported by a grant from the Office of Naval Research, and the system re-engineering and refinements is partially supported by DHS sponsorship.

• Improvement of MSL abilities and installation of two radars, AIS and new IR/Optic surveillance system was done with support and in collaboration with 4D security.

• Improvement of automated diver detection algorithms was supported by ONR and was done in collaboration with Advanced Acoustic Concepts. This algorithm was successfully tested in diver detections tests conducted in Naval Undersea Warfare Center (NUWC), Newport, RI

Collaborations
a. Improvement of MSL abilities and installation of two radars, AIS and new IR/Optic surveillance system was done with support and in collaboration with 4D security.
b. **USCG Sector New York** via information-sharing, and permits for in-water sensors in NY Harbor, and HF RADAR on Staten Island.

c. **USCG Sector Miami** provided support and deployment of SPADES system in Miami experiment.

d. **University of Miami** provides satellite optical imaging in multilayer approach for detection, tracking and identification of vessels.

e. **Rutgers University** performed HF Radar sensing in multilayer approach for detection, tracking and identification of vessels.

f. Joint test with **TNO (Netherlands)** demonstrated passive acoustic open circuit scuba diver detection at distances up to 400m in noisy conditions of the Dutch port (Den Helder).

**Future Plans**
1. Conduct measurements and analysis of background ambient noise in various areas and environmental conditions.

2. Conduct measurements and analysis of acoustic signatures of surface and underwater vessels in the Hudson River for various environmental conditions.

3. Develop vessel classification methods using the library of acoustic signatures collected by Stevens.

4. Consider various methods of optimization of vessel acoustic detection systems based on collected vessel signatures, ambient noise, and acoustic characteristics.

5. Re-engineer and improve the passive acoustic sensor system, including portability and data display.

**Documentation**
**Task 1.4, Decision-Support Systems** *(Note: there are two PIs on Task 1.4, J. Nickerson, Stevens Institute of Technology, and B. Reagor, Monmouth University)*

**Task 1.4 Project 1. Stevens Institute of Technology (Dr. Jeff Nickerson, PI) TRL 4**

**Bringing social cognition to decision making in emergencies**

**Project Description and Significance to Stakeholders**

Imagine a freighter burning in New York Harbor. The New York City Fire Department responds with one boat, the United States Coast Guard responds with three boats. Beyond the obvious goods of public safety and protection of property, this collaborative endeavor could yield several goods for the collaborating agencies: interagency respect, public acclaim, and additional funding. The success of collaboration might hinge on whether the two agencies can agree on who will command the operation, who will address the press, and who, later that year, might appropriate a new fire boat. Without agreement on how to allocate these agency-related goods, the joint operation might devolve into parallel, possibly competitive, single-agency efforts; the benefits of collaboration would be lost. Over the last year, we investigated ways to improve inter-agency collaboration by promoting the coordination of interpersonal and, consequently, instrumental interests. Throughout these ongoing investigations, we have demonstrated that perspective taking (imaging another person’s thoughts or emotions) helps collaborators look past conflict towards common interests. Simply making an effort to imagine another perspective helps collaborators override differences of resources and identity. They can, then, envision sharing a “bigger pie” and make decisions that benefit a wider range of stakeholders. These decisions represent a form of “social rationality.” As we continue our work on collaborative decision-making, we will investigate how this social rationality might help people override cognitive biases in relation to managing risks and detecting threats.

Our over-arching goal is to improve inter-agency collaboration by promoting the coordination of instrumental and interpersonal interests. DHS is responsible for facilitating and actualizing collaborations that exert the full force and utility of federal, state, and local resources. Our findings can offer empirical clues as to why inter-agency collaborations can sometimes devolve into multiple parallel efforts, lacking that collaborative force and utility. Further, our findings can serve as the basis for metrics and protocols towards more productive inter-agency negotiation and collaboration. Thus, the benefits to DHS are two-fold: awareness of various psychological effects on collaborative efforts, and ways to dampen or, even, harness those effects. This work can therefore benefit federal, state, and local agencies that must collaborate in security and emergency response, including U.S. Coast Guard, Federal Emergency Management Agency, Transportation Security Administration, state port authorities, and local police and fire departments.

**Milestones Met**
Bargaining often entails explicit and face-to-face efforts to coordinate both interpersonal (identity, status, and other “social realities”) and instrumental (money, tools, and other tangible resources) interests. Before face-to-face bargaining, though, collaborators independently decide how much to demand and how little to accept. These independent decisions ultimately influence negotiated agreements and, thus, constitute a tacit form of bargaining. In emergency situations such as the one we described in the introduction, collaborators likely have little time for anything more than tacit bargaining.

In our ongoing research, we aim to help people mitigate conflicting interests before they collaborate, before they even start negotiating the terms of collaboration. We aim to bring common interests into mutual focus before people independently decide how much to demand and how little to accept. To that end, we have run several human subjects experiments in which we compare the mitigating effects of cognitive effort (specifically, cognitive reflection; see Figure 1A) and social-cognitive effort (specifically, cognitive vs. emotional perspective-taking; see Figure 1B & C) on conflicting interests in a tacit bargaining task.

Across these experiments, we modeled a conflict similar to that between the Fire Department and Coast Guard: collaborators invest (and can reclaim) unequal amounts towards a collaboratively generated good. Subjects played a card game in which a four-ace hand wins a prize (see Figure 2). Each player receives a four-card hand with one to three aces from an eight-card deck containing four aces and four kings. Players are told that a partner holds the complementary hand. Players must pool their aces with this alleged partner, who contributes more, fewer, or an equal number of aces. They win only if they tacitly agree (agree without communication) on how to share the prize. Fairness might dictate that players either split the prize proportionately to their investments (75/25%) or reclaim their investments and then equally divide the excess (60/40%). Absent any explicit negotiation we did not expect nor did we see many "fair" proposals for how to share the prize. Instead, we looked for how often players tacitly agreed that equal division (50/50%) offered the next most obvious alternative to fairness.
A. Example of Cognitive Reflection Task

In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 46 days for the patch to cover half of the lake, how long would it take for the patch to cover half of the lake?

Earn a 2¢ bonus for correct answer.

B. Example of Cognitive Perspective-Taking Task

Name a fruit:

Earn a 2¢ bonus if you and your randomly selected partner give the same answer.

C. Example of Emotional Perspective-Taking Task

Click one word that best describes what the person in the picture is feeling.

CONTENTED JOKING

INTERESTED AFFECTIONATE

Earn a 2¢ bonus for picking the correct feeling.

Figure 1: Priming Tasks
During Year Two, we showed that unequal investment yields few equal divisions (much less fair divisions). Cognitive perspective-taking significantly increased equal divisions. Emotional perspective-taking also increased equal divisions, but to a lesser extent. During Year Three we further showed that interpersonal conflict—pointing out differences in cultural identity and gender identity—exacerbates the effects of unequal investment on the probability of equal division. Again, cognitive perspective-taking significantly increased equal divisions across all identity groups. On the other hand, emotional perspective-taking further exacerbated conflict. Players who imagined what another person was feeling were less likely to equally divide the prize with a partner belonging to another identity group than with an anonymous partner. We continue to collect data on how power asymmetries (high vs. low power) and social stigma might affect the coordination of interests, but preliminary results suggest that these factors increase interpersonal conflict in ways similar to identity differences. Forthcoming experiments will reveal whether cognitive and/or emotional perspective-taking might mitigate these effects.

We have produced reports on all extant results for submission to both journals and academic conferences. Across these reports, we argue that coordination of interests depends on social-cognitive effort rather than on the accuracy of social cognitions: when players try to anticipate one another’s beliefs or feelings, they also anticipate errors and
opt for the next most obvious settlement: equal shares. Reviewers have pointed out that any kind of cognitive effort might yield similar results. In response, we have designed a task that primes players to expend more cognitive (as opposed to social-cognitive) effort: specifically, subjects solve simple puzzles that require a moment of reflection in order to avoid intuitive but mistaken responses. During the latter part of Year Three, we replicated our previous experiments contrasting the effects of cognitive vs. social-cognitive effort on the likelihood of equal division. Preliminary results suggest that “garden-variety” cognitive effort yields no better results than no effort.

**On-going Additional Project Activities**

**Dampening Conflicts in Emergency Decisions**: For DHS and its stakeholders, resource conflicts may occur in the context of emergency response. In collaboration with colleagues outside of the CSR, we developed a “games server” for several Web-based “games” based on emergency scenarios. These are “games” both in the sense used by game theorists—that is, scenarios that require strategic decision-making—and in the everyday sense of recreational contests or challenges. In these games, the “players” will bargain over both instrumental and interpersonal goods. Across games, players must apply these goods towards responding to some risk or threat.

**Dampening Conflicts through Dynamical Decision-Making**: Earlier in the Project Description, we claimed that perspective taking helps collaborators to envision sharing a “bigger pie” and make decisions that benefit a wider range of stakeholders. Nevertheless, our one-shot games do not offer collaborators the opportunity to actually increase the size of the pie, i.e. to negotiate intangibles and/or other resources. Repeated games do offer such opportunities. Reciprocity in repeated games offers one way to enlarge the pie. We illustrate this with a toy example, referred to in decision-making literature as “the battle of the sexes.” In a repeated battle of the sexes game, players can reciprocate opportunities to “win” across time (Figure 3A: the husband concedes to attend the boxing match and the wife concedes a future date at the opera) or across different types of goods (Figure 3A: the husband concedes to attend the boxing match and the wife concedes to dine vegetarian). We will adapt the emergency games to allow for such forms of reciprocity.
A. Reciprocity Across Time

B. Reciprocity Across Kind

Figure 3. Two approaches to reciprocity in dynamical decision-making.

For example, stakeholders might use reciprocity to facilitate the trading of resources across different emergencies: the present one and the next one. Or they might use reciprocity in the current situation, trading preferences for different types of equipment (boats vs. helicopters) or different types of roles (operations vs. public relations).

Harnessing the Crowd: Information is one resource that people appear to share freely. In part, this tendency explains the successful expansion of the "see something, say something" campaign from New York City to the nation as a whole. People also share information through less formal and fully public channels, such as Twitter. In fact, Twitter users often report and spread information about events and emergencies ahead of the corporate news cycle. In collaboration with colleagues outside of the CSR, we have developed tools for collecting and analyzing tweets. Specifically for the CSR, we have collected tweets related to the Arab Spring, the earthquake and Tsunami in Japan, and the tornado in Joplin, MO. We will examine how people disseminate information and coordinate their actions through Twitter. Our finding can help DHS and its stakeholders leverage many eyes and many hand in many places.

Educational Activities (Maritime Threat Detection): We brought a cognitive perspective to this year’s Summer Research Institute (SRI). Specifically, we applied our findings on anomaly detection (from Years One & Two of our CSR project) to the problem of detecting threats in an urban port environment. Instead of trying to characterize highly improbable and deceptively “normal” looking anomalies, we encouraged students to begin the iterative process of characterizing normal maritime traffic. To that end, one of
our SRI students designed what might be the first database of the features that characterize all known vessel types, indicating whether and how those features appear to various detection technologies. Further, we applied findings from Cognitive Science and Human Computer Interaction to the problem of integrating information about maritime threats. Human decision makers need a single, coherent information source to make timely and reliable decisions. Another of our SRI students designed what might be the first integrated interface for the sensor technologies that our CSR colleagues have developed.

Specific Research Milestones:

In this section, we first enumerate the sub-tasks that we completed towards the goals (labeled as “goal”) that we explicitly stated in the Year 3 Proposal (1-5) and new goals (6-8) that we set in response to our ongoing efforts. As suggested below and as explained in the Year 4 Proposal, many of these high-level goals remain active (i.e. “in process”).

1. **Goal: Perform experiments on factors affecting tacit coordination**
   a. Experiments on dampening regional identity [DONE]
   b. Experiments on dampening gender identity [DONE]
   c. Design & pilot test power-conflict games [DONE]
   d. Design & pilot test measure of social-cognitive skill/ability (for h & i) [DONE]
   e. Adapt & pilot test reasoning tasks (for h-j) [DONE]
   f. Design & pilot test intention-reading task (for j) [DONE]
   g. Experiments on intention-reading [DONE]
   h. Experiments on dampening resource conflicts + Cognitive Reflection [IN PROCESS]
   i. Experiments on dampening regional identity + Cognitive Reflection [IN PROCESS]
   j. Experiments on dampening biases in intention-reading + Cognitive Reflection [IN PROCESS]

2. **Goal: Report experiments on factors affecting tacit coordination**
   a. Prepare journal report on dampening resource conflicts [DONE, under revision]
   b. Prepare conference papers comparing extant results (Society for Judgment & Decision Making) [DONE]

3. **Goal: Develop a game engine to support synchronous explicit games**
   a. Develop user validation system. [DONE]
   b. Develop game engine that connects the actions of 2+ players [DONE]
   c. Develop technologies to run games on Amazon’s Mechanical Turk and/or Facebook [DONE]
d. Design initial explicit/applied bargaining games (see 4-5) [IN PROCESS]

4. **Goal: Observe of relevant emergency response exercises**
   a. We continue to seek the opportunity to observe the process of designing or executing an emergency response exercises [IN PROCESS]
   b. **Absent that opportunity** we seek to examine specifications and/or reports of past exercises [IN PROCESS]

5. **Goal: Perform experiments on explicit bargaining games**
   a. In the absence of observational data, we adapted a natural-disaster response scenario based on curricular materials from Columbia University’s School of Social Work [DONE]
   b. Pilot team-selection task (from 5a) as a measure of Social Value Orientation [IN PROCESS]
   c. Design & pilot test resource exchange task (from 5a) based on “the battle of the sexes” [IN PROCESS]
   d. Refine and continue experiments on explicit bargaining games [PENDING TASKS 4a or 4b & 5b-c]

Goals not enumerated in Year 3 Proposal…

6. **Goal: Collect tweets on recent emergencies and events** [DONE]
7. **Goal: Design feature database for known vessel types** [DONE]
8. **Goal: Design integrated interface for sensor technologies** [DONE]

**Collaborations:**
In developing the game engine, we collaborated with colleagues in an NSF-funded project working on “Crowdsourcing Creativity.” We also collaborated with colleagues who are funded by the Department of Defense to collect and analyze data from Twitter.

**Future Plans:**
We will continue to investigate the ways in which perspective taking can reduce the impact of instrumental and interpersonal conflicts on the effectiveness of collaboration and collaborative decision-making. In addition to the distributive problems we have used before, we will increasingly use experimental game scenarios that relate to managing risks and detecting threats. For these new experimental scenarios, we will build on the work described in the above sections on Dampening Conflicts in Emergency Decisions and Dampening Conflicts through Dynamical Decision-Making. In this way, we will investigate how players coordinate their overall interests and efforts across several smaller conflicts. In Year 4, we are especially interested in when and why the process of coordination dampens cognitive biases and promotes decisions that yield a greater good. We hope to systematize the mechanisms of social rationality into protocols that DHS might use for more productive inter-agency negotiation and collaboration.
Project Objectives and Significance to Stakeholders

The Rapid Response Institute (RRI) led by Dr. Barbara T Reagor, Director, was established in 2004 to leverage the University’s extant software engineering, modeling, and simulation talent and research capabilities to support military and civilian rapid decision making to Prevent, Protect, Respond and Recover in the event of a homeland security, homeland defense or all hazard disaster events.

The Urban Coast Institute (UCI) led by Anthony Macdonald Esq., Director, was established in 2005 to facilitate the application of the available best science and research to address coastal and ocean policy issues and to leverage these applications in the development of Coastal Resilient Communities.

Together UCI and RRI support CSR relevant initiatives including the Summer Research Institute, workshops, outreach, and training.

Milestones Met

During Year 3 we have contributed to the CSR and its stakeholders in several areas.

- MU Faculty Participated in CSR Summer Research Institute in June 2011 to Present Emergency Strategies, Policies and Educational Outreach in Support of 2011 SRP Ports and Harbor Security Research;
  - Provided educational presentations and exercises for SRI Students on Emergency Management, Piracy Impacts to the Maritime Environment, Maritime Piracy and Policy Issues, Piracy and Terrorism the new connection, and Managing Military and Civilian Messaging
  - Previous MU High School Summer Researcher, Greg Sciarretta, Binghamton University, NY participated in the 2011 CSR Summer Research Institute and assisted in the development of the Magello Web Portal
- RRI continued the 2010 STEM Summer Research program for High School Students and High School Teachers to assist in the development of hazard resilient coastal community indicators and to create a framework to enhance stewardship, storm readiness and vulnerability reduction;
  - In July and August of 2010 (reported in Year 2 report) our students created a prototype web portal for Emergency
Preparedness, Emergency Management and Flood Prediction utilizing real-time sensor data (Floodview).

- Four high school students continued the development of the FLOODVIEW System and delivered it to the Monmouth County OEM (Office of Emergency Management) on December 10, 2010. Additional sensors have been added to the system. It currently provides flood weather and flood height data to 13 municipalities, and was used to initiate evacuations for Hurricane Irene.

- Assisted local communities’ adaptation strategies to address the climate change and sea level rise issues that impact our National Security.

- Continued to Work with CSR and their Stakeholders to identify user needs, societal benefits and improved links between coastal monitoring and ocean observations networks;

Our participation for the year included:

- Presentation at the Mid-Year Conference: January 11, 2011 in Honolulu, HI
- RRI/UCI Overview and presentation of Year 3 work to CSR and Summer Research Institute, June 15, 2010
- Faculty Research Mentor for Stevens CSR Summer Research Institute June 6, 2011 through July 28, 2011 at Stevens
- RRI Presentations and outside speaker coordination for the CSR SRI
- Participated in meetings at Stevens and conference calls as needed
- Continued the development of the Floodview web portal with high school students and delivered the system to Oceanport OEM on December 10, 2010. Students have continued stakeholders meetings and modifications.
- Previous MU High School Summer Researcher, Greg Sciarretta, Binghamton University, NY participated in the 2011 CSR Summer Research Institute and assisted in the development of the Magello Web Portal
- Ms. Lauren Landrigan has continued her PhD Research program at Stevens Institute (Current GPA 4.0) working for Dr. Jon Wade School of in support of RRI – Rises and Stevens – CSR
- Supported CSR through our collaborations and current programs

**Floodview**

During Year 3 support from CSR, RRI continued the development of the Floodview Web Portal with MU-UCI and Stevens and continued to leverage research funded by the US Army. The RRI applied research/education program has two main research thrusts: 1) the integration of technology components in innovative ways to satisfy a customer need by communicating directly with the customer to ascertain those needs and then forming a
systems solution, and 2) the use of emerging technologies as required components of the overall systems solution. This provides the ability to explore the implications of leveraging these technologies and integrating them with more mature technology components. A principal outcome of this program is training students to continue their interest in computer science and software engineering and develop a curriculum model for integration of stakeholder driven software design using emerging technologies.

One prototype addressed the display of real time and archival flood sensor data in the Shrewsbury River Basin. This visualization took the form of a prototype web site for Monmouth University’s Urban Coastal Institute to support citizens, emergency managers, and researchers. The prototype acquired the sensor data in real time and displayed the information in graphical and map-based modes. Useful information like evacuation routes and safety procedures were also provided. This prototype was dubbed Floodview.

**Project Description:** During fall of 2010 and spring of 2011, the Rapid Response Institute of Monmouth University worked with four AP high school students on further development of a Flood Detection Visualization Program. The program was intended to provide advanced training to these HS students in the University environment where students were to learn about technologies, systems perspectives, customers/stakeholders, teamwork, process in building systems, and prototyping. The final goal is to have students continue in STEM Careers in college.

The students worked with the Shrewsbury River Flood Warning System. This is a set of sensors that provides not only valuable but crucial information for the stakeholders: the general public, emergency managers, and researchers. It helps the public to take precautionary measures, evacuate, and/or view conditions. It helps the emergency managers declare evacuation and determine evacuation routes. Finally, it helps the researcher figure out flood trends. The warning system reads the sensor values, and the Flood Detection Visualization displays the information on a user interface so those who access it can interpret the information delivered.

**Description of Product/Research Results:** The High School students developed a website system that was delivered to Monmouth County on December 10, 2010 and is administered by the Office of Emergency Management, Oceanport NJ. Additional funding is being sought to enhance the product as a result of additional requests from the end user community. The purpose of Flood Detection Visualization was to deploy a website that displays current and expected flooding in the Shrewsbury River basin. There are five water level sensors and three meteorological sensors* deployed on local bridges which were:

1. Highlands
2. Oceanic*
3. Rumson*
4. Pleasure Bay
5. Gooseneck*

**Objectives for Floodview**
• Prototype a web site that displays data from five deployed flood sensors
  – Define users of the web site
  – Determine how they would use the web site
  – Determine how best to show the information the users need
  – Discover algorithms for predicting water levels and flood stages

• Users
  – Public
    • Take precautionary measures
    • Evacuate
    • Recreation conditions
  – Emergency Management
    • Declare evacuation
    • Determine evacuation routes
  – Researcher
    • Trends

System Architecture
Floodview Web Portal Shots Showing Live Data

The system is currently being used by Monmouth County OEM and 12 surrounding local municipalities in the Shrewsbury River Basin. It is being used for real-time emergency management planning, preparedness and evacuation recommendations. Additional research is planned to allow the sensors to predict flooding events and provide direction.
for the best evacuation routes. The system provides real-time decision support information for emergency managers in the Shrewsbury River Basin.

During Hurricane Irene’s march up the New Jersey Coast, Oceanport OEM used the Floodview System to order a Zone One Mandatory evacuation for Oceanport, NJ. The servers were hit by a power outage as shown due to wind damage in Monmouth County. But returned working when power was restored.

A demo view of the website system can be found using the link below. The login and password is oem. You must use Mozilla/Firefox as the web browser to launch the site. http://rises.monmouth.edu:8080/demo. The live system is password protected from view. A live civilian view is being implemented.

Year 3 Milestones

<table>
<thead>
<tr>
<th>Task</th>
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<tbody>
<tr>
<td>1. Support the CSR experiments with the Joint Mobile Command and Training Center</td>
</tr>
<tr>
<td>2. PI’s attendance at workshops and meetings</td>
</tr>
<tr>
<td>3. Coordinate RRI Research assets into CSR</td>
</tr>
<tr>
<td>4. Coordinate UCI Research assets into CSR</td>
</tr>
</tbody>
</table>

Task 1: The CSR exercise on a boat creating an explosion under the George Washington bridge never developed enough for the JMCTC Truck to participate. We diverted the small amount of funding to continue the support of the high school students to support further development of Floodview.

Tasks 2-4 where completed in full.

Collaborations - Leveraging Existing Programs: “RISES”

RISES Executive Summary

The Rapid Information Sharing for Event Decision Support (RISES) project examined cross domain interoperability in incident emergency response. The domains are the civilian, military and private sectors collaborating on large scale incidents. RISES looked at the future of incident response collaboration that involved the use of standardized data messaging as an integral element of that collaboration. In this data messaging aspect of
incident response, RISES looked at the general introduction of information technologies into this arena and the manner in which that should be done to enhance interoperability and improve the accuracy and timeliness of decision making.

The RISES team addressed this challenge through various types of research including traditional academic and industry sources, attendance at pertinent conferences, examination of the state of the art technologies in this arena, conversations with emergency management practitioners, and attendance at exercises of various kinds. This research resulted in an understanding of the state of the art, documented as part of this report, and the articulation of 21 Principles that should guide a RISES-informed system. Following this research the RISES team set out to demonstrate these principles through the conveyance of data messages in standard form across a Test Bed and observed in part via a Web Portal. This effort involved the delineation of a set of large scale scenarios composed of events in those scenarios that themselves would be characterized by a sequence of standard data messages. The messages were either CAP or EDXL-RM. Those messages were carried across Test Beds to demonstrate the RISES principles in two demonstration series. One was at the Coalition Warfighter Interoperability Demonstration (CWID) in June 2011, and a second in a RISES Test Bed in August 2011. The CWID exercise focused on military <> civilian interoperability while the August demos looked at private sector <> civilian <> military messaging via the Web Portal.

From this work RISES reached the following principal conclusions:

1. The adoption of standard messaging in incident response is a crucial element in achieving stable and persistent interoperability both intra and inter domain.
2. While standard messaging like CAP and the rest of the EDXL family are emerging, their introduction into use in actual incident response has a long way to go.
3. The broader use of CAP and EDXL standards in incident response in which many organizations would originate and receive messages requires another layer of agreements on how the fields in these messages would be used.
4. A Common Operating Picture (COP) is also a crucial element in effective interoperability.
5. CAP and EDXL messages should integrate with and drive a Common Operating Picture (COP) for use locally by all organizations as they wish.
6. The increased use of information technologies in emergency management will enable major strides in improving effective incident response. However, the management of these technologies and their effective use is a daunting task requiring close attention to ease of use, effective technology introduction, and close attention to change management.
7. There must be continued exercises and innovative means of training to achieve this vision of effective interoperability.
Moving forward the following are key areas to address:

1. The rapid implementation of standard data messaging by all three domains following the RISES Principles. For civilian IMSs this should be a requirement placed on vendors for their government products at appropriate stages of the data standards maturity. For military and private sector domains these standards should be implemented in systems with civilian governmental interactions.
2. The development of technology introduction plans that detail how specific technologies, like EDXL-RM, would be placed in the hands of those who would use them.
3. The development of training tools and methods to help introduce these technologies in effective ways with the prospect of infrequent real incidents and volunteer or part time users.
4. The establishment of technology management mechanisms, possibly on a regional basis, to support the system level deployment of information technologies and aid the addressing of ongoing interoperability incompatibilities and the ease of use of these technologies by practitioners.
5. Ongoing research and prototyping in value-add areas of the applicability of information technology in emergency management.

RISES Integrated Test Bed
RISES Web Portal

The Figure above shows the state of a Web Portal display for the Nuclear Detonation scenario. At the moment of this screenshot of the Web Portal, the first message of the third event of that scenario is depicted. The Event widget shows the three events to this point in the scenario. The message widget shows the current message for event ND07. This is the first message for that event, and more messages for that event would add to the Message widget as they are processed. The message displayed includes the type of Message like CAP as in this case.

The Web Portal prototype was easily the most complex of the several prototypes that were part of RISES. During its development interval of about one year, a total of seven students participated in the architecture, design and coding work. Thus more efforts at increased press were used in the Web Portal development. However, the basic iterative development model was used but with more discipline and intermediate stages. This began with some requirements being stipulated in the August 2010 time frame. These were use cases and some high level functionality. The requirements at this stage were about eight pages in length. To proceed beyond this point, agile development methods were used. A series of five Sprints were conducted from the late summer 2010 to early 2011. Subsequent to these Sprints there was a sequence of activities focusing on the Web Portal GUI. This utilized a sequence of flipcharts that captured user interface requirements at a detailed level. Some basic system testing was performed, but the bulk of the test effort evolved to be performing the RISES demos, which would be a complete system test case.
Trial 2.32 - Managing Military Civilian Messaging

Coalition Warrior Interoperability Demonstration (CWID)

Trial 2.32 - M2CM employed a mix of program of record, commercial, and S&T applications/tools to provide end-to-end communications. Military First Responders on scene and Military Stabilization Forces (NG, Army Reserve) operating an Incident Command Center (IOC) were able to generate and share United States Message Text Format (USMTF) or Allied Data Publication No. 3 (ADatP-3) messages with a Military Emergency Operations Center (EOC) running JPM Guardian's Decision Support Services (DSS) 5.0 and C2PC with Joint Warning and Reporting Network (JWARN). The USMTF and ADatP-3 military messages were translated into Common Alert Protocol (CAP) using the Remote Message Center (RMC) Translation Tool. The messages were then shared with the Civilian EOC via the Integrated Public Alert and Warning System (IPAWS) Open Platform for Emergency networks (OPEN). The representative civilian incident management tool, Disaster LAN, was used to issue alerts via CAP messages to Military and Civilian Emergency Operation Centers (EOC). The RMC was used to translate the CAP messages received from the Civilian EOC and pass the resultant USMTF and ADatP3 messages within military channels. Emergency Data Exchange Language (EDXL) Resource Messages (EDXL-RM) were also generated and shared using the RMC. Wireless networks, nuclear, biological, chemical and first responder
sensors, and common military and civilian planning tools were used to generate and share information. This allowed the team to play an all hazards response using messaging that is germane to either the civilian or military communities.

RISES
Rapid Information Sharing for Event Decision Support
(21 Principles)

1. Communicate with standards-based data messaging
2. Create messages used by both humans and processors
3. Support all incidents
4. Handle classified and unclassified information
5. Automate message transactions fully
6. Support by a full range of civilian/military networks
7. Accommodate all message types
8. Include private sector organizations fully
9. Support all civilian and military information management systems
10. Communicate to maximize trustability
11. Support standards based and legacy systems
12. Assume non-interoperability of systems
13. Support improvisation in incident response
14. Be organization and process agnostic
15. Utilize new information technology concepts
16. Effect information sharing using messages, displays, and alerts
17. Share identical incident status with all parties
18. Share critical information even if a criminal aspect is possible
19. Ensure easy to use technologies
20. Filter classified information intelligently
21. Derive a common operating picture from comprehensive information sharing.

The RISES Principles shown in red were demonstrated during CWID ’11. During the nine days of scenario play, Trial 2.32 – M2CM was successful in meeting the primary objective to demonstrate the exchange of information across a combination of existing military, civilian, and emerging S&T Tools. Role players from the DEARNG and New Jersey National Guard, after being trained on the various technologies (i.e., JWARN, JPM Guardian’s Decision Support Service 5.0, Disaster LAN, JWARN Remote Message Center, etc…), successfully generated, sent, and received CAP, EDXL-RM, and ADatP-3 messages using the Civilian and Military tools.

The RISES Test Bed and Web Portal were created as the basis for studying incident management interoperability among the three sectors. They were not created with a view toward productization but could be used for future applied research work particularly in some of the areas suggested in this section of the report. The most natural uses are in direct extensions of the RISES-type work. Specifically, it can be used as a Test Bed environment for evaluating aspects of interoperability based upon the use of standard data messages. In addition, it can be used to evaluate, demonstrate, and test aspects of proposed Technology Introduction plans.

Future Plans
In order to create and utilize effective decision support systems for the protection of our ports and harbors, all stakeholders must communicate rapidly and accurately to enable timely decisions to emergency events. Inadequate or failed communications have been at the heart of many problems in incident response and recovery, and have been documented thoroughly over the last few years. The Rapid Response Institute has been conducting research that addresses a specific aspect of this issue – the rapid sharing of information between Decision Makers (Federal, State, Local, Public/Private entities and the Military), and the first responder community. These same issues are faced by our Ports and Harbors and are being address by the research within CSR.

**Methodology**

We continue to build upon our Dynamic Information Visualization research work to directly support evolving CSR sensor systems. From our HS Summer Research Program (HSSRP) deliverables in years 1-3, we have developed two web portals that provide dynamic information visualization of data generated from the Stevens/Rutgers/UCI NJ Coastal Chemical Sensor program and the Stevens/UCI Shrewsbury River Basin Flood Detection program.

For CSR Year 4, we will research the sensor systems’ data being developed from the Satellite, HF Radar and Underwater Acoustics and investigate a web portal system to enhance rapid information sharing for event decision support.

**Benefits to DHS**

Our current research approaches includes; Rapid Information Sharing for Event Decision Support “RISES,” which is based on an end-to-end perspective of the realistic and detailed environment in which these critical communications will take place CSR research goals and initiatives. RISES is a project that demonstrates the future direction of interoperability among key organizational participants in major incidents. These organizations are the civilian government, military, and private sector. Technologically, the RISES focus is the leveraging of computing and data messaging. From an objectives perspective, the focus is on more rapid and accurate joint decision-making.

These MU activities allow for a strong connection from the CSR effort to the Federal and State and local first responder communities. The partnerships and information exchange developed herein are critical to ensuring that the work of the CSR is responsive to the stakeholder community’s needs.

As part of the US Army contracted work, RRI is continuing the sponsorship a PhD thesis student to support CSR goals that will explore the aspects of these messages from a trust and credibility perspective.

**Project Description**
Dr. Barbara T. Reagor, Director of the Rapid Response Institute, is the Co-PI and a liaison between the US Army research deliverables and the DHS CSR research community. We will continue to leverage our research finding in support of Cognitive and Resilient Port and Harbor Security specifically working within Decision Support Systems area.

Two Monmouth University Software Engineering graduate students will research the dynamic information visualization of sensor systems’ data generated from the Satellite, HF Radar and Underwater Acoustics programs and investigate the design of a web portal system to enhance rapid information sharing for event decision support.

Mr. Anthony Macdonald Esq., Director of the Urban Coast Institute and C0-PI, will continue to provide guidance and coordination on Coastal and Oceans Policy as it relates to Cognitive and Resilient Maritime Commerce in support of CSR.

**Leverage**

<table>
<thead>
<tr>
<th><strong>Rapid Information Sharing for Event Decision Support</strong></th>
<th>Provide key learnings, procedures and methodologies useful to CSR – provide assistance from professors and students.</th>
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</thead>
<tbody>
<tr>
<td><strong>Monmouth University’s Rapid Response Institute</strong></td>
<td>Director Barbara Reagor is a CO-PI and will leverage RRI’s Dynamic Information Visualization work on sensor integration and work with PSU-EOC on Harbor Sentinel and Data Base Systems Studies</td>
</tr>
<tr>
<td><strong>Monmouth University’s Urban Coast Institute</strong></td>
<td>Director Tony MacDonald is a CO-PI and will leverage the Coastal and Oceans Policy work of the UCI for Community Outreach</td>
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</tbody>
</table>
2. **Topics in Global Policies influencing MTS Security and Coastal Safety**

*Task 2.1 Resiliency Modeling (Enterprise Resiliency Modeling – Architecting Strategic Intent) Stevens Institute of Technology (Dr. Brian Sauser, PI) TRL 4*

**Project Objectives and Significance to Stakeholders**

For this research, we utilized a graphical systemic diagramming technique (i.e. Systemigrams™) to better understand and identify the significant elements within an enterprise (i.e. Small Vessel Security) and their inter-relationships captured in multiple and diverse expressions of stakeholder concerns and needs. This technique allowed for an initial enterprise-level concept of operation of small vessel security from which we can build models that will consider the perspective of stakeholders in the resilience planning of a maritime port enterprise.

This research focuses on meeting the needs of disaster victims during the critical time period immediately after a disaster strikes. It proposes the use of the enterprise constituents to close the gap between disaster requirements and response capabilities for small vessel security. A primary motivation for this work is that as identified in the DHS QHSR, “neighbor-to-neighbor assistance, when done safely, decreases the burden on first responders, individuals should be seen as force multipliers who may also offer specialized knowledge and skills.”

In Years 1 and 2 of this research we built upon the work of Dr. John Boardman by extending Systemigrams (i.e. systemic diagrams) and the Boardman Soft Systems Methodology as a graphical tool for articulating strategic intent for DHS challenges. We built Systemigrams for Resilience and Singapore Port Operations. In Year 2 we began efforts to understand how we can transition Systemigrams from static representation of stakeholders perspectives to dynamic and actionable models. Thus, in Year 3 we built upon the Systemigram modeling efforts as concepts of operation to begin to create models and simulations of port resilience in a small vessel security enterprise as influenced by enterprises constituents for effective emergency response and rapidity of recovery.

This research worked towards two deliverables:

- a. Systemigram CONOPS for DHS Challenges (i.e. Small Vessel Security Strategy, Resiliency Port)
- b. Figures of Merit for Operational Modeling and Simulation of the Maritime Port Enterprise

**Significance to Stakeholders**

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1. *QHSR, Pg. 60*
The key benefit of this research to DHS is a quantitative and qualitative understanding of the influence of enterprise constituents on the small vessel security enterprise for effective emergency response and rapidity of recovery. This is fundamental to developing security strategies and operational policy that considers the emergent, decentralized behavior (e.g. actions of spontaneous individuals) of the enterprise as a positive contribution to port service continuity. Thus, this research focused on the DHS Core Mission #5 as defined in the QHSR of “Ensuring Resilience to Disaster.” It considered this mission from the resilience perspective of not the centralized “top-down emergency management” but to that of the bottom-up decentralized “individuals, families, and communities.” As part of DHS Core Mission #5, this research had a primary focus on Goal 5.3 (Ensure Effective Emergency Response) and a secondary focus on Goal 5.4 (Rapidly Recover).

The long-term objective of this research is to align with the following strategic outcomes as identified in the QHSR:

- A standard for general community hazard mitigation is collaboratively developed and adopted by all communities.
- Individuals and families understand their responsibilities in the event of a community-disrupting event and have a plan to fulfill these responsibilities.

**Milestones Met**

This effort involved two research efforts (i.e. Systemigram Modeling for Enterprise Operations; and Operational Modeling and Simulation) executed in three phases:

**Systemigrams Modeling for Enterprise Concept of Operation (CONOPS):** As an enterprise model, Systemigrams can help identify organizational and communicational bottlenecks, provide stakeholders with the right knowledge about the architectural structure of the extended network of activities in their environment and equip system analysts with relevant information on understanding systemic issues with consideration of resilience factors. Having this kind of information about an enterprise is essential for effective governance, security management, and resilience. We utilized Systemigrams to capture systemic intent of port resilience for the small vessel security enterprise so we may better understand disaster recovery.

**Operational Modeling and Simulation:** The second effort of this research used quantitative modeling to investigate the impact (positive or negative) enterprise constituents could have to disaster recovery of the small vessel security enterprise. This can be used to observe the interactions with regards to enterprise constituents and how they may influence the small vessel security enterprise.

This approach built upon pervious work conducted by the PI, thesis work by Chen-En James Chou, and dissertation work by William Baldwin:

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2 *QHSR, Pg. 31*

Phase 1: Built a Systemigram CONOPS model of a DHS challenge as it related to port enterprise resilience, i.e. Small Vessel Security. Since Systemigrams can be used as a tool for capturing strategic intent of an enterprise, in a way that provides its stakeholders with the common ground for communication and participation in decision-making, we chose to model the DHS Small Vessel Security Strategy.

Phase 2: Data was mined from the Systemigram to begin to build a requirements set to develop Figures of Merit (FOM) for qualitative models. This allows us to begin to study the temporal and special characteristics of our Systemigram CONOPS. From this point we can execute simulations and collect quantitative data for understanding the dynamics of our CONOPS.

Phase 3: Incorporating Systemigrams with strategic intent, linking this with execution of tactical operations, and embedding resilient and agile principles and frameworks into enterprise culture and governance, with a goal to produce an industrial strength toolkit for designing resilient enterprises. Each year will build upon the previous in developing any methods, processes, or tools as they related to the governance of port enterprise resilience. Thus, Phase 3 is a spiral development in line with the long-term objectives.

Results

Systemigram Modeling for Enterprise CONOPS: We used the DHS Small Vessel Security Strategy (SVSS) as our baseline to better understand and identify the significant elements within the small vessel security enterprise. This includes the role of small vessel strategies to ensure the function of maritime transportation in the face of emerging threats and the ability to measure strategy outcomes in terms of security capability. As a result of this effort the Systemigram model represented in Figure 1 was created. For a more detail description of Figure 1 and the analysis see (Sauser, B., Q. Li, and J. Ramirez-Marquez. (2011). Systemigram Modeling of the Small Vessel Security Strategy for Developing Enterprise Resilience. Marine Technology Society Journal. 45(3):88-102).
Some key observations we made from this model can be observed when comparing the SVSS to the recently release DHS Small Vessel Security Implementation Plan: Report to the Public (the Plan) (DHS 2011). Generally, the Plan takes the DHS SVSS’s four major goals and their associated objectives and aims at providing more details on identifying related activities and how programs may be developed and coordinated to achieve these goals. If we interpret the SVSS Systemigram as an architecture of the SVSS, then we can use this as a framework to assess how consistent and coherent the Plan is in conjunction with SVSS by comparing the nodes and their underlying relationships and make key observation. Based on our analysis, the following observations were made about the Systemigram and the scenes (next page) that comprise the Systemigram:
Observation 1. A layered approach is adopted in the Plan to create defense in depth against the potential small vessel threats. Comparing this approach to the Systemigram reveals some potential issues not effectively articulated by the Plan:

a) The layered approach gives a clear chart of techniques and operational capabilities and the need to increase Maritime Domain Awareness (MDA) among the stakeholders. These can be mapped in the SVSS Scope and Small Vessel Risk where the definition of small vessel risks and four risk scenarios are also given by the SVSS. Though the adversary actions by small vessels are identified over time, the Plan does not provide an analytic method to assess
these risks, nor give any description of characteristics for each of the adversary actions. That is, as an overall method, it does not guide government agencies, which are supposed to manage the specific risks, how the risks would vary when adversary action changes over time.

b) From the Systemigram Small Vessel Community and the Major Goals A and D in SVSS, it is clearly stated that the small vessel community is one of the key components for the enterprise solution of small vessel threat; however, the Plan does not integrate this element when considering their interagency operations that support maritime homeland security. In Observation 4, we will discuss how this can be articulated as a paradox in the solution to small vessel security.

**Observation 2.** In the section of the Plan on “Goals, Objectives, Actions and Program Highlights,” the Plan states several objectives and suggested example activities for Major Goal A. Although the Plan gives detailed suggestions on how DHS and its components collaborate with the broad maritime community, current programs still have limits to the reporting ability of the small vessel community and the general public. They are also able to offer emergent medical treatment for victims, provide evacuation transportation vehicles, assist with crowd control and offer instant communication in the event of a small vessel attack. In related research, we have identified these participants and their actions as Enterprise constituents for enterprise solutions to homeland security (Baldwin 2010; Li, Sauser et al. 2011). Reporting suspect terrorist activities can be recognized as an effective way in the phase of prevention, while the other potential capabilities could also serve as flexible and timely resources in response strategies and should be considered as part of an enterprise solution.

**Observation 3.** The Systemigram, Relationship to Other Strategies and Plans, indicates that the SVSS complements and is consistent with applicable portions of the legislations and strategies, e.g. 2002 Maritime Transportation Security Act, 2005 National Strategy for Maritime Security and some other national security strategies. As a new enterprise implementation plan, it is necessary to check the coherence and applicability of the Plan with other DHS or national strategies. This could result in this scene having more detail in a later version.

**Observation 4.** The most interesting observation that the Systemigram revealed, that we do not believe was apparent in just reading the text alone, was the paradoxical tension that would exist in the realization of the SVSS via the Maritime Governance between the Maritime Security Partners and the Small Vessel Community. While Maritime Governance appears to be a construct that links these two constituencies, they have differing perspectives on the role of Maritime Governance. For example, the Maritime Security Partners define their success on a Unified Effort via the Maritime Governance as executed by effective risk mitigation. While the Small Vessel Community see Maritime Governance as distributed and believe that it is their autonomous behavior that empowers them, for which to relinquish their autonomy would be to lose their independence (Roblich 2009, December 9). In addition, Major Goal A states that the Maritime Security
Partners must develop and leverage partnerships with a community that does not function with the same perspective on Maritime Governance. What results is a paradoxical tension that will at this point render the current SVSS inoperable. This paradox demonstrates that in an enterprise, what we may believe to be the solution, can also be our problem. How does the small vessel community who may become our disruption also serve as our solution? This is not an organization problem but an enterprise problem for which the DHS has stated that our security solutions are enterprise solutions and we must find ways to engage all levels of the enterprise (DHS 2010).

In an enterprise founded upon structure and control, paradox is designed out, or mitigated via a rigorous risk strategy. We contend that the future of enterprise resilience resides in our ability to accept paradox as a norm of enterprise behavior. Paradox is an emerging area of research in systems and enterprises (Cameron and Quinn 1988; Lewis 2000; Lewis and Dehler 2000; Luscher, Lewis et al. 2006; John, Boardman et al. 2008; Baldwin, Sauser et al. 2010), and the advent of this in the systemigram was profound and encouraging. Paradox exists for a reason, and there are reasons to appreciate it. It will be our ability to govern, not control, these paradoxes that will bring new knowledge to our understanding on how to manage the emerging complexity of enterprises (Sauser, Boardman et al. 2008). For dealing with paradox, management and control is replaced by governance and openness. A key research question in our understanding of how to govern resilience is, “How can we consider something that is both a challenge and solution at the same time?”

Operational Modeling and Simulation: Based on the Systemigram model, we were able to put into context the DSH strategy on small vessel security. With that, human casualties, financial losses, environmental damages as well as the political impact that have been caused by some small vessel attacks has driven plans and strategies to fill the security gap in this area. The SVSS defined four typical small vessel threat scenarios: Domestic Use of Waterborne Improvised Explosive Devices (WBIEDs), Conveyance for smuggling weapons (including Weapons of Mass Destruction (WMD)) into the United States, Conveyance for smuggling terrorists into the United States, and Waterborne platform for conducting a stand-off attack (e.g. Man-Portable Air-Defense System (MANPADS) attacks).

As a byproduct of this strategy and a recognition of the potential benefits of enterprise constituents, there are a growing number of programs that have been launched with the focus of utilizing the public as an effective resource against the Small Vessel Threats: “America’s Waterway Watch”, launched by the US Coast Guard, engages the maritime and recreational boating community to report suspicious and unusual activities on the waterway; “Small Vessel Reporting System”, funded by the US Custom and Border Protection, is a web-based automated on-line reporting system to expeditiously report local boaters’ intended arrivals from foreign locations. Unfortunately, these programs only limit enterprise constituents into the area of detecting and reporting the suspicious small boat at the prevention stage while unable to provide better response strategies. In order to further address the Small Vessel Threats to the Maritime Port Enterprise, and to
advance our understanding of the challenge stated in 2010 DHS Quadrennial Homeland Security Review Report, a quantifiable model of the enterprise constituent influence within the context of a small vessel security scenario is highly applicable.

While we will not achieve exactly the same set of results from different types of threats, and much of the variation will be based on the nature and consequences of each scenario, we will explain the quantifiable results based on one of the threat scenarios of WBIED. Since a possible WBIED attack can be directed towards multiple types of targets, and a successful WBIED attack may broadly affect numerous networks, such as transportation networks, communication networks and supply chain networks associated with a certain port, the proposed model will focus on attacking a link within the scope of a ground-based transportation network for appropriate quantification purpose.

FOM of Transportation Network: Figure of Merit (FOM) is a quantitative measurement of performance for a device/system and is often adopted to effectively, though not necessarily to be complete, in describing the functionality of such device/system. To evaluate a transportation network, besides the most obvious index such as travel time and travel distance, there are several FOMs, which are commonly seen in literatures:

- Travel-time cost (Orabi, El-Rayes et al. 2009) – a flow-dependant metrics. Travel-time cost of each link is a function of traffic flow.

- Volume/capacity (V/C) ratio (Scott 2006) – a ratio of volume over capacity of a link that is used to evaluate congestion on certain links. The gamma index is a connectivity index that considers for a network the relationship between the actual number of links and the maximum number of possible links.

- Network Robustness Index (NRI) (Scott, Novak et al. 2006) – defined for evaluating the importance of a given highway segment (i.e., network link) to the overall system as the change in travel-time cost associated with rerouting all traffic in the system.

Resilience is becoming a useful FOM for network-level systems. Within the extensive literatures, there is no uniformed definition of resilience and it varies from case to case. For multicomputer systems (Najjar and Gaudiot 1990), resilience is defined as the number of failures that a system can sustain while service continues. Tierney and Bruneau (2007) suggest resilience for disaster response domain as the ability of social units to mitigate the results while carrying out recovery activities. For system and enterprises, Jackson (2007) describes resilience in terms of the ability of hardware and software system to reduce the likelihood of failures or losses. In the field of seismology and earthquake engineering, resilience (Cimellaro, Reinhorn et al. 2010) is proposed as a fragility function considering multidimensional performance limit thresholds. For a higher level of abstraction, Rosenkrantz, Goel, et al. (2009) categorize resilience FOM into Node Resilience and Edge Resilience based on where the disruptive event occur in a general service-oriented network. For transportation network, resilience (Ip and Wang...
of a node is defined as the weighted sum of the reliability of the independent paths between this node and all other nodes in the network. The overall network resilience is defined correspondingly as the weighted sum of all resilient nodes. However, many of these quantifications fail to capture the disaster effect throughout the complete cycle of response and recovery. Making an effort to be consistent with the basic meaning of resilience (Whitson and Ramirez-Marquez 2009), the proposed model is going to investigate transportation network’s intrinsic ability to “bounce back” by comparing the three statuses illustrated in Figure 2.

**Figure 2. System State Transition in Resilience**

- $S_0$: original state of the transportation network before a WBIED attack;
- $S_d$: degraded state of the transportation network as a result of WBIED attack;
- $S_f$: stable recovery state after resilience actions are taken to the system.
- $t_0$: initial time;
- $t_d$: time of entering $S_d$;
- $t_f$: time of entering $S_f$
- $\Delta_t = (t_f - t_d)$, as shown in Figure 2;

The influence of enterprise constituents could therefore become measurable by comparing the time differences $\Delta_t$ and the differences of selected delivery function for scenarios with and without enterprise constituents involved. Figure 2 can also be depicted as Figure 3 with consideration of delivery function $F(t)$.

With the given scenario, if the WBIED attack occurs on a link in the transportation network, with consideration on the need of disaster response, Shortest Path is selected as the FOM. Denote the transportation network as $G (N, A)$ where $N$ is a finite set of $n$ nodes and $A$ is a finite set of $m$ links. Each link $(i,j) \in A$ also has a weight (in distance) $d_{ij} \geq 0$.

For a given pair of source-sink nodes in the network, Shortest Path is the sum of the weights of its constituent arcs, denote as set $SP$. Suppose the WBIED attack occurs on any link in the $SP$ set, the system goes into $S_d$ and during the reparation of an attacked road, then the new set of $SP$ can be obtained. And the value of delivery function is the weighted sum of the new $SP$. There are several mature algorithms (Cherkassky, Goldberg et al. 1996) available to compute the Shortest Path(s). Dijkstra first made efforts in 1959 on efficient shortest path algorithm single-source single-pair networks with static and deterministic links. Bellman-Ford algorithm also aims at single-source network with consideration of negative weight on the link. Floyd algorithm while Floyd algorithm is
able to solve any given pair of source-sink nodes in the network. For a given land-based transportation network of a port where the distance of each link is known, once the source-sink is determined, corresponding SP can be obtained.

During the restoration of damaged road, a new link is selected as the temporary Shortest Path. Since the weight on the network is determined and other arcs in the network are either selected or not, instead of a smooth curve, the FOM shows as in Figure 4.

Collaborations
- Ali Mostashari, Stevens Institute of Technology (CSR, infrastructure resiliency)
- Roshanak Nilchiani, Stevens Institute of Technology (CSR, infrastructure resiliency)
- Jim Rice, MIT (CSR, supply chain)
- Michael Tortorella, Rutgers, The State University of NJ
Future Plans
The Year 4 effort for this research will seek to further increase our understanding of the various potential failure scenarios, and use through the use of our data, metrics and models understanding the tradeoff among different protection and restoration policies that improve the ability of the Port to withstand or “bounce back” rapidly in the presence of threats. As leverage in future plans, this work will capitalize research performed in the CSR that includes: 1) identification of port failure modes (by gathering input from port operators), 2) identification of potential threats, effects and restoration policies (by developing systemigrams) and, 3) developing resiliency models that allow quantifying system resilience.

Documentation
Publications resulting from this research:


Resources Leveraged
We have fostered relationships with the Homeland Security Institute (e.g. Drs. Charles Brownstein and Margaret Velardo), to better define the appropriate enterprise elements in our modeling efforts and assist in identifying other relevant stakeholders in the small vessel security enterprise.

References
Project Objectives and Significance to Stakeholders

The objectives of this project are based upon the first two year’s efforts and going beyond; Our research group aimed at developing a combined quantitative/qualitative framework allowing decision-makers to assess the resiliency of the maritime transportation system, while researched the concept of cognitive ports as port infrastructure with the ability to sense changes, assess potential strategies, implement responses and monitor the impact of the responses in the face of security and natural disaster threats. Such cognition capability will help ports adapt and recover quickly in the face of attacks or disasters. We have created Frameworks and methodologies for next generations of cognitive port infrastructures.

Milestones Met

The approach adopted included the development of a qualitative/quantitative model for maritime and port infrastructure systems resiliency with a focus on frameworks and methodologies for cognitive ports.

i) Cognitive Ports: Concepts, Methodologies, and Frameworks defined

A cognitive system is one that learns and adapts its behavior based on past experience and is able to sense, understand and respond to changes in its environment. A Cognitive Maritime and Port Security Enterprise Architecture will allow leveraging information technology and human resources to couple efficiency, security and resilience in a cost-effective manner. It will allow currently separate efforts in maritime domain awareness, emergency response and resiliency to be integrated and create significant synergies over time.
Figure 1: Cognition Centric System Capabilities

**Sensing** internal and external (local) system conditions

**Monitoring and Learning** from the consequences of the action

**Perceiving / Understanding** the (local/global) system state

**Implementing** action by adjusting resources and configurations

**Associating** the situation with past experiences

**Selecting** course of action for response to situation

**Trading-off** various alternatives

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**Figure 2 – Logical Architecture of a Cognitive System**

**SYSTEM PARAMETERS**
- Key Performance Parameters (KPP₁, ..., KPPₙ)
- Key Environmental Parameters (KEP₁, ..., KEPₙ)

**SYSTEM CONFIGURATION PARAMETERS** (SCP₁, ..., SCPᵢ)

**SYSTEM RESOURCE ALLOCATION PARAMETERS** (SRAP₁, ..., SRAPᵢ)

**SYSTEM CAPABILITIES**
- Synthetic & Abstraction
- Alternative Generation
- Tradeoff Analysis

**SYSTEM EXPERIENTIAL KNOWLEDGE DATA BASE**
- Case based reasoning
- Heuristics
- etc

**SYSTEM PRINCIPLES, RULES AND VALUES**

**EXTERNAL KNOWLEDGE SOURCE**

**CHANGE**
The cognitive behavior is achievable by designing the logical architecture shown in Figure 2. The Current System Parameters process senses changes in the system’s environmental parameters (SEPs) and their impact on the system performance parameters (SPPs). The SEP’s and SEP are collected by sensors and then passed to the System’s Capabilities process where all the sensor data is abstracted and synthesized in order to provide the first level of perceiving the change in the larger context. This process also compares the situation to potential past experiences and understanding what scenario may be unfolding. Based on the initial assessment, a set of responses are generated and evaluated in a tradeoff space. These responses consist of decisions that change the Systems Configuration Parameters (SCPs) and/or the System Resource Allocation Parameters (SRAPs). The result of this action is a change on the environment, which will then be monitored by the system through changes in the SEPs and/or SPPs. As time goes on, the Knowledge Data Base which contains the heuristic experiential data base of the system learns more about what responses work under what conditions and provides a more robust basis for abstraction and synthesis, alternative generation and tradeoff analysis. There is also learning from external knowledge bases, such as the experience of other similar systems elsewhere (for example other seaports), or through simulation and modeling exercises that serve as a learning basis for the system.

Cognitive architecting of port processes and the port enterprise improves the port performance and higher levels of cognition help improve the resiliency of the ports over time. Integrating the concept of cognitive processes into ports increases the probability of predicting threats, minimizes the impacts of shocks and improves response and recovery. A cognitive process has several capabilities and runs through the following cycle (Mostashari, 2009):

1. Sensing changes (internal and external)
2. Perceiving the data that is sensed and creating an image of it
3. Associating the current state with past states and acting accordingly if similar
4. Planning response alternatives to address the change within a given response timeline
5. Choosing a set of response alternatives based on trade-off analysis
6. Taking action by implementing the response alternatives
7. Monitoring and learning from the impacts of steps 1-6

These capabilities are realized by the Cognitive Processes Architectural Framework (CPAF) (Mostashari et al., 2011). This framework aims to architect cognitive processes and integrate them into the cognitive enterprise architecture as illustrated in Figure 3. The descriptions are as follows:

CPAF Stage 1 -- Cognitive Architecture
Step 1. Identify key performance parameters: This step identifies the key performance metrics of the system. These parameters describe the behavior of the system.
Step 2. Identify key environmental parameters: The key environmental metrics that should be measured in order to understand the environment are identified. Environmental parameters impact performance metrics.

Step 3. Design sensor network: The sensor network is designed in this step. The sensors measure the previously defined key performance and environmental metrics. Sensors might be human, technological or a combination of both.

Step 4. Develop scenario database: In this step, the scenario database is developed. The database is based on the information provided by the sensor network. The scenarios are divided into two groups: “baseline” scenarios and “change” scenarios. A baseline scenario runs in a system when the system is operating normally. “Normality” is defined by a set of performance and environmental parameters within a specific range. A change scenario occurs when the metrics do not fall within the normality range.

Step 5. Identify scenario-based response alternatives and actors: The final step of this stage of the CPAF is to identify the involved stakeholders and the response alternative(s) for each one of them.

CPAF: Stage 2 - Cognitive Processes

Step 1. Measure key performance and environmental parameters: The key performance and environmental metrics are measured.

Step 2. Identify closest scenario: Based on the results, the closest scenario is identified. This scenario may be baseline or change.

Step 3. Select response alternatives: Next, response alternatives from the database developed in the first stage are evaluated based on trade off analysis. If the scenario is new to the system, the intelligence component of the system suggests response alternatives and this is the case where human/stakeholder intelligence is critical.

Step 4. Implement response alternative: When the response alternative is decided, it is implemented.

Step 5. Monitor impact of response alternatives: The key point that allows cognition to happen is monitoring. After implementation, the results are observed.

Step 6. Cognitive architecture revision: Based on the results of the monitoring phase, revision of the first stage of the CPAF might be required. Examples of this revision include: adding new metrics, scenarios, response alternatives or actors.

Step 7. Go back to step 1 of stage 2: Lastly, the performance and environmental parameters are measured again and the process goes on. This measurement might lead to the perception that the change scenario has turned into baseline.
Step 3. Design sensor network:

Designing a sensor network for a port is challenging especially when it comes to security issues. The first step of the cognitive process is to sense the environment. Sensors provide data for perception, decision making and action. Therefore it is crucial for ports to design effective sensor networks. Whatever the architecture of the sensor network is, it has two sub-networks: the network that all stakeholders are allowed to access and the network that are available to certain actors. Stakeholders might be able to change the sensor data or might be able to read them only. The sensors could be categorized based on their location, functionality constraints, functionality agent, process level, mobility and technology. The network shall be secured, connected/integrated and flexible. Table 1 names examples of the sensor categories.
Future Work

- Development of Advanced Network Model for International Maritime Transportation System with Pacific Ports as an in-depth Case Study
- Development of a Cognitive Integrated Architecture for Port Infrastructure Enterprises
- The research on cognitive and resilient port infrastructure systems and enterprises will also look at the human aspects of response including information and data sharing interfaces that allow responding units to monitor and respond to situations of interest.
- The design requirements for graphical user interfaces that incorporate understanding of decision-making under stress will also be explored.
- Risks and threat scenario databases for the cognitive port systems will be explored and integrated into the cognitive response.

Publications:

Task 2.3 Port Resilience Project (Note: there are two PIs on Task 2.3, M. Mattingley, The Mattingley Group; and J. Rice, MIT) TRL 6

Task 2.3, Project 1. The Mattingley Group, LLC (M. Mattingley, PI)

Project Objectives and Significance to Stakeholders

MG Group seeks to leverage its expertise in port and supply chain security to improve the ability of US ports to provide and maintain an acceptable level of service in the face of major changes or disruptions. A key objective is the development of methodologies that ports can use to evaluate their resilience and strategies for port authorities to improve their resilience. This will include the identification and prioritization of issues and failure nodes by port authorities and stakeholders in coordination with the CSR Team. In addition to relying on sensors and technologies, resiliency can be enhanced through increased adaptive capacity and building redundancy into the design and operation of ports. To achieve this objective, ports must be seen as a network of physical nodes with multiple layers that include freight processing, customs and immigration, and freight intermodal connection systems. Such a systemic view provides a large degree of flexibility and combination of response alternatives, adding to the resilience of port operations design and management. MG Group will assist in the preparation and development of such policies through direct and indirect interaction with port and supply chain stakeholders.

Milestones Met

a. Continued literature review and analysis for lessons learned of real-world port and supply chain disruptions. This effort built upon the Year 1&2 reviews. Particular emphasis was devoted to the Japan earthquake and tsunami of March 2011. Other notable disruptions included the Icelandic volcano and its effect on European port and supply chain operations; the Mississippi River flooding and its impact on inland ports and waterways as well as on highways and railways; the Deepwater Horizon Oil Spill on port and supply chain operations in the Gulf. Focus included effectiveness of preparation, response, and recovery plans; impact of disruptions on port capacity; rail and road infrastructure; ship diversion to alternate ports; public safety issues; restoration of police, fire, and medical capabilities; evacuation and temporary housing concerns; debris removal/cleanup; business loss and unemployment; economic recovery; and mitigation measures to address these issues.

b. Continued analysis of statutory and regulatory laws and regulations impacting port resiliency capabilities and effectiveness. Topics were selected for potential impact on port authorities and stakeholders to effectively manage their responsibilities. Representative reviews included SAFE Port Act; Maritime Transportation Security Act (MTSA); Port and Waterways Safety Act; Port and Tanker Safety Act; Convention for the Safety of Life at Sea
(SOLAS); International Ship and Port Facility Security Code (ISPS); Jones Act; 96 Hour Advance Notification of Arrival in US Ports; 10+2 Filing Requirements; Port Hours of Service Rules; US Visa Requirements for Foreign Ship Crewmen; USCG Vessel Inspections Program; US Government Cargo Inspection Programs; Petrochemical Shipment Restrictions. Review expanded to include Function of Marine Transportation System Recovery Unit (MTSRU); USCG Command and Control Authority for Directing Vessel Movement; US Container Security Initiative; ISO Standard 28000 for Port Security Principles; and Presidential Policy Directive 8 on National Preparedness. These issues were addressed in exchanges with port authorities, terminal operators, vessel carriers, shippers, freight forwarders, etc, to assess the impact on the impact on delays in port operations attributable to Government policies and enforcement actions.


d. Continued to analyze and refine the initial draft survey instrument as part of a team under the overall management of MIT. Discussed findings and sought feedback through coordination with trade associations such as the American Association of Port Authorities and CSR advisors such as the Port Security Manager for the Port Authority of New York/New Jersey. Determined concerns, actions, trends, challenges for port operators, shippers, carriers, importers, trade associations, port authorities, local government, etc., for application to future research efforts, field visits, and a follow-up survey instrument to address these issues.

e. Contributed to update of port capacity study to determine traffic volumes for selected ports and ability of alternate ports to absorb additional traffic in event of a major port disruption with focus on operating hours, labor issues, intermodal capability, cargo types and specialized handling requirements, vessel configuration and dockside crane capabilities. Recommended expansion of scope of port capacity review to include inland ports and waterways.
f. Assess status and refine scope of failure mode analysis to identify supply chain vulnerabilities to disruptions, impact on port operations, communications, infrastructure, personnel.

g. Coordinated on field visit to Ports of Seattle and Tacoma to benefit from lessons learned in real-world port operations, review port disruption historical events and impact on critical systems, review stakeholder agreements for consultation and cooperation, port recovery plans, decision-making processes and authority. This builds upon previous field visits to the ports of Los Angeles, Long Beach, Hueneme CA, Houston, Boston, and New York/New Jersey. These visits provided insight into the current perceptions of the maritime community regarding resilience, the impact of state, federal, and local laws and regulations on port operations, causes of port disruptions, resolution of such disruptions, and the average length of such disruptions.

h. Established dialog with the Committee on the Marine Transportation System (CMTS). Our research on port resiliency has progressed to a degree where it is appropriate to begin coordination with those who will be end-users of the findings of the study. The number of agencies and organizations with responsibility in the Marine Transportation System renders individual coordination inefficient and redundant. CMTS, with its unique responsibility as coordinating body for 18 such Federal agencies involved with MTS issues, is a potential forum for this effort. Initial discussions were held to brief status of the research study and to map out future coordination. The Transportation Research Board of the National Academies was also identified as a conduit for disseminating findings and feedback.

i. Much of the study focus to date has been on the traditional coastal port geography. Having addressed that sector in our field visits to date, we are now adjusting our focus to expand our research to the US inland waterways and ports to ensure we capture the issues of this important segment of maritime commerce. Forty-one states, including all states east of the Mississippi River, are served by commercially navigable waterways. The U.S. inland waterway system consists of 12,000 miles of navigable waterways serving forty-one states, including all states east to the Mississippi, in four systems—the Mississippi River, the Ohio River Basin, the Gulf Intercoastal Waterway, and the Pacific Coast systems. The American Society of Civil Engineers has stated that “the current system of inland waterways lacks resilience.” Waterway usage is increasing, but facilities are aging and many are well past their design life of 50 years. Recovery from any event of significance would be negatively impacted by the age and deteriorating condition of the system, posing a direct threat to the American economy. Of particular interest from a resiliency perspective is that the system includes 257 locks. Forty-seven percent of all locks maintained by the U.S. Army Corps of Engineers were classified as functionally obsolete in 2006. Assuming that no
new locks are built within the next 20 years, by 2020, another 93 existing locks will be obsolete—rendering more than 8 out of every 10 locks now in service outdated.

j. Examined the need for a follow-on port resilience survey (subject to data collection needs after Q3) and determined that it is not a current priority.

Field visits will be conducted to selected inland ports in the same manner in which coastal ports were visited. Data gathered during these visits will be evaluated against the previously gathered coastal port data to validate the issues common to both as well as those unique to inland ports.

**Collaborations**

a. Port Authority of New York & New Jersey
   i. Identification of port operations, processes, and systems vulnerable to disruption with Marine Transportation System Recovery Unit (MTSRU).
   ii. Enhance understanding of the dynamics of port operations as they relate to resiliency.
   iii. Discuss results and findings of initial survey instrument to refine focus for follow-up survey.

b. Massachusetts Institute of Technology
   i. Perform field visits to Ports of Seattle and Tacoma.
   ii. Analyze survey instrument to identify and prioritize issues of maritime transportation system.
   iii. Develop supply chain failure mode analysis
   iv. Develop port capacity study

c. University of Minnesota
   i. Draw upon lessons learned by National Center for Food Protection and Defense

d. US Coast Guard
   i. Identification of port resiliency issues
   ii. Responsibilities of the Captain of the Port
   iii. Implementation and enforcement of Safety and Security Zones
   iv. Command and control authority in directing vessel movement within US territorial waters and navigable waterways
   v. Interagency Operations and Planning with Maritime Security Stakeholders

e. University of Arkansas
   i. Draw upon lessons learned by Mack-Blackwell Rural Transportation Center.
   ii. Review intermodal transportation system security issues.
f. Committee on Marine Transportation System (CMTS)
   i. Discuss progress and findings of port resiliency study
   ii. Communicate with end-user customers through CMTS

Future Plans
1. Continue review and analysis for lessons learned from real-world port disruptions
2. Continue review of laws and regulations impacting port resiliency capabilities and effectiveness
3. Continue effort to define maritime supply chain operations in terms of failure modes to identify vulnerable points and devise mitigation strategies
4. Refine port capacity study to determine ability of maritime system to absorb port disruptions
5. Refine and validate survey of port resiliency issues
6. Accomplish additional port visits for representative sampling of port resiliency issues
   • Adjust focus to inland ports and waterways
7. Continue collaboration efforts to include University of Southern California and National Center for Risk and Economic Analysis of Terrorism Events
8. Continue collaboration efforts to include University of Maryland and National Consortium for the Study of Terrorism and Responses to Terrorism
9. Expand collaboration efforts to include University of Arkansas Mack-Blackwell Rural Transportation Center.
10. Communicate study progress to end-use customers to include the Committee on Marine Transportation System (CMTS) and Transportation Research Board (TRB) and select industry trade associations
11. A planned Port Resilience Event was delayed in order to maximize the effectiveness and impact. We have tentative plans to organize an event focused on resilience in 3Q 2012.

Documentation:
6. US Government Accountability Office, “DHS Should Test and Evaluate Container Security Technologies Consistent with All Identified Operational Scenarios to Ensure the Technologies Will Function as Intended,” September 2010

Resources Leveraged:
1. Port Authority of New York & New Jersey
   i. Provided first hand experience on development of port recovery plans
   ii. Provided real world expertise on port disruption scenarios
   iii. Provided lessons learned on first response capabilities, stakeholder coordination and involvement, dealing with multiple political jurisdictions, and business continuity

2. Massachusetts Institute of Technology Center for Transportation and Logistics
   i. Provides expertise in supply chain efficiency and security studies
   ii. Provides extensive background in data analysis and modeling and simulation capabilities
   iii. Capability to bring research resources to bear on resiliency issues and identify mitigation strategies

3. Port of Seattle
   i. Identification of port operations, processes, and systems vulnerable to disruption.
   ii. Enhance understanding of the dynamics of port operations as they relate to resiliency.
4. Port of Tacoma
   i. Identification of port operations, processes, and systems vulnerable to disruption.
   ii. Enhance understanding of the dynamics of port operations as they relate to resiliency.

5. University of Minnesota - National Center for Food Protection and Defense
   i. Draw upon experience in reducing supply chain vulnerabilities
   ii. Identify similarities between strengthening resiliency in maritime supply chains and food supply chains
   iii. Compare mitigation efforts to minimize impact of disruptions through effective response and recovery measures

6. University of Arkansas – Mack-Blackwell Rural Transportation Center
   i. Provides expertise on security of the intermodal transportation systems of the United States at the local, state, and national levels.
   ii. Develops solutions for solving critical scientific and technological issues related to transportation security
   iii. Evaluates research and develops technologies to protect US transportation networks
Project Objectives and Significance to Stakeholders

The project objectives for Port and Supply Chain Resiliency research continue as follows:
1. Identify critical processes and systems of the MTS that need to be resilient
2. Identify methods for making critical MTS processes and systems resilient.

These objectives remain significant to the key CSR stakeholders. There is meaningful evidence indicating that the economic security of the United States is dependent upon the effectiveness and efficiency of the maritime transportation system. Failure of the maritime transportation system would likely have a significant impact on the US economy.

With the economic downturn that started in 2008, cargo volumes have dropped, resulting in lower utilization rates among the various throughput systems used in ports. This implicitly means that these systems have additional unused capacity, which in turn makes those systems more capable of handling disruptions – therefore, the downturn has helped make the systems more resilient. Yet, operating businesses will work to shed unused and underutilized capacity, which will reduce that resilience that may be derived from excess capacity. These variations in capacity utilization will continue over time and therefore operators cannot depend heavily on economic downturn to provide resilience for their systems. The need for port resilience remains.

Our year 2 work initiated the first known assessment of port capacity in the US. Our work in Year 3 further examined port capacity under varying conditions – specifically lower economic activity during the years 2008-2009. As we have come to recognize, the US economy is dependent upon global trade – imports and exports – in order to maintain the US economic productivity. It therefore continues to be important to understand how to make the US ports capable of handling various disruptions to maintain economic activity.

Milestones Met

i. Port Resilience Survey

Progress
In year 2, data collection for the port resilience survey was completed and initial analysis was conducted. The intent of the survey was to provide an initial assessment of the experience of port actors as well as the opinions of those port actors regarding the need and best methods to achieve resilience in ports. The survey was the first of its type to solicit input on the port resilience.
The on-line survey collected responses from 525 shippers, carriers, terminal operators, port authorities, third parties, freight forwarders and others operating in the port environment. The largest distinct respondent group was shippers (123). Carriers and terminal operators were also well represented in the survey (see graph below).

In year 3, the initial analysis was documented and prepared in an unpublished white paper. The insights will be shared with the survey participants and in particular, the observations will be a useful source for the Year 4 effort to identify potential methods to make ports and port operations resilient.

Also in Year 3, a second round of analysis was conducted. Because the survey was not developed with specific constructs in mind, additional insights from the survey were mined by using the Structural Equation Modeling (SEM) method to extract respondent intentions from the survey. The SEM analysis entailed several stages of analysis that included exploratory factor analysis using the 29 coded question areas, and then associating these coded questions with others that may contribute to resilience. The analysis and documentation are to be completed September-October 2011.

**Observations/Contribution**
The Port Survey achieved its objective of providing a useful foundation of understanding of the experience and perspective of port actors regarding disruptions and resilience. The
survey helped further identify the needs of the different parties involved in port operations and impressed the need for defining port resilience considering the different perspectives – the port authority, terminal operator, carrier, and shippers will each have different perspectives on what constitutes port resilience.

**Critical Actions for Reducing Impact of Disruptions**

The total respondent pool overall provided a unanimous assertion that virtually all port operations and systems were critical for resilience. When asked which were the most important actions to reduce the impact of disruptions in ports, the total respondent pool identified two key areas – communication / information systems, and flexible labor agreements were identified. These responses vary significantly by respondent type as noted below:

<table>
<thead>
<tr>
<th>Most Important Actions to Reduce Impact of Disruptions on Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Op</td>
</tr>
<tr>
<td>Flex Labor</td>
</tr>
<tr>
<td>Flex Intra Port</td>
</tr>
<tr>
<td>Flex Inter Port</td>
</tr>
<tr>
<td>Terminal Equipment</td>
</tr>
<tr>
<td>Intermodal Connections</td>
</tr>
<tr>
<td>Gate Ops</td>
</tr>
<tr>
<td>Waterway Ops</td>
</tr>
<tr>
<td>Maritime Transportation</td>
</tr>
<tr>
<td>Comm/Info Systems</td>
</tr>
</tbody>
</table>

This highlights the very different perspectives of the various parties, and may illustrate the different perspective on what constitutes a resilient port. For example, the terminal operator is traditionally focused on reducing costs in operations, and therefore may view flexible labor agreements a critical need that may not have a comparative cost impact (all terminal operators must use the same labor at the same cost structure); terminal operators however bear the distinct cost of additional capacity that comes at a literal high cost to the operator. Considering the time of the data collection – 2009-2010 when cargo volumes and capacity utilization were dropping, it makes sense that the terminal operator may focus just on the exogenous flexible labor agreement. Shippers on the other hand place the ability to receive their cargo as the highest priority and therefore would identify all those capabilities that would further enhance their ability to get their cargo in a port disruption – that would include the flexible arrangements in ports, more capacity at intermodal and gate operations. Again, this suggests that analyzing the needs to make a
port (all the operations and parties operating in the port) resilient requires considering the perspective and needs of those different parties.

Experience of Delays in Ports
The respondents provided their observation and experience with delays in 28 different subsystems across three areas of operation within the port – terminal operations, intermodal connections and waterway operations. Few reported delays outside their primary focus area/interface (e.g. shippers experienced delays at the intermodal connections, terminal operators reported delays in terminal operations and carriers reported delays in waterways). Approximately half of the respondents reported incident frequency annually or less frequent. But approximately a third reported incidents quarterly or more frequently in many of the 28 subsystems. While the probability of experiencing a delay in any one of the 28 subsystems is relatively small based on the survey input, the probability of a disruption at any of the 28 subsystems is not small – potentially as frequent as a delay-creating incident occurring nearly every other week. The finding that delay incidents occur somewhere in the MTS as frequently as every other week might lead to the conclusion that the MTS is neither an effective nor efficient operation. Another interpretation that seems more likely is the opposite – there is no evidence to suggest that US ports are not effective in receiving cargo and transferring the goods to other modes of transportation. In comparison with other parts globally, US Ports are not the most efficient with some below-par cycle times for cargo through put, and delays ultimately add cost to any cargo system. But the collection of loosely coordinated, independently operated port entities seem to effectively move cargo from waterborne modes to truck and rail (and vice versa) without crippling delays. The overall supply chain and system seems to have accommodated the efficiency of the system such that the ports in the US are apparently effective. Do the delays hurt some companies? Invariably the answer is yes. Do they significantly hurt many companies? The data suggest that the answer is no. This appears to be the case for all disruptions short of those where infrastructure is destroyed.

Role of Government Regulation
The respondents were asked to provide their opinion regarding the impact of regulations on delays within ports and on port resilience. The results were fairly evenly spread, with some respondents indicating that regulations have a favorable affect on port resilience and more indicating an unfavorable affect on port resilience. Two thirds of the respondents suggested that government regulations had a slight impact on delays in ports, particularly 10+2 and cargo inspection requirements, and hours of service rules. Perhaps more interesting, the survey team received many qualitative comments regarding these questions. Some respondents suggested that the government (and by implication, government policies) plays an important role in enabling commerce in ports. Some called for ‘more US Customs Involvement within the Port,’ improvements in inspection facilities, staff and processes, and greater coordination and integration among the various US government entities operating in the port environment. On the surface it seems surprising that private enterprises would call for more government involvement in their industry. However, these responses reflect a general recognition that government does
play a critical role in enabling trade in ports and impacts efficiency since official agencies can prolong cargo clearance processes. It is not unreasonable to interpret the comments as a call for the government to make necessary regulatory processes more efficient and smooth, and to permit individual entities to perform their roles without undue delay or interruption.

ii. US Port Capacity Study

Progress
In year 2, the MIT Port Resilience Team initiated a study assessing the ability of the 310+ ports in the US to handle disruptions. Two approaches were used, building off of publicly available data, primarily from the Army Corps of Engineers (ACOE) database of port volumes through 2007. The first analysis identified the distance and the average number of stops required to relocate the volume (this only applied to the volume in port at the time of disruption). The analysis concluded that the ports do not have capacity to withstand a disruption at the largest ports. The second analysis sought to identify the maximum current capacity utilization in order for the remaining ports to absorb the volume from any one port closure. For each commodity class, a calculation was made of the maximum level of capacity utilization of all other ports serving that commodity class in order for the remaining ports to absorb the displaced volume. This analysis revealed that for each commodity class, a surprisingly low level of maximum capacity utilization was required in order for the undisrupted ports to be able to handle the displaced volume.

In Year 3, the study was updated using a more current data set, analyzing the more current ACOE data/trade volumes from 2008-2009. The data set included different data for the port volumes (some of the port volumes were consolidated/deconsolidated in the updated set), and the list included a different set of ports as well. This required some preliminary work to restructure the data sets to enable comparison between the two data sets. A comparison of 2006-2007 against 2008-2009 was desirable to reflect the capacity constraints and concerns associated with lower economic activity that became more evident in 2008-2009.

Observations/Contribution
Because of differences in how the ports are classified by the ACOE data, results have changed between the (pre-2007) initial and the current study (2008-2009). The changes in general reflect a lower capacity requirement because more ports have been added to the system that were originally included as part of aggregates (as seen in the chart below). As a result, the minimum capacity requirements are generally lower than in the original study.

Though cargo volumes have generally decreased between 2006-2007 and 2008-2009, the relationship of the largest ports to the system total has remained relatively consistent. This is shown in the stability of the capacity requirements between the two numbers.
In general capacity requirements were higher in 2006-2007. This can be seen in the lower capacity requirements when 2008-2009 numbers are applied against a base of 2006-2007 numbers. In general the increase or decrease falls within a 2-5% range. This suggests that volumes have decreased for the system as a whole, but that small ports are likely to have experienced a greater reduction in cargo volumes than larger ports.

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Top 3 Ports for the commodity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Los Angeles, Long Beach, NY/NJ</td>
<td>25%</td>
<td>26%</td>
</tr>
<tr>
<td>Chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Houston, South Louisiana, Baton Rouge</td>
<td>29%</td>
<td>23%</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Mobile, Pittsburgh, Hampton Roads</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Food and Farm Products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: So. Louisiana, New Orleans, Plaquemines</td>
<td>58%</td>
<td>50%</td>
</tr>
<tr>
<td>Manufactured Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Los Angeles, NY/NJ, Hampton Roads</td>
<td>26%</td>
<td>18%</td>
</tr>
<tr>
<td>Manufactured Goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Houston, South Louisiana, Los Angeles</td>
<td>11%</td>
<td>7%</td>
</tr>
<tr>
<td>Petroleum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Houston, NY/NJ, South Louisiana</td>
<td>18%</td>
<td>16%</td>
</tr>
<tr>
<td>Raw Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Duluth-Superior, NY/NJ, So. Louisiana</td>
<td>7%</td>
<td>5%</td>
</tr>
<tr>
<td>Waste and Scrap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: Port Arthur, South Louisiana, Vancouver</td>
<td>81%</td>
<td>46%</td>
</tr>
<tr>
<td>All Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top 3 Ports: NY/NJ, Los Angeles, Houston</td>
<td>23%</td>
<td>16%</td>
</tr>
</tbody>
</table>

As the economy has changed, the ranking of the top ports has changed. In some instances, this is a reflection of the type of cargo handled – a prime example is the change
experienced at Hampton Roads which saw its cargo volume increase, likely as a result of increased military cargo movements.

Overall the study shows that the configuration of the US port system has not changed very much over the past four years. The largest ports remain the largest ports, and ports that handled large volumes of particular cargos continue to do so. Overall, though volume has decreased, the capacity requirements have not altered significantly most likely as a result of the "stickiness" of cargo to be directed towards the same destination ports.

The important take-away from this analysis is that the US system of ports is not capable by itself to handle the volumes that may be displaced if any of the large ports are disrupted for an extended period of time. There are other non-domestic US options for bringing cargo into the US, including through Mexico and Canada. In fact, some volume of cargo already enters the US through Mexico and Canada; it is not clear however whether those ports in Mexico and Canada would be able to handle enough additional volumes to avoid significant delays and costs associated with rerouting cargo flows to different destinations.

iii. Framework for Port Capacity Analysis

Progress
In Year 3, Dr. Ioannis Lagoudis of the University of the Aegean joined the MIT Center for Transportation and Logistics as a Visiting Scholar and worked on the MIT Port Resilience Team during his visit. He conducted his work with James Rice and together focused on developing a unique theoretical approach to calculating port capacity. Their research indicated that a systematic approach to calculating capacity from waterway through terminal through intermodal connection had not yet been conducted.

Observations/Contribution
The study takes into consideration the multiple links in the port – from waterway through terminal through intermodal connection – and created a format for quantifying the capacity in the port. This included looking at capacity for each of the three noted core port operations. A paper was prepared on the method – “Revisiting Port Capacity: A practice method for Investment and Policy decisions” – and was presented two important conferences in recent months (Specifically at ECONSHIP in Greece in June 2011 and also at Global Supply Chain Security Conference 2011 in London, England in July 2011.

This paper and analysis can be useful for making a quantified assessment of the capacity within a specific port and can be helpful in identifying the critical elements necessary for system resilience. Traditionally large systems are considered when identifying critical systems and processes, but smaller systems are overlooked. Ultimately all systems are necessary for performance and this method provides a comprehensive analysis in detail
that can highlight all necessary capacities for effective operation. This will be useful in a business continuity planning (BCP) process for designing and planning for resilience.

iv. Port Case Study Database Disruption Case Listing

**Progress**
In Year 3, the Port Case Study Database was expanded. It includes a listing of over 55 disruptions that affected port operations. The data came from public sources and also from interviews and discussions with industry participants. An analysis of the impact of the East Japan/Sendai Disaster was conducted, with initial study of the impact of the disaster on port operations.

**Observations/Contribution**
The database will become more useful as several of the case examples are expanded in detail. Going forward, data will be collected on several specific disruptions and the potential insights on how the port was able to respond and recover; in short, how the port demonstrated its resilience and the potential key success factors for creating that resilience. This included work understanding the impact of the great East Japan Sendai Earthquake/Tsunami and Fukushima Nuclear Plant meltdown that ensued. A number of ports suffered various types of damages and ‘after action’ learning reports and analysis may provide useful guidance and insight into port resilience in action. Additional work is necessary to understand the impact as well as the actions taken and design characteristics of the ports that exhibited resilience in their performance.

v. Ocean Conveyance/Port Delay Study

**Progress**
In Year 3, the MIT Center for Transportation Studies initiated a study (Global Ocean Transportation Project) at the request of a major automotive OEM. The study utilized ocean conveyance data from the automotive OEM, and was intended to understand the role of delays along the supply chain, with particular focus on ocean conveyances and the sources of delay and variation along the supply chain. The nature of the work and research was related to the dynamics in port systems and port operations, and has since provided some useful insights that may be valuable for the study of port resilience.

**Observations/Contribution**
The Global Ocean Transportation Project study analysis suggested that ocean conveyances were actually the most reliable leg of the five-leg journey from point-of-origin to point-of-destination. [The five legs of the supply chain are considered conveyance from production source to port terminal, through port operations, ocean conveyance, through port terminals/operations, conveyance from port terminal to point of distribution]. The leg within the port tended to be the leg with the most variation. This is
an important observation as common wisdom held that the ocean conveyance leg was the major source of variation. Given this, it is important to understand the sources of variation for throughput time in the port terminal (inbound and outbound) in order to understand and improve the terminal’s ability to add resilience to their system. Some research studies have identified several reasons for delay, and one study indicated the top five reasons explaining 98% of schedule unreliability (in descending order of incidence): port/terminal congestion, productivity below expectations (loading/discharging), delay due to weather or on route mechanical problems, delay in port channel access (pilotage, towage), and delay in port channel access (tidal window).³

In the Global Ocean Transportation Project study, nine specific causes of delays explaining 99% of schedule delays were identified based on 10 months of shipments into North American ports (in descending order): vessel schedule delays, port congestion, weather issues, vessel operational delays, vessel skipping port, cut-and-run, customs inspection, and strike.⁴

A subsequent study is being launched to more systematically examine the throughput performance (via studying delays) of different ports. This additional study seeks to understand the variations in delays at different ports and potentially identify ports that are more capable of handling cargo flows more efficiently and effectively. Those ports and terminal operations may have certain policies that lend themselves to be more resilient. Currently, the research team is working with a major freight forwarder to provide data for analysis.

vi. Summer Research Institute Education

During the summer of 2011, James Rice worked with one of the CSR Summer Institute research teams in preparing their response to the surprise simulation regarding the economic impact of a radiological terrorist attack on New York-New Jersey harbor. Rice continues to work with this team and they are preparing a paper on “A Framework for Consequence Assessment of an Incident in Maritime Transportation Infrastructure” that will be proposed for an IEEE Conference in November 2011.

Additionally, Rice conducted a supply chain disruption simulation with the CSR Summer Institute Students, and this was used as a precursor to the surprise simulation that the students experienced in their final weeks of the program.


⁴ Global Ocean Transportation Project Report, Spring 2011, by Arntzen, B., Caplice, C., Harrison, A., Kalkanci, B., and Solomon, M.
vii. **Field Visits**

In Year 2, the MIT Port Resilience Team conducted field visits to various parties in several ports. This included visits to major ports, visiting with port authorities, USCG personnel, terminal operators and related third parties.

In Year 3, additional field visits were made to the Port of Seattle Port Authority, with the US Coast Guard area representatives, and with the Port of Tacoma Port Authority. These visits further enlightened the research; additional visits focusing on inland waterways will be conducted in year 4.

viii. **Documentation and Brief Commentary**

In Year 3, a number of draft reports were produced reflecting some but not all work to-date. This includes progressive work introducing important concepts of failure modes, frameworks for calculating seaport capacity, analyses of US port capacity constraints and concerns. In year 4, additional reports will be submitted reflecting further work on the US port capacity analysis, the port delay study and the port resilience survey.

**Collaborations**

a. Primary collaboration with Mr. Matt Mattingley on many elements of the work to-date.

b. Secondary collaboration with Stevens Institute of Technology colleagues Brian Sauser.

**Resources Leveraged**

- Port Authority of Tacoma
- Port Authority of Seattle
- US Coast Guard: Sector Puget Sound
- Global Ocean Transportation Project – MIT CTL

**Future Plans**

The future plans include continuing to harvest insights from the survey data and the capacity study, and the Year 4 workplan includes the following milestones:

a. Port Resilience Action List – Develop a proposed set of actions for creating port resilience.

b. Port Capacity Study – Update, refine and publish the US port capacity study which will include a vulnerability assessment. The data collected on terminal and port capacities will be organized by SIC codes, noting the most vulnerable ports in terms of the perceived ability for displaced cargo to be relocated and handled elsewhere.
c. Port Survey(s). Complete and publish the analysis from the US Port Survey, consider and develop a follow-up survey of stakeholders.

d. Provide critical data and structural input to the modeling effort. Data from the port survey, field visits, interviews, and failure mode analysis will be harvested to inform a modeling effort by the broader CSR port resilience team.

e. Port Delay Study – conduct study on port delays and document insights in report.

f. Port Case Study Database – prepare an initial draft listing of port disruptions and case examples illustrating learning points.

These activities will likely be supported by field visits and collaboration with several other COEs, including:

- The Center for Risk and Economic Analysis of Terrorism Events (CREATE)
- The National Center for Food Protection and Defense (NCFPD)
- The National Consortium for the Study of Terrorism and Responses to Terrorism (START).

Additionally, we will continue to collaborate with various government agencies and hope to reach out to additional agencies including the following:

- US Customs and Border Protection
- US Coast Guard
- US Dept. of Commerce
- US Dept. of Transportation (various groups)

**Documentation**

In Year 2 the MIT Port Resilience team worked on these papers in process that document some of the work:


In Year 3, the following preliminary draft reports and white papers were in process or were completed and posted online at:

http://ctl.mit.edu/research/port_resilience_project_reference_and_publications:

a. Revisiting Port Capacity: A practical method for Investment and Policy decisions; Lagoudis, I and Rice, J.


c. DRAFT White Paper - 'The Impact of Port Disruptions on Water and Land Travel Distances, by Kai Trepte, Research Associate, MIT CTL, Summer 2010
d. **DRAFT White Paper - An Exploration of Port Growth in the United States, by Kai Trepte, Research Associate MIT CTL, Summer 2010**

e. **DRAFT White Paper - Port Investment and Resilience, by Kai Trepte, Research Associate, MIT CTL, Fall 2009**

IV. EDUCATIONAL ACTIVITIES

Educational Programs and Activities
Central to CSR’s mission is the transfer of its research and expertise into highly relevant, innovative educational programs designed to enhance maritime domain awareness and the interest, knowledge, technical skills and leadership capabilities of our nation’s current and future maritime security workforce.

Since the Center’s inception in 2008, CSR in collaboration with its academic partners, Stevens Institute of Technology, Rutgers University, University of Miami, University of Puerto Rico, Massachusetts Institute of Technology and Monmouth University, have worked together to develop a comprehensive portfolio of maritime security-centric educational programs. These programs include:

• Funding for science, technology, engineering and mathematics (STEM) K-12 teacher workshops,
• Curriculum development in MDA for undergraduate education and the general public,
• Professional development courses in port security sensing technologies tailored to maritime industry and homeland security practitioners, and
• A four-course Graduate Certificate in Maritime Security delivered online via Stevens Institute of Technology’s WebCampus.
• The Summer Research Institute - a multi-disciplinary, intensive summer research program designed to provide qualified undergraduate and graduate-level students with the unique opportunity to engage in rigorous hands-on research in collaboration with CSR faculty to address critical issues in maritime domain awareness (MDA), the marine transportation system (MTS), emergency response and preparedness, and maritime system resilience.

CSR’s educational programs leverage the teaching talents and research expertise of its faculty and the participation of its maritime industry and homeland security partners to provide real-world, multi-disciplinary learning opportunities for students, professionals, and the general public.

1. Educational Programs and Activities
Year 3 marked another active and productive year for the CSR and its educational programs and activities. Through the continued collaboration and support of its academic partners (Stevens Institute of Technology, Rutgers University, University of Miami, University of Puerto Rico-Mayaguez, Massachusetts Institute of Technology, and Monmouth University) and the engagement of its industry and Government maritime partners, CSR was able to expand its outreach, develop new programs, and mature the educational programs that it had established during Year 2.

These programs included:
• STEM K-12 Teachers Workshop
• Professional development courses for maritime security practitioners
• The Maritime Systems Master’s Degree Fellowship program, and
• The Summer Research Institute

Year 3 reflected the many achievements and impacts of the previous year’s programming, including an active alumni network, increased academic, industry and government contacts and networks, enhanced program pathways, and the national recognition and achievements of its faculty and students. Year 3 also involved enhanced educational collaborations with CSR’s sister research center, the Center for Island, Maritime, and Extreme Environment Security (CIMES) and with several Minority Serving Institutions (MSIs) and Historically Black Colleges and Universities (HBCUs).

CSR’s educational programs continue to leverage the teaching talents and research expertise of its faculty and the participation of its maritime industry and homeland security partners to provide real-world, multi-disciplinary learning opportunities for students, professionals, stakeholders, and the general public.

Central to the CSR’s mission is the transfer of its research and expertise into highly relevant, innovative educational programs designed to enhance maritime domain awareness and the interest, knowledge, technical skills and leadership capabilities of our nation’s current and future maritime security workforce.

This section of the CSR Year 3 annual report highlights the Center’s educational activities and notable achievements for 2011.

1.2. STEM K-12 Teachers Workshop
CSR in collaboration with the Center for Innovation in Engineering and Science Education (CIESE), a recent recipient of the prestigious Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring, offered a week long teachers workshop focused on Underwater Detection Technologies and Port Security, in August 2010, at the Stevens campus in Hoboken, NJ.

The workshop leveraged an existing research project sponsored by the National Science Foundation (NSF’s) Information Technology for Students and Teachers (ITEST) program. The goal of this Build IT program is to catalyze student interest and achievement in engineering, science and information technology through a unique design challenge to build submersible robots from LEGO and other design pieces.

The CSR sponsored Underwater Detection Technologies and Port Security teacher’s workshop expanded on the already successful Built IT program and introduced teachers to advanced concepts in underwater detection and sensor technologies used in port security applications. The CSR’s goal in sponsoring the workshop was to provide teachers with creative ideas and lesson plans and activities within a maritime security-centric context that they could bring back to their classrooms.
Twenty middle and high school teachers representing lower-income and urban school districts in the NY/NJ metropolitan area attended the program.

Follow-up communications with the workshop participants has provided limited information on the impacts of the program curriculum on their classroom activities and students. Many of the teachers contacted during the spring of 2011 had not yet had the opportunity to implement the Underwater Detection Technology activities in their classrooms due to time and curriculum constraints.

CIESE representatives and CSR administrators will continue to periodically communicate with the teachers to solicit their feedback on the implementation of the Underwater Detection Technologies curriculum and classroom activities, and will seek information about the elements of the program that resonated with their students and the areas that were not well received.

CSR continues to look for opportunities for collaboration with CIESE and with the Build IT program. Since the August 2010 delivery of the teacher’s workshop, the Build IT program has been extended to four hub cities, reaching up to 12,000 middle school students nationwide. Through its continued collaboration with CIESE, CSR could potentially continue to participate in this national effort and expand its STEM K-12 program offerings.

1.3. Port Security Sensing Technologies – Professional Development Course
On October 18-20, 2010 and again on April 4-6, 2011, faculty from the CSR academic partners teamed together to deliver two sessions of the three-day professional
development module course in Port Security Sensing Technologies. The three-day intensive sessions were delivered to representatives of the U.S. Coast Guard at the Stevens Institute of Technology campus, located in the Ronald Reagan Building in Washington, DC.

Based on student feedback received from previous course offerings, CSR modified the delivery format of the course from a five-day module to a three-day module, thus providing participants with greater flexibility and convenience and less time spent out of the office.

The objective of the Port Security Sensing Technologies module is to provide maritime industry and homeland security practitioners who possess minimal to moderate technical expertise, with a basic understanding of the capabilities and limitations of sensor technologies used in maritime and port security applications. The course is designed to provide participants with a basis to make informed managerial decisions regarding relevant technology-based solutions.

Student participants learn the principal aspects of HF Radar, Satellites, Acoustics and Electro-Optics, as they are used in near shore and over the horizon vessel detection, tracking and classification.

Course assessments for the module course have been very positive and student feedback has reflected the utility of the three-day professional development course to their job requirements and responsibilities. One student testimonial said: “I can think of at least six times following the course, that the information I learned in class had direct applicability to my job and helped me consider the application and use of a particular sensor technology and its capabilities and limitations.” October 2010 course, Student Testimonial.

CSR faculty members have been equally positive about their classroom experience in the module course. In his assessment of the April 2011 course, Dr. Scott Glenn said, “this is the most engaged group that I have had. Despite their small numbers, they were the most interactive.... relating what I was talking about, to what they did in the field for the Coast Guard.”

Instructors for the Port Security Sensing Technologies course included:

- Dr. Barry Bunin, Research Professor, Stevens Institute of Technology,
- Dr. Scott Glenn, Director, Coastal Ocean Observation Laboratory, Rutgers University,
- Dr. Hans Graber, Director, Center for Southeastern Tropical Advanced Remote Sensing, University of Miami.
- Dr. Hady Salloum, Director of Port Security Initiatives, CSR
- Dr. Alexander Sutin, Research Professor, Stevens Institute of Technology,
- Dr. Thomas Wakeman, Deputy Director, Center for Maritime Systems
The Port Security Sensing Technologies course can be taken for graduate credit leading to a Graduate Certificate in Maritime Security or a Master’s Degree in Maritime Systems from Stevens Institute of Technology, or for professional development purposes for 2 continuing education units (CEU’s). Students completing the course for graduate credit must complete a final course project.

CSR has been in recent discussions with the Port of Los Angeles to deliver the three-day professional development course, among others, at the Port’s new National Maritime Security Training Center in Los Angeles, CA. CSR hopes to begin west coast delivery of the course as early as spring 2012.

1.3. Maritime Security Graduate Certificate program
Enrollment in Stevens Institute of Technology’s Maritime Security Graduate Certificate program continues to grow. Since the start of the Maritime Security program in 2009, four students have completed the degree requirements to receive the Graduate Certificate and four new students recently joined the program as of the 2010-2011 academic year.

While enrollment in the Certificate program appears small, students from other degree programs enroll in the programs’ courses. Many students take one or two courses out of the four-course sequence to fulfill their elective course requirements, or for personal or professional reasons.

The Maritime Security Graduate Certificate is delivered on-campus at Stevens Institute of Technology in Hoboken, NJ and is offered completely online via Stevens WebCampus.

Students enrolled in the Maritime Security courses have included representatives from the US Navy and the USCG, and currently include students in the Maritime Systems Master’s Degree Fellowship program.

1.4. DHS STEM Career Development Grant Award - Maritime Systems Master’s Degree Fellowship program
In the fall of 2010, CSR was awarded its first DHS Career Development Grant (CDG) to provide full-tuition support and stipends for three full-time Master’s degree students pursuing a Stevens Institute of Technology Master of Science in Maritime Systems with a Graduate Certificate in Maritime Security.

The fellowship program requires that students participate in the following activities during 24-month fellowship program:

- Students must maintain full-time enrollment in the Master's Degree program.
- Complete required courses for the Master's Degree in Maritime Systems and the Graduate Certificate in Maritime Security, including a six-credit Master's Thesis.
- Engage in a 10-week summer research internship at Stevens or at a CSR partner university.
- Attend at least one DHS Science & Technology (S&T) Education & Career Fair.
- Participate in Stevens Career Development workshops and career fairs.
- Participate in the CSR's eight-week Summer Research Institute.
- Work closely with an assigned Stevens faculty advisor/mentor.

Following completion of the fellowship program, students are required to commit to one year of employment in the maritime/homeland security domain. CSR’s director of education serves as the program coordinator for the DHS-funded fellowship program, and Dr. Barry Bunin, Research Professor and Chief Architect, Maritime Security Laboratory serves as the academic advisor.

Upon receiving the 2010 CDG grant, Stevens conducted a rigorous admissions review process and awarded three highly qualified, high-potential students with Maritime Systems Master’s Degree fellowships.

Competitively selected by a team of Stevens administrators and Center for Secure and Resilient Maritime Commerce (CSR) researchers, Brandon Gorton, Christopher Francis and Danielle Holden were chosen to receive fellowship awards based on their academic excellence and their stated commitment to working within the homeland security domain following their academic tenure. Due to the timing of the 2010 CDG award, Brandon Gorton was able to begin the program in Spring 2011 while Christopher Francis and Danielle Holden started their programs in June 2011.

1.4.1 Maritime Systems Fellowship Recipients

Brandon Gorton joined the Maritime Systems fellowship program in Spring 2011 and is currently enrolled full-time in the Maritime Systems Master’s Degree program. Brandon received a Bachelor of Science degree in Engineering Management Technology from Western Michigan University in 2010 and achieved a cumulative GPA of 3.9. Brandon is a former DHS Scholar student and an HS-STEM summer intern at Savannah River
National Laboratory (SRNL), where he worked within the Global Security Section: Marine Group. Brandon’s career objectives are to “work full-time in a position that enhances the nation’s capabilities in defense and homeland security.”

Brandon participated in the CSR’s 2011 Summer Research Institute (SRI) this past summer and served as a team leader for the Sensor Technology Applications research team. Brandon’s team was successful in developing a new graphical user interface and information system that can be used to identify vessel traffic abnormalities in the New York Harbor.

![Image: Maritime Systems Fellowship Students, (L to R) Christopher Francis, Danielle Holden, and Brandon Gorton]

**Christopher (Chris) Francis** recently completed his degree requirements for a Bachelor of Engineering in Naval Engineering at Stevens Institute of Technology. Chris maintained a cumulative GPA of 3.9 and ranked 9th in his undergraduate class of 499.

As an undergraduate student, Chris worked on a Senior Design project focused on the forensic and engineering analysis of semi-submersible vessels to assist law enforcement in the interdiction of such vessels used by drug traffickers. Throughout his Senior Design project, Chris collaborated with Stevens engineering faculty and CSR affiliate faculty and researchers. His career goals are to build upon his skills as a naval engineer and contribute to the development of new maritime security technologies and our nation’s maritime domain awareness capabilities through his continued research and course work in the Maritime Systems Master’s degree program.

During the summer of 2011, Chris participated in the CSR Summer Research Institute and served as a team leader for the Modeling and Simulation sub-team within the Consequence Assessment and Management Team. Chris and his team successfully developed a new web interfaced called Magello. Magello combines multi-source data into one user-friendly interface for the purpose of providing first responders and decision-makers with critical environmental and atmospheric information needed during emergency and crisis situations.
Danielle Holden completed her Bachelor of Science degree in Marine Sciences and Physical Oceanography, at Rutgers University in May 2011, and joined the fellowship program in June 2011 as a team leader and participant in the CSR 2011 Summer Research Institute.

Throughout her undergraduate degree program, Danielle had conducted cutting-edge research in collaboration with faculty from Rutgers University’s Coastal Ocean Observation Laboratory (COOL). In 2009, Danielle participated in the COOL Lab’s successful transatlantic deployment of an underwater glider from the shores of New Jersey to the coast of Spain. The first voyage of its kind by an underwater glider, the Slocum glider (RU27) is now on display at the Smithsonian in Washington, DC. Through her work conducted on the RU27, Danielle also engaged in the North America-Norway educational program (NORUS). Leveraging her research in the area of High Frequency (HF) radar, Danielle earned a trip to Norway where she worked with an international team of student researchers to conduct marine monitoring and ocean observation experiments.

In the summer of 2010, Danielle was selected to participate in the CSR’s Summer Research Institute where she served as a team member on the HF radar student research team assessing the capabilities and limitations of HF radar on the detection of small vessel threats in the Hudson River Estuary opposite of New York City. Danielle’s accomplishments during the SRI earned her recognition at the 5th Annual DHS University Network Summit and at the 2011 American Society of Limnology and Oceanography (ASLO) meeting in San Juan, PR, where she provided a presentation on her teams’ summer research findings.

Work completed by the three fellowship students in the Summer Research Institute resulted in team research papers, power point presentations and research posters. Copies of the team research papers and final presentations can be found on the following webpage: http://www.stevens.edu/csr/education/SRI-2011.html

A Stevens Institute of Technology news article featuring the three DHS CDG Fellowship students can be found via the following web link: http://www.stevens.edu/news/content/stevens-educates-next-generation-maritime-security-leaders

In September 2011, Stevens was awarded a second DHS S&T Career Development Grant. The award will complement the university’s existing Maritime Systems Fellowship program and will provide full-tuition support and stipends for three new full-time students in the Maritime Systems Master’s degree program. Fellowship awards will be made available to qualified students for the Spring and Summer 2012 semesters.

1.5. Summer Research Institute (SRI) 2011 Program Overview

Following the success of the CSR’s inaugural Summer Research Institute in 2010, the
CSR held its second annual Summer Research Institute, from June 6 to July 29, 2011 at the Stevens Institute of Technology campus in Hoboken, NJ.

![Figure 3. SRI 2011 program brochure](image)

Lessons learned during the 2010 SRI served as the guiding framework for the 2011 summer research program. Student and faculty feedback received from the 2010 SRI taught us that the program format needed to be flexible and that students needed more time and greater opportunities to collaborate and engage in their research and field experiments earlier on in the program. By limiting the number of in-class lectures, it was anticipated and was ultimately proved true, that student teams would have more time to conduct innovative research and produce high-quality, substantive research outcomes.

In addition to the modifications in the SRI program format, CSR also enhanced its academic collaborations and expanded its outreach to include students from its sister research center, The Center for Island, Maritime and Extreme Environment Security (CIMES) and from two of the nation’s top Minority Serving Institution’s (MSIs) and Historically Black Colleges and University’s (HBCUs), Jackson State University and Norfolk State University.

In the same collaborative spirit as the previous year, faculty members from each of the six CSR partner universities participated at various stages throughout the eight-week program contributing their teaching talents and subject matter expertise to expose a new cohort of SRI students to the maritime domain, the marine transportation system (MTS) and to the tools and technologies used in maritime and port security applications. See Appendix A for a list of the participating faculty members by partner school.

Twenty-one students, representing eight universities from around the nation were admitted into this year’s summer research program.
Eight of the students were Master’s and/or PhD students and 13 were undergraduate students in their junior and/or senior year of study. Altogether the student participants represented a broad base of Engineering and Science disciplines including, Aerospace Engineering, Applied Mathematics, Computer Engineering, Electrical Engineering, Engineering Management, Marine Sciences, Maritime Systems, Ocean Resources and Systems Engineering.

1.5.1. SRI Guest Lectures and Visitors
Students engaged in weekly lectures by CSR faculty and maritime industry and homeland security experts including:

- Dana Goward, Director, Marine Transportation Systems Management, USCG
- Richard Larrabee, Dir. of Port Commerce Port Authority of NY & NJ (PANYNJ),
- Jeanne Lin, Deputy Director, DHS HSARPA/Infrastructure Protection and Disaster Management Division
- Nick Pera, Chief Systems Engineer, NWS Acquisition and Operations Branch, US Navy,
- Bethann Rooney, Port Security, PANYNJ,
- Carolyn Thornton, US Navy Sealift Command

1.5.2. Field visits and Meetings with Practitioners

Field visits and meetings with industry practitioners provided students with a contextual framework and practical insight into the real-world implications of their research. During the eight-week program, students had the unique opportunity to meet and engage with representatives from the Regional Catastrophic Planning Team (RCPT) in New York City, the Office of Emergency Management (OEM) in Brooklyn, NY, the Port Authority...
of New York and New Jersey and APM Terminals at the Port of Newark.

The SRI 2011 students were organized into two research teams: the Consequence Assessment and Management (CAM) Team, led by Dr. Julie Pullen, Director, Maritime Security Laboratory and Philip Orton, Research Associate, Stevens Institute of Technology, and the Sensor Technology Applications in Port Security (STAPS) Team, led by Dr. Barry Bunin, Chief Architect, Maritime Security Laboratory, and Dr. Alexander Sutin, Research Professor, Stevens Institute of Technology. Faculty time constraints and research commitments warranted the need for CSR administrators to modify the previous year’s team structure from four research teams into two teams. Each of the two student teams was further divided into sub-teams. The CAMS Team included the Modeling and Response sub-team and the Impact on Supply Chain Sub-Team, and the STAPS Team included the following three sub-teams: Near Shore Technologies, Long Range Technologies and Decision Support.

1.5.3. SRI Research Challenge
Working closely with their designated faculty mentors and the rest of the CSR faculty team, the SRI students were given the research challenge to utilize sensor technologies and atmospheric and plume modeling forecasts to assess the potential impacts of a radiological dispersion and oil spill in the New York Harbor.

1.5.4. Student Recruitment and Selection
Efforts to recruit students for the SRI 2011 program began in the late fall of 2010. The CSR’s recruitment efforts included the following initiatives:

- Hardcopy and electronic distribution of the SRI program brochure to CSR academic partners, DHS education representatives, and CSR contacts
- Extended program outreach was also conducted through the DHS S&T academic channels to target MSI and HBCU students.

The admission criteria remained the same as the previous year with the exception that students were now asked to submit one letter of recommendation together with their online applications.

The criteria for admission are stated below:

- To be considered for admission, students must be enrolled in an Engineering or Science related discipline. Undergraduate students had to be in their junior and/or senior year of study and possess an excellent academic record and GPA of 3.0 or better. Graduate students had to demonstrate a GPA of 3.5 or better.

In addition to the above stated criteria, students were required to complete an online application and provide a statement of interest. Student applicants from CSR partner universities were given priority in the application process.

Overall, CSR received more than 73 applications and several more inquiries. From the 73
applicants, the CSR faculty and administrators selected the top 21 who best met the admissions criteria. Table 1 provides a list of this year’s admitted students together with their university affiliations and degree majors.

Table 1. SRI 2011 Admitted Student List

<table>
<thead>
<tr>
<th>UNIVERSITY</th>
<th>STUDENT</th>
<th>MAJOR &amp; DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jackson State University</td>
<td>Fatimata Diop</td>
<td>Civil Engineering, Undergrad</td>
</tr>
<tr>
<td></td>
<td>Yulian Kebede</td>
<td>Civil Engineering, Undergrad</td>
</tr>
<tr>
<td>Norfolk State University</td>
<td>Rachel Simpson</td>
<td>Applied Mathematics, Undergrad</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Christopher Filosa</td>
<td>Marine Sciences, Undergrad</td>
</tr>
<tr>
<td>Stevens Institute of Technology</td>
<td>Lisbeth Concho</td>
<td>Engineering Mgt., PhD</td>
</tr>
<tr>
<td></td>
<td>Hamid Darabi</td>
<td>Enterprise Systems, PhD</td>
</tr>
<tr>
<td></td>
<td>Christopher Francis</td>
<td>Maritime Systems, Graduate</td>
</tr>
<tr>
<td></td>
<td>Brandon Gorton</td>
<td>Maritime Systems, Graduate</td>
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<td>Danielle Holden</td>
<td>Maritime Systems, Graduate</td>
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<td>Andrew Orvieto</td>
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<td>Tyler Hee Wai</td>
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<td>Samuel Otu-Amoah</td>
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<td></td>
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<td>Fernando Arroyo</td>
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<td>Enrique Questell</td>
<td>Civil Eng., Undergrad.</td>
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<tr>
<td>State University of New York at Binghampton</td>
<td>Gregory F Sciarretta</td>
<td>undecided</td>
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1.5.5. Stipends and Accommodations

Admitted students received summer stipends of up to $4,500 and were provided free accommodations at Stevens’ off-campus residential complex located at 800 Madison Street, Hoboken, NJ. Student participants residing outside of New Jersey and the metropolitan area were also provided with up to $1,000 in travel reimbursement to and
from the summer research program.

Out of the 21 students admitted into the program, eight attended the program fully funded by external sources. Four of the students were Stevens students who attend the SRI based on Stevens Fellowship and Scholarship program support, and the four other students were supported (stipends, housing and travel costs) by our sister research center, the Center for Island, Maritime and Extreme Environment Security (CIMES).

1.5.6. Program Administration and Coordination
The day-to-day administration and coordination of the SRI was a team effort supported by Beth Austin DeFares, CSR Director of Education, Dr. Barry Bunin, Chief Architect, Maritime Security Laboratory, and Dr. Thomas Wakeman, CSR Deputy Director, under the executive leadership of Dr. Michael Bruno, CSR Director and Dean of the School of Engineering and Science at Stevens Institute of Technology.

Drs. Bunin and Wakeman served as the lead faculty facilitators and curriculum developers, and Ms. DeFares functioned as the primary program and student coordinator.

CSR “Faculty Mentors” and “Faculty Leads” continued to play an essential role in the coordination and administration of the research program. The faculty mentors were instrumental in helping to shape the strategy and research agenda for their students and for facilitating opportunities for field experiments and exercises.

Faculty leads, on the other hand, were responsible for coordinating weekly lectures and in-class activities. The theme and topic of the week reflected the faculty leads’ research expertise and contributions within the CSR’s research agenda.

1.5.7. Program Format and Curriculum
Based on student and faculty feedback from inaugural program offering in 2010, the eight-week program format was modified and redesigned to provide a better balance between in-class lectures and student research project time. Figure 5 below illustrates the updated SRI weekly schedule format for the 2011 program.

The first two weeks of the SRI program were devoted to providing a contextual framework in which the diverse group of students would begin to understand the critical nature and complexity of port and maritime security. Faculty and guest lectures discussed the economic impact of the marine transportation system in global trade and to the US economy, and the significance of maritime domain awareness in helping to protect and secure our nation’s ports, inland waterways, and island and coastal borders. Lectures and field visits also introduced students to the various private and government stakeholders in the maritime and port security domain.
**MONDAY**  |  **TUESDAY**  |  **WEDNESDAY**  |  **THURSDAY**  |  **FRIDAY**  
--- | --- | --- | --- | ---  
Faculty/Guest Lectures | Faculty/Guest Lectures | Field Visits/Research Project Time | Student Research Team Status Update Presentations | Research Project Time  
--- | --- | --- | --- | ---  
Faculty/Guest Lectures | Research Project Time | Field visits/Research Project Time | Research Project Time | Research Project Time  

*Figure 5. SRI 2011 Weekly Schedule Format*

During **Week One** of the program the students were given their research team assignments and were provided with the collective research challenge to utilize sensor technologies and atmospheric and plume modeling tools and forecasts to assess the potential impacts of a radiological dispersion and oil spill in the New York Harbor.

Paired with their designated faculty mentors, the teams went to work immediately, developing their research strategy and agenda.

Drs. Thomas Wakeman and John Voiklis, served as the faculty leads for Week One. Week One also provided the opportunity for a small group of students to assist in the deployment of Stevens Passive Acoustics and Electro-Optics Detection Systems (SPADES) in the Hudson River adjacent to the Stevens Babbio Center and Maritime Security Laboratory. The deployment of the SPADES system would later be used to support the research and data collection of the Sensor Technology Applications in Port Security Team.

Starting **Week Two**, students attended a series of lectures on the capabilities and limitations of sensor technologies used in port and maritime security applications. Dr. Hans Graber, Director CSTARS, University of Miami provided an intensive overview on the uses of Satellites in over-the-horizon detection, tracking and classification of vessels. Dr. Barry Bunin, Chief Architect, Maritime Security Laboratory, addressed the uses of
Electro-Optics in maritime domain awareness and the properties of long-wave and short wave infrared imaging. Dr. Scott Glenn, Director, COOL Lab, Rutgers University, exposed students to the principals of HF Radar and its utility in the near-shore and over-the-horizon detection and tracking of vessels. Lastly, Dr. Alexander Sutin, Research Professor, Stevens Institute of Technology, introduced student to sound waves and acoustic signatures, and the uses of Acoustics in detecting threats posed by waterborne vessels and unmanned underwater vehicles (UUVs).

Students also participated in a field visit to APM Terminals and to the Port Authority of New York and New Jersey in Port Newark.

Dr. Julie Pullen, Director, Maritime Security Laboratory served as the faculty lead for Week Three, providing an in-depth overview of ocean and atmospheric plume model forecasts and weather models used to assess environmental impacts and the dispersion of contaminants. During this week, Dr. Scott Glenn, Rutgers University also led a field visit to Sandy Hook, NJ, where students observed first-hand the Codar equipment deployed along the NJ coastline.

Starting **Week Three**, faculty and guest lectures were primarily held on Mondays and Tuesdays and the remaining part of the week was intended for unstructured research time and student team status update presentations.

During **Week Four**, Dr. Bobbie Reagor, Director, Rapid Response Institute, Monmouth University, led in-class lectures and student exercises on topics related to emergency management, response and preparedness. Students also participated in a Radiological Dispersion exercise conducted by Ms. Carolyn Thornton, US Navy Military Sealift Command.

Dr. Jorge Corredor, Professor, Marine Sciences, University of Puerto Rico-Mayaguez participated as the faculty lead for **Week Five**, introducing students to research being conducted in the Mona Passage in Puerto Rico, utilizing HF Radar applications. During this week, students also engaged a supply chain disruption exercise led by Jim Rice, Deputy Director, Center for Transportation and Logistics, MIT, and participated in a field visit to the Office of Emergency Management in Brooklyn, NY.

**Week Six** marked a unique Crisis Simulation organized by Drs. Barry Bunin, Julie Pullen and Philip Orton, the Faculty Mentors for the Sensor Technology Applications in Port Security Team and the Consequence Assessment and Management teams. The crisis simulation modeled a fictitious explosion of a vessel in the New York Harbor and the release of radiological contaminants into the atmosphere and a simultaneous (collocated due to the explosion) oil spill into the water. Stevens research vessel the *RV Savitsky* was used in the crisis simulation, and served as the hijacked vessel transiting the New York Harbor.

Dr. Roy Wilkens, Emeritus Research Scientist, University of Hawaii and former Director
of CIMES, was the faculty lead for **Week Seven**. Dr. Wilkins discussed the research conducted by CIMES and provided a lecture on the *Hawaii Undersea Military Munitions Assessment*. Students presented their last weekly team status update presentations to an audience of Ms. Jeanne Lin, Deputy Director, DHS Borders and Maritime Security Division and Ms. Bethann Rooney from the Port Authority.

**Week Eight** of the Summer Research Institute signified the end of the summer research program. In eight short weeks, the students had completed a substantial number of hours working on their respective team projects and collaborating with CSR faculty and other industry and government maritime and homeland security practitioners and experts. The student teams generated high-quality research outcomes that can potentially be transferred to the USCG and other maritime and homeland security entities. The student team projects will be discussed in detail in the next section of this report.

On July 28, 2011, the student teams presented their final team projects to CSR faculty and a group of USCG representatives from Sector New York, the USCG Auxiliary University Programs, and the Port Authority of New York and New Jersey.

Table 2 below illustrates the detailed eight-week schedule.

<table>
<thead>
<tr>
<th>SCHEDULE</th>
<th>TOPIC</th>
<th>FACULTY LEADS</th>
<th>FACULTY/GUEST SPEAKERS</th>
<th>SRI 2011 ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEEK ONE</td>
<td>MDA/MTS Industry Overview</td>
<td>Thomas Wakeman, Stevens Inst. of Technology &amp; John Voiklis, Stevens Inst. of Technology</td>
<td>Dana Goward, Dir., Marine Transportation Systems Mgt., USCG Richard Larrabee, Dir. of Port Commerce PANYNJ Nick Pera, US Navy, Chief Systems Engineer</td>
<td>Faculty/Student introductions &amp; tour of Stevens research labs &amp; facilities</td>
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<tr>
<td>June 6 - 10</td>
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<td>June 13 - 17</td>
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### WEEK THREE
**June 20 - 24**


### WEEK FOUR
**Jun. 27 – July 1**

| Emergency Response | Bobbie Reagor, Monmouth University | S. Negahdaripour - Underwater Optical Imagery Carolyn Thornton, US Navy Military Sealift Command | Radiological Dispersion Exercise Team status updates |

### WEEK FIVE
**July 5 – 8**

| Meso-scale Ocean Phenomena & MDA | Jorge Corredor, Univ. of Puerto Rico-Mayaguez | Jim Rice – Supply Chain Disruption | Field visit to OEM Brooklyn, NY & meeting w/RCPT. Team status updates |

### WEEK SIX
**July 11 - 15**

| Crisis Simulation Exercise | Barry Bunin, Stevens Inst. of Technology | | Crisis Simulation Hotwash & Report-out. Team status updates |

### WEEK SEVEN
**July 18 - 22**

| Research Projects | Roy Wilkens, Univ. of Hawaii | Jeanne Lin, DHS Bethann Rooney, PANYNJ | Team status updates |

### WEEK EIGHT
**July 25 - 29**

| Program Synthesis Final team reports & presentations | Barry Bunin, Stevens Inst. of Technology | Michael Bruno, Director, CSR | Final Presentations SRI Commencement |

### 1.5.8. Student Teams and Research Projects

The student research teams were organized to reflect relative balance between school representation, degree status, academic discipline, and student research interest. More than half of the students in the SRI had reported minimal to no knowledge of the maritime domain prior to their participation in the maritime security-focused summer research program. With that said, each team was challenged with producing new and novel approaches to address complex issues in port and maritime security and maritime
domain awareness, together with addressing issues as they relate to the supply chain and emergency management and response.

The student teams had at their disposal a robust set of research assets including a collection of sensor technologies, use of research vessels, access to analysis and visualization tools, plume modeling and simulation tools and unprecedented access to CSR researchers and leaders and experts in the field of maritime and homeland security.

Figure 6. SRI students participate in a Radiological Dispersion Exercise in the Maritime Security Laboratory

A. Consequence Assessment and Management (CAM) Team
The goal of the Consequence Assessment and Management team was to “improve preparedness for and the understanding of the impacts of a major catastrophic event” in the New York Harbor and the corresponding metropolitan area. The team also sought to “provide information and tools to facilitate efficient and effective decision-making in the aftermath of such an event.”

Divided into two sub-teams, the Modeling and Response sub-team “focused on consequence assessment through the use of oceanic and atmospheric data gathering and analysis, atmospheric plume modeling, and oceanic spill simulations.”

The Impact on Supply Chain sub-team focused on determining the most critical and high-impact targets in the New York Harbor and surrounding NYC metropolitan area, and determining the immediate and long-term effects of a catastrophic event on the economy, infrastructure and population.

The two sub-teams based their research on the SRI’s collective research challenge and hypothetical scenario in which a hijacked vessel detonated a radiological bomb in the
New York Harbor opposite of New York City, releasing oil and a radiological plume into the water and atmosphere.

In their assessment of such an event, the team took into consideration the immediate physical and psychological impacts of a dirty bomb release, as well as the atmospheric dispersion of the radiological plume in various environmental and seasonal conditions.

In their efforts to assess the consequences of a radiological dispersion, the Modeling and Response (MR) sub-team assessed that there were several atmospheric and oceanic modeling and simulation tools available to determine the dispersion of a radiological release, however, these tools were largely independent of one another and found in disparate locations across several national laboratory websites, Stevens, and the internet. Presenting a unique challenge and opportunity for the MR team, the team decided to focus their research activities and efforts into integrating these modeling and simulation tools and capabilities into one user-friendly web interface. Subsequently the team developed a new web interface called Magello. The Magello website was designed to enhance maritime domain awareness and to provide readily available environmental and atmospheric data to first-responders and decision makers in the event of an emergency situation or an extreme catastrophic event.

The Magello interface enables end-users to monitor models of plumes in the atmosphere and ocean spills using real-time environmental data inputs, while also incorporating important data such as marine vessel traffic, temperature, wind and currents, and environmental emergency alerts including earthquakes and tornado, hurricane, and flood warnings.

The students in the MR sub-team were provided with unparalleled access to high-resolution data and were able to collaborate directly with research scientists and experts from the Naval Research Laboratory and the Naval Meteorology and Oceanography Center, through the research contacts and collaborations of their research mentors, Dr. Julie Pullen, Director, Maritime Security Laboratory and Dr. Philip Orton, Research Associate, Stevens Institute of Technology. The environmental information drew on Stevens research and collaborations producing ~300 m urban-aware weather predictions and ~50 m resolution ocean and river forecasts, all in real-time.

The MR team was able to test and put into operation the Magello website in a real-world event of a massive sewage spill in the Hudson River in New York City. On July 20, 2011, the MR sub-team was notified by Dr. Alan Blumberg, Director, Center for Maritime Systems, that a fire at the North River Wastewater Treatment Plant in upper Manhattan had disabled the plant and caused the plant to shut-down and subsequently result in the spill of millions of gallons of untreated wastewater into the Hudson River. Empowered by the vote of confidence, the team quickly went to work to generate a sewage transport forecast and provided this critical information to Dr. Blumberg and the New York City Department of Environmental Protection (NYCDEP) and the New Jersey State Department of Environmental Protection (NJDEP).
The MR sub-team students were recognized in a letter of appreciation sent to Dr. Blumberg, by the NYCDEP. Information regarding the sewage spill can be found on the Sea and Sky Blog, hosted by Drs. Philip Orton, Julie Pullen, and Michael Bruno via the following weblink: \texttt{http://seaandskyny.com/}. Additional information about the sewage spill can be found in a July 22, 2011, NY Times new item posted on the following website: \texttt{http://www.nytimes.com/2011/07/22/nyregion/sewage-spill-renders-new-york-harbor-unfit.html}

The Impact on Supply Chain (ISC) sub-team focused their research efforts on two main tasks. The first task was to determine at which high-potential critical infrastructure targets would the detonation of a dirty bomb would create the greatest economic, psychological and disruptive impacts, and the second task was to assess the potential sequence of events and aftereffects that would emanate from such a catastrophic event.

Students in the ISC sub-team used an analytical hierarchy approach to assess the magnitude of impacts to specific critical infrastructure targets in the New York Harbor and surrounding metropolitan area. The students divided the targets into four distinct categories: bridges and tunnels, airports, maritime ports and cruise terminals. The criticality and magnitude of impacts that would occur if any of these categories were disrupted or destroyed by a dirty bomb, were based on the following criteria: Impacts and implications on traffic, revenues and the population.

Once the critical targets were determined, the students’ research shifted to determining the impacts that a dirty bomb and radiological dispersion would have on the economy, the NYC critical infrastructure and the population of individuals in and around each of these potential target sites.

Students prepared causal loop diagrams to illustrate the complex and extensive nature of the sequence of events and impacts that would occur if any critical infrastructure targets were destroyed or impacted by a dirty bomb release.

Using port and maritime shipping economic data provided by contacts at the Port Authority of New York and New Jersey, and the support and guidance of Jim Rice, Deputy Director, Center for Transportation and Logistics at MIT, the ISC sub-team used analytical and mathematical models to assess the economic impact of a disruption to the local and national supply chain.

The ISC sub-teams research resulted in an assessment and determination of the most critical targets in the New York Harbor and surround area. The team identified the anticipated immediate and long-term effects that a dirty bomb at any of these site/targets would have on the regional supply chain.

Comprehensive details regarding the Consequence Assessment and Management Team’s research and project outcomes can be found in their final research report and presentation.

**Consequence Assessment and Management Student Team members:**

<table>
<thead>
<tr>
<th>Student</th>
<th>Academic Discipline</th>
<th>School</th>
<th>Sub-Team</th>
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<tbody>
<tr>
<td>Fernando Arroyo-Lopez</td>
<td>Computer Engineering</td>
<td>Univ. of Puerto Rico-Mayaguez</td>
<td>MR</td>
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<tr>
<td>Lisbeth Concho (Team Leader)</td>
<td>Engineering Management</td>
<td>Stevens Institute of Technology</td>
<td>ISC</td>
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<td>Hamid Darabi</td>
<td>Enterprise Systems</td>
<td>Stevens Institute of Technology</td>
<td>ISC</td>
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<td>Richard de los Reyes</td>
<td>Systems Engineering</td>
<td>Stevens Institute of Technology</td>
<td>ISC</td>
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<tr>
<td>Christopher Filosa</td>
<td>Marine Sciences</td>
<td>Rutgers University</td>
<td>MR</td>
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<tr>
<td>Christopher Francis (Team Leader)</td>
<td>Maritime Systems</td>
<td>Stevens Institute of Technology</td>
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<td>Yulian Kebede</td>
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<td>Greg Sciarretta</td>
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<tr>
<td>Rachel Simpson</td>
<td>Applied Mathematics</td>
<td>Norfolk State University</td>
<td>ISC</td>
</tr>
</tbody>
</table>

**Faculty Mentors:** Dr. Julie Pullen (Stevens Institute of Technology) and Dr. Philip Orton (Stevens Institute of Technology) with assistance by Jim Rice (MIT) and Miguel Canals (Univ. of Puerto Rico-Mayaguez)

**B. Sensor Technology Applications in Port Security (STAPS) Team**

The research goals of the Sensor Technology Applications in Port Security (STAPS) team were to employ sensor technologies in a layered approach to enhance maritime domain awareness, through the detection, tracking and classification of vessels transiting the New York Harbor estuary.

Given the same research scenario and challenge as the CAM team, the STAPS team was organized into the following three sub-teams: Near Shore Technologies, Long Range Technologies, and the Decision Support sub-team.

The Near Shore Technologies sub-team explored the capabilities and limitations of Acoustics and Electro-Optics and Microwave Radar to detect, track and classify vessels in the New York Harbor and Hudson River estuary. The Long Range Technologies sub-team analyzed the uses of HF Radar and Satellites in long range and over the horizon detection and tracking of vessels, and the Decision Support sub-team worked to develop a
vessel classification and threat assessment system, together with a graphical user interface (GUI) to integrate the STAP team sensor data.

The Near Shore Technologies (NST) sub-team’s research utilized Stevens Passive Acoustic Detection System (SPADES). SPADES allows for the detection, tracking and classification of surface and underwater vessels through a system of four underwater hydrophones that collect and record acoustic signals. The NST team examined spectral, cross correlation and vessel signatures received and displayed through a graphical user interface called New Buoy.

The NST sub-team also utilized and assessed high-resolution visible light and infrared cameras to observe surface vessel traffic in the Hudson River.

The Long Range Technologies (LRT) sub-team was able to incorporate HF Radar, Satellite imagery and Automatic Information System data into one long-range system graphical user interface. With the HF Radar, Satellite, and AIS data overlays, the sub-team was able to visualize and demonstrate the efficiency of the long-range system. The Satellite imagery and AIS data were largely used to validate the detection capabilities of the HF Radar data. Dr. Scott Glenn, Rutgers University and his colleagues in the Coastal Ocean Observation Laboratory, provided hands-on assistance and research guidance to the LRT sub-team in their analysis and use of the HF Radar equipment.

The LRT sub-team also worked closely with Dr. Shariar Negadaripour, University of Miami, to assess the uses of digital image processing to compare images for enhanced vessel detection capabilities.

The Decision and Support sub-team served as the data fusion and integration component of the Sensor Technology Applications in Port Security team. The Decision and Support sub-team developed a one-stop-shop graphical user interface named Bay and Oceanographic Observation and Management System (BOOM) aimed at providing maritime security practitioners and law enforcement professionals with a user-friendly web interface that combined multiple sensor data outputs to provide a comprehensive operational overview, together with threat assessment capabilities. With the ability to track vessel traffic abnormalities, BOOM could potentially assistance maritime security and law enforcement practitioners with critical decision support capabilities.

The Decision and Support team consulted with representatives of the USCG to get input on the types of data sources and information that would be most useful to them.

Complete details regarding the Sensor Technology Applications in Port Security research and project outcomes can be found in their final research report and presentation slides located on the CSR’s Summer Research Institute website at http://www.stevens.edu/csr/education/SRI-2011.html.
Sensor Technology Applications in Port Security Team Student Team members

<table>
<thead>
<tr>
<th>Student</th>
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<th>Sub-Team</th>
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<tr>
<td>Fatimata Diop</td>
<td>Civil Engineering</td>
<td>Jackson State University</td>
<td>NST</td>
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<tr>
<td>Kay Gemba</td>
<td>Ocean Resources</td>
<td>University of Hawaii</td>
<td>NST</td>
</tr>
<tr>
<td>Brandon Gorton</td>
<td>Maritime Systems</td>
<td>Stevens Institute of Technology</td>
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<tr>
<td>(Team Leader)</td>
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<td>Tyler Hee Wai</td>
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<td>Samuel Otu-Amoah</td>
<td>Aerospace Engineering</td>
<td>University of Miami</td>
<td>Decision Support</td>
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</table>

**Faculty Mentors:** Dr. Barry Bunin (Stevens Institute of Technology) and Dr. Alexander Sutin (Stevens Institute of Technology), with support by Dr. Scott Glenn (Rutgers University), Dr. Hans Graber (University of Miami) and Dr. John Voiklis (Stevens Institute of Technology).

1.5.9. Crisis Simulation Exercise

The SRI 2011 students engaged in a surprise crisis simulation during Week Six of their program. On July 11, 2011 the CAM and STAPS teams each located in separate locations on the Stevens campus, were provided with fictitious intelligence that a vessel had detonated a bomb in the Hudson River, exploding itself and releasing oil and debris into the river. The fictitious intelligence also mentioned that radiation sensors were indicating that radioactive contaminants were detected in the air. Soon after, students received additional follow-up intelligence, informing the student teams that the USCG and NYC Office of Emergency Management (OEM) and Hoboken Police (HPD) had begun cordonning off and evacuating a 500 meter radius around the bomb site.

With no additional information provided or directions, the two SRI research teams were asked to assist with the disaster by providing situational awareness utilizing the CSR’s remote sensing technologies and its simulation and modeling tools and capabilities.
For their part, the STAPS team employed Stevens Passive Acoustics Detection System, (SPADES), HF Radar, AIS, CCTV cameras, New York Harbor Observation and Prediction System (NYHOPS) and Satellite imagery collected early in the day, to gather relevant and pertinent data. Team members also observed real-time vessel traffic in the Hudson River and spotted what they thought was a suspicious vessel. Posing as a fictitious hijacked vessel, the RV Savitsky, was spotted and reported to the STAPS team in the MSL lab.

The STAPS team quickly confirmed the vessel using the CCTV cameras, however the SPADES acoustics system did not pick up the vessel’s acoustic signature and due to incorrect settings, the AIS system was unsuccessful as well.

Students on the CAM team were simultaneously trying to gather data and used the Magello website to visually depict the 500 meter radius around the bombsite. The student team noted that the 500 meter radius included the Hoboken PATH and NJ Transit station and the Hoboken Police Station. Trying to gather additional information about the vessel size and payload, the CAM team established communication with the STAPS team to see if they had any intelligence on hijacked vessel.

The CAM team began to model the spill and atmospheric plume based on many assumptions regarding the size and cargo of the vessel. Overall, it took the Modeling and Response sub-team more than two hours to gather information and develop the spill and atmospheric models.

In the meantime the Impact on Supply Chain team created a causal loop diagram to demonstrate the anticipated effects on the regional supply chain.

Following the Crisis Simulation Exercise, the student teams and CSR faculty gathered together the next day for a “hotwash” review of the exercise and a discussion on the lessons learned in the simulation.

Both teams discussed the frustration of addressing a crisis simulation with limited intelligence and the absence of known facts. The teams also commented on the need to make decisions based on assumptions and how these assumptions can impact the integrity of their sensor data and modeling and simulation tools.

The teams also acknowledge the need for enhanced communications between the two research teams and that the processing of data would have been more effective and efficient had these communication channels already been established. The students also identified the need to create an emergency protocol instruction sheet in the event of future emergency situations.

In a twist of fate, the same “emergency protocol instruction sheet” that was created in the Crisis Simulation exercise was later used real-time when the CAM team was asked to
provide a sewage transport forecast to the NYCDEP.

A detailed overview of the student’s experience in the SRI Crisis Simulation can be found in a team prepared report located on the CSR Summer Research Institute website at http://www.stevens.edu/csr/education/SRI-2011.html

1.6. SRI Assessment
An assessment of the SRI 2011 program outcomes and lessons learned was conducted at the end of the eight-week summer research program in the form of a student and faculty survey. Feedback from the survey responses, together with the student team project outcomes, research reports and presentations all indicate that the SRI was effective in meeting its program objectives and successful in creating positive research experiences for its students and faculty.

1.6.1. Student Survey Results
Overall, twenty students of out the 21 program participants completed the SRI student survey.

A majority of the student respondents rated the SRI “Excellent” in the following areas:

- Faculty Mentor Guidance and Assistance
- Quality of Program Coordination/Administration
- Quality of Teamwork
- Quality of Research Outcomes
- Quality of Research Facilities

When asked to identify the top 3 takeaways from the SRI, students commonly mentioned the following items:

- Increased knowledge and awareness of the maritime domain and the complexities of maritime and port security.
- Teamwork and collaboration with faculty members and teammates.
- Experience with sensor technologies.
- Increased research skills and enhanced interest in research
- Great networking opportunities
- Importance of teamwork and communications

When asked how best to describe their experience in the SRI, some students said:

- *Very enlightening, very productive and a lot of fun.*
- *An excellent research experience.*
- *I feel, for the first time since starting school, that I (and my team) am contributing something important to the “real world” and not simply performing an academic exercise.*
- *It is highly rewarding to feel as though we are contributing something to the greater community, which may improve the country’s ability to protect itself from catastrophic events.*
• The student and faculty interactions define the experience more than anything. There was so much interaction while researching, before and after lectures and during field trips.
• I feel that the relationship formed with fellow students and SIT’s faculty and guest lecturers was so valuable, on a personal and professional level.
• The SRI has been invaluable in providing me with real world experience in the maritime domain.

In relation to their knowledge and understanding, a majority of the students reported “adequate” to “substantial improvement” in their knowledge and understanding of the capabilities and limitations of Acoustics, Electo-Optics and HF Radar technologies in vessel detection, and in their knowledge and understanding of Port Operations, Port Security and Supply Chain and Port Resilience.

Out of the following skills; Ability to Conduct Research, Communications Skills, Leadership skills, Networking, Oral Presentations, Professional Confidence, Teamwork/Collaboration and Writing Skills, a majority of the students said that the SRI had “Improved Substantially” their Networking and Professional Confidence skills. Of the remaining areas, student said that the SRI had “Effectively Improved” their Communication Skills, Leadership Skills, Oral Presentations, Teamwork/Collaboration and Writing Skills.

In a true testament to the effectiveness of the SRI in enhancing student interest in maritime and homeland security, 85% of the students said that they would consider advanced academic study and/or a career in homeland because of their experience in the SRI, and 100% of the student respondents said that they would recommend the SRI to their friends and colleagues at their respective universities.

1.6.2. Faculty Survey
The SRI faculty survey responses reflected the enthusiasm and genuine satisfaction with the activities and outcomes of this summer’s program.

A majority of the SRI faculty said that the following areas had positively “Exceeded their expectations”:
• Quality of Student Work & Outputs
• Quality of Student Participants
• Student Team Composition
• Faculty Mentors
• Program Administration and Coordination

When asked what they considered the strengths of the SRI program, faculty members commented:
• The quality of students and their dedication;
• The dedication of the faculty mentors and the teamwork among the faculty.
• Great organization; terrific & motivated students, and their engagement

When asked to identify the weaknesses of the program, one faculty member commented:
• The simulation exercise was “little disjointed” and that “short hands-on sessions in the early weeks of the program” would have been useful.
• Visiting faculty members could be used more effectively

1.6.3. SRI 2011 Outcomes and Lessons Learned
The innovative and tangible outcomes generated by this summer’s research program far exceeded the CSR faculty and administrators expectations. Students in both the CAM and STAPS teams produced practical user-friendly tools, The Magello web interface and the Bay and Oceanographic Observation and Management System (BOOM), that each have the potential to enhance the maritime domain awareness and security capabilities for maritime security professionals, emergency management personnel and homeland security decision makers.

The students worked in close collaboration with CSR faculty and had the unique opportunity to interact and engage with real-world industry and government maritime and homeland security leaders and practitioners.

Overall, the SRI was effective in achieving the following outcomes:

• Student research projects resulted in the development of tools and technologies that can be used to assist in maritime domain awareness and enhance the security capabilities of maritime security practitioners, first responders and homeland security decision makers.
• Student research reports, field experiments and weekly presentations demonstrated the student’s knowledge and understanding of the marine transportation system and maritime domain awareness.
• Students enhanced their professional skills by providing weekly research status updates and oral presentations.
• Students developed strong professional bonds and friendships with each other.
• Students expressed enhanced interest in pursuing careers and/or advanced academic study in maritime/homeland security as a result of their participation in the SRI.

Lessons learned in this year’s program demonstrate that student research outcomes are positively affected by the following factors: the amount of time spent conducting research, collaborations and engagement with CSR faculty and industry and government practitioners, and access to real-time, state-of-the-art tools and technologies.

1.6.4. Recommendations
The following recommendations for the future delivery of the SRI, take into consideration conversations held between CSR faculty and administrators, and specific comments received in the student and faculty survey responses.
DHS Career and Internship Opportunities:
As reflected in this year and last year’s SRI student surveys, a majority of the students expressed enhanced interest in pursuing advanced academic study and/or positions within homeland security as a result of the SRI. In an effort to capitalize on the talent and interest of the SRI students, it is recommended that DHS representatives continue to play a role in the SRI and share with the students next step internships and/or career opportunities for those that are interested.

Program Format:
While CSR made a number of modifications to the 2011 SRI program format, administrators should continue to find ways and opportunities to engage students in their research and field experiments earlier on in the program. Recommendations have been made to engage students in their research from the start of the program, and to extend the program from eight to ten weeks to accommodate student needs for adequate research time.

Student feedback also recommends that the team status update presentations be less structured and formal. Student comments suggest that too much time was spent preparing for the weekly presentations and that this placed constraints on their time to complete their research projects.

Research Teams and Topics:
SRI 2011 students suggest that next year’s participants continue to build on the tools and technologies developed in this summer’s program.

1.6.5. Conclusion
Lessons learned in the SRI 2010 inaugural program provided a strong framework for the 2011 summer research program. Modifications to the program format to allow for increased student research time, positively and significantly influenced the 2011 student research project outcomes.

Collaborations in and among the student teams and the CSR faculty and administrators, and the involvement of real-world industry and government homeland security practitioners continue to be the key features of the SRI program.

Students were provided with unprecedented opportunities to interact with representatives from the following organizations and federal agencies: USCG, US Navy, the Naval Research Laboratory, the Naval Meteorology and Oceanography Center, the Port Authority of New York and New Jersey, the Office of Emergency Management in Brooklyn, NY, and the Regional Catastrophic Planning Team.

These unique interactions and networking opportunities provided a real-world context for the students to frame their research and enhance their summer research experience.
Student survey responses reflected the success of the CSR in meeting its’ program objectives. In a true testament to the impacts of the SRI on student interest, 85% of the student participants said that the SRI had enhanced their interest in pursuing a career and/or further academic study in the field of maritime/homeland security. In addition, 100% of the student participants said that they would recommend the program to their friends and colleagues.

Press releases and news items highlighting the SRI can be found via the following web links:
Stevens Institute of Technology: http://www.stevens.edu/news/content/csr-summer-research-institute-2011


1.7. SRI 2010 Alumni Network and Student Achievements
The CSR has actively worked to maintain communication and connections with its student participants from the 2010 Summer Research Institute. The CSR considers these students as ambassadors for the summer research program and more importantly as the next generation of maritime security practitioners and homeland security professionals.

Since the SRI’s inaugural program offering, CSR’s director of education has continued to provide the program alumni with information on relevant academic and professional career opportunities. It is through these communications that CSR has been able to track the impacts of its program on the activities and achievements of its program participants.

Some of the relevant and notable achievements include:
- Danielle Holden, SRI 2010, was awarded a DHS-funded Stevens Maritime Systems Master’s Degree Fellowship based on her work and experience in the SRI.
- Three out of the four SRI 2010 student research teams submitted abstracts to the DHS University Network Summit. All three were selected to present their SRI research at the 5th Annual event held March 29 – April 1, 2011. Student papers included: A Study of Small Vessel Threats Using Acoustic and Electro-optic Technologies (Student authors: Andreas Graber, Qing Li, Saiyam Shah, Walter Seme, Ariel Marrero, and Wojciech Czerwonka), Aiding in the Prevention of Terrorist Attacks in the Hudson River Through Detection of Small Vessels with UHF Radar (Student authors: Angelica Sogor, Lenny Llauger, Omar Lopez, Shankar Nilakantan, Danielle Holden, and Dakota Hahn), and Systems Thinking Approach to Small Vessel Security (Student authors: Leonid Lantsman, Hardik Gajjar, Nazanin Andalibi, Blake Cignarella, Tanaira Cullens, Jose Mesa, and Tiffany Walter).
- Talmor Meir, SRI 2010 participant received the 5th Annual DHS University Network Summit “Best Paper Award” for her paper submission entitled
**Decision Learning Algorithm for Acoustic Vessel Classification.**

- White paper submissions by CSR faculty members Dr. Brian Sauser and Drs. Roshanak Nilchiani and Ali Mostashari were also recognized and selected for presentation. Dr. Sauser's white paper entitled *Modeling the Influence of ZEROTH Responders* was co-authored in part by Qing Li, SRI 2010 participant and PhD student at Stevens. Nazanine Andalibi, SRI 2010 participant and Stevens master's degree student served as a co-author on Drs. Nilchiani and Mostashari’s paper entitled *Architecting Cognitive Port Processes and Port Resilience.*

### 1.8. Students Mentored and Supported by CSR Academic Partners

In addition to the SRI student support, CSR academic partners have provided mentorship and financial support to 10 students throughout Year 3. These students include undergraduate, master’s and PhD level students attending CSR partner schools. Working in collaboration with CSR faculty, the students have served in various research support capacities and have contributed to the CSR’s research in Acoustics, HF Radar and Port Resilience. With the support and guidance of the CSR faculty, the students have had the unique opportunity to participate in summer internship programs and have prepared and presented research papers at relevant maritime and homeland security conferences. Table 3 below provides an overview of the students mentored and supported by the CSR along with their respective accomplishments.

#### Table 3. Students Mentored and Supported by CSR

<table>
<thead>
<tr>
<th>CSR Academic Partner</th>
<th>Students supported through DHS/CSR funding</th>
<th>Type of Support/Advisor</th>
<th>Accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stevens Institute of Technology</td>
<td>Hardik Gajjar, PhD, Ocean Engineering</td>
<td>Research Assistantship</td>
<td>Papers: Systems thinking approach to small vessel security. –Poster submission DHS 5th Annual S&amp;T University Network Summit, L.Lantsman, H.Gajjar, N.Andalibi, B.Cignarella, T.Cullens, T. Walters, J.Mesa Conference attended: Presenter at the Coasts, Oceans, Ports and River Institute (COPRI), April 27, 2010 DHS Career Fair, October 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advisor: Dr. Thomas Wakeman</td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Qing Li, PhD, Engineering</td>
<td>Research Assistantship</td>
<td>Papers: Modeling the Influence of ZEROTH Responders for Resilience in Small Vessel Security, B.Sauser, J. Ramirez-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advisor: Dr. Brian</td>
<td></td>
</tr>
<tr>
<td>Institution</td>
<td>Name</td>
<td>Position</td>
<td>Work Experience</td>
</tr>
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<td>-------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Monmouth University</td>
<td>Brian Besmanoff, Nolan Lum, Andrew Fishburg, Justin Schlemm</td>
<td>Advisor: Dr. Barbara T Reagor</td>
<td>Working with MU’s Urban Coast Institute the students developed the prototype flood view system created in the summer of 2010 to provide dynamic information visualization of the UCI/Stevens flood sensor for the Shrewsbury River Basin.</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Chris Filosa, Undergrad., Marine Sciences</td>
<td>Work -Study Advisor: Dr. Scott Glenn</td>
<td>Earned summer internship with CSR Summer Research Institute.</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Colin Evans, Undergrad., Marine</td>
<td>Work Study Advisor: Dr. Scott Glenn</td>
<td>Earned Summer Traineeship for HF Radar Technician.</td>
</tr>
<tr>
<td>Talmor Meir – PhD, Ocean Engineering</td>
<td>Research Assistantship</td>
<td>Advisor: Dr. Julie Pullen</td>
<td>DHS 5th Annual S&amp;T University Network Summit, Best Student Paper Award for paper entitled: Decision Learning Algorithm for Acoustic Vessel Classification Conferences attended: DHS 5th Annual S&amp;T University Network Summit 2011 PIANC Conference, Sept. 2010 DHS 4th Annual S&amp;T University Network Summit 2010</td>
</tr>
<tr>
<td>Michael Trent, Maritime Systems, M.S., May 2010</td>
<td></td>
<td></td>
<td>Conferences attended: DHS S&amp;T Career Fair, October 2010</td>
</tr>
<tr>
<td>Sciences</td>
<td>Glenn</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Shannon Harrison, Undergrad., Marine Sciences</td>
<td>Work-study Advisor: Dr. Scott Glenn</td>
<td>Earned spring break internship to Glider School in the Canary Islands. Earned Summer Glider Internship at University West Australia</td>
<td></td>
</tr>
<tr>
<td>David Kaminsky, Undergrad., Marine Sciences</td>
<td>Work-Study Advisor: Dr. Scott Glenn</td>
<td>Earned spring break internship to Glider School in the Canary Islands. Earned Summer Glider Internship at University West Australia</td>
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</tbody>
</table>

1.9. Future Plans
CSR will continue to grow and extend its educational program offerings and outreach.
Plans are being made to develop and enhance the following programs areas:

- Explore opportunities to build-upon the project outcomes of the 2011 SRI, namely the Magello website and the BOOM graphical user interface.
- New professional development course offerings held in Washington, DC and on the West Coast.
- CSR will continue to seek opportunities to host DHS Scholar & Fellow interns during the summer of 2012
- Increased collaborations with other DHS CoE’s and stronger networks with MSI and HBCU’s institutions.
V. APPENDICES

Appendix A – SRI Faculty List
June 6 – July 29, 2011

Steven Institute of Technology
Dr. Michael Bruno, Director, Center for Secure and Resilient Maritime Commerce (CSR) and Dean, Charles V. Schaefer Jr., School of Engineering and Science
Dr. Barry Bunin, Research Professor, Maritime Security Laboratory
Beth Austin DeFares, Director of Education, CSR
Dr. Julie Pullen, Director, Maritime Security Laboratory
Dr. Hady Salloum, Director Port Security Initiatives, CSR
Dr. Alexander Sutin, Research Professor, Center for Maritime Systems
Dr. John Voiklis, Research Assistant Professor, Howe School of Technology Management
Dr. Thomas Wakeman, Deputy Director, Center for Maritime Systems and Research Professor, Civil, Environmental and Ocean Engineering

Massachusetts Institute of Technology
James Rice, Deputy Director, MIT Center for Transportation and Logistics

Monmouth University
Dr. Barbara “Bobbie” Reagor, Director, Rapid Response Institute

Rutgers University
Dr. Scott Glenn, Professor, Coastal Ocean Observation Laboratory, Department & Institute of Marine and Coastal Sciences

University of Hawaii
Dr. Roy Wilkens, Emeritus Research Scientist, and former Director, Center for Island, Maritime and Extreme Environment Security (CIMES)

University of Miami
Dr. Hans Graber, Executive Director, The Center for Southeastern Tropical Advanced Remote Sensing (CSTARS)
Dr. Shahriar Negahdaripour, Professor of Electrical and Computer Engineering
Dr. Roland Romeiser, Associate Professor, Rosenstiel School of Marine & Atmospheric Science

University of Puerto Rico - Mayaguez
Dr. Jorge Corredor, Professor, Marine Sciences
Dr. Miguel Canals, Assistant Professor, Department of Engineering Science and Material
Appendix B – Outline of Year-4 Plans

Introduction
In Year 4, we will continue the CSR’s integrated research and education efforts in two basic areas:

- Maritime Domain Awareness (MDA), and
- MTS Resiliency

We expect that in Year 4, these research activities will result in publications in professional journals and academic conferences, and presentations at industry workshops and conferences. We also anticipate that the CSR PIs and researchers will be asked to continue to provide information and advice to representatives from DHS member agencies and other Federal, State, and local agencies with responsibility for maritime security. We expect to develop and/or enhance the following products:

1) prototype of underwater passive acoustic sensors for use in the detection of small surface and underwater objects;
2) computer algorithms for the analysis of passive acoustic sensor data;
3) database of signatures of small surface and underwater vehicles and threats, including small powered surface vessels, manned and unmanned underwater vehicles, and divers;
4) visualization algorithms to support decision-making using the passive acoustic system;
5) algorithms to support the use of space-based sensor information in the detection and characterization of surface vessels;
6) algorithms to support the use of HF Radar data in the detection and characterization of surface vessels;
7) data and preliminary models to support the evaluation of the national MTS, in terms of e.g., vulnerability to disruption, national capacity distribution, and critical components of the national supply chain;
8) analytical models of the national and international MTS, including modeling, simulation, and visualization tools;
9) metrics and procedures for the assessment of MTS resiliency;
10) database and analysis of decision-making in complex environments; and
11) visualization algorithms and training tools for decision-makers.

Education and Outreach Overview
Central to CSR’s mission is the transfer of its research and expertise into highly relevant, innovative educational programs designed to enhance maritime domain awareness and the knowledge, technical skills and leadership capabilities of our nation’s current and future maritime security workforce. Since the Center’s inception in 2008, CSR, via collaboration with its academic partners, Stevens Institute of Technology, Rutgers University, University of Miami, University of Puerto Rico, Massachusetts Institute of Technology and Monmouth University, have worked together to develop a comprehensive portfolio of maritime security-centric educational programs. These programs include:
• Science, technology, engineering and mathematics (STEM) K-12 teacher workshops,
• Curriculum development in MDA for undergraduate education and the general public,
• Professional development courses in port security sensing technologies tailored to maritime industry and homeland security practitioners, and
• A four-course Graduate Certificate in Maritime Security delivered online via Stevens Institute of Technology’s WebCampus.
• The Summer Research Institute (SRI) - a multi-disciplinary, intensive summer research program designed to provide qualified undergraduate and graduate-level students with the unique opportunity to engage in rigorous hands-on research in collaboration with CSR faculty to address critical issues in MDA, the MTS, emergency response and preparedness, and maritime system resilience.

Through a DHS Career Development Grant, CSR in conjunction with Stevens Institute of Technology developed a Maritime Systems Master’s Degree Fellowship program designed to provide high-potential U.S. students with the opportunity to pursue advanced academic study in a Maritime Security focused Master’s degree program. The fellowship provides full-tuition support, stipends and a comprehensive suite of experiential opportunities tailored to cultivate the next generation of maritime security leaders and practitioners. Following completion of the fellowship program, students will employ their knowledge and skills in positions within the maritime and homeland security domain.

CSR’s educational programs leverage the teaching talents and research expertise of its faculty and the participation of its maritime industry and homeland security partners to provide real-world, multi-disciplinary learning opportunities for students, professionals, and the general public.

The CSR has three essential components to its educational activities: Education; Training; and Outreach (ETO). The ETO approach is guided by a series of four objectives. Specifically, each CSR university partner will:
• Contribute significantly to one or more of the components of the ETO;
• Use their existing education platforms to achieve the CSR ETO objectives and maximize impact;
• Execute their plans such that maximum impact to underrepresented and minority populations is ensured; and
• Work toward eliminating institutional barriers such that the ETO effort becomes seamless and integrated.

Our Year 4 plans include the continued delivery of highly-successful programs such as the CSR Summer Research Institute and the maritime security professional development short courses. Budget permitting, these programs will be expanded and will be augmented by new activities aimed at a much broader audience, the general public. Taken together, our revamped and enhanced education activities will address the following important issues:
1. Minority Participation
CSR has begun to collect demographic information relative to the students applying and participating in the Summer Research Institute. Information is collected regarding gender, age, ethnicity, GPA, and academic major. CSR has initiated a concerted effort to increase the number of minority students participating in the SRI and in all of our educational offerings by reaching out to representatives of Minority Serving Institutions (MSI’s) and Historically Black Colleges and Universities (HBCU’s) through personal contact and targeted email distributions, some of which are facilitated through the DHS S&T University Programs academic channels. CSR and CIMES have each worked to create summer research opportunities for MSI researchers and students through the DHS Summer Research Team Program for Minority Serving Institutions. While the proposed MSI summer research projects have been independent, the Centers do see opportunities for collaboration in this regard. It should also be mentioned that the University of Miami is one of the “emerging Hispanic Serving Institutions (HSI)” and currently has a 22.1% Latino enrollment. We will continue to capitalize on opportunities to engage students from this under-represented population, via our partners at the University of Puerto Rico and the University of Miami.

2. Distance Learning
CSR, leveraging the capabilities of Stevens Institute of Technology, has already begun to deliver a series of online distance learning programs for students and current maritime industry practitioners. The programs include an online four-course, 12 credit Graduate Certificate program in Maritime Security and a Maritime Systems Seminar Series. The four-course program is instructor-led and delivered in an asynchronous format. The Maritime Systems Seminar Series is delivered on-campus at Stevens in Hoboken, NJ, and is made available live via Stevens web-based WebCT. One key partnership for education is the NSF Ocean Observing Initiative (OOI). The OOI’s Education and Public Engagement (EPE) Implementing Organization (IO) is led by CSR’s Dr. Scott Glenn, at Rutgers University. The EPE IO will build tools to enable education developers to use real time data in undergraduate classrooms and in free-choice learning environments. CSR is a natural testbed for these new educational tools, and we plan to actively engage the community in order to fully capitalize on this exciting opportunity. If our budget allows, we plan to expand our offerings and our venues to include our other university partners. For example, the University of Miami was in the process of developing an option in remote sensing applied to broad marine and environmental issues in its successful undergraduate Marine Science Program, but lack of funding for these new educational thrusts caused the program to be canceled. We might also include Spanish-language instruction via our partners at the University of Puerto Rico. We would also seek to transition the CSR professional development courses to an online platform, enabling nationwide dissemination and even shipboard instruction.

3. Expanded Professional Development Offerings
The CSR partner universities are committed to working together to expand the reach of our professional development courses, presently offered only at the Stevens facility in Washington, DC. We are discussing a partnership with the just-completed regional
training center at the Port of LA that specializes in maritime tactical training. The Port of LA has been working with the State of California and DHS (Federal Law Enforcement Training Center) on the development of the training center. The port has spent approximately $20 million on the development of a facility (approximately one half of the funding was from grants). They are planning to expand from training and tactics to other areas such as evaluation of security technology. CSR believes that we can play a strong role in this arena. We will work with the Port of LA to take advantage of this exciting opportunity. We see this as the first of what we hope will be several new educational partnerships in different regions of the US.

4. Public Outreach
One area for improvement of the CSR education portfolio is the education of the public about the importance of the MTS to the nation’s economy, the threats and challenges to the MTS, and the ongoing efforts to minimize those threats and ensure the safe, secure, and efficient transport of people and cargo in the maritime domain. CSR will seek opportunities for public outreach, working with DHS and its member agencies, the partner universities, and our Advisory Board. We will improve existing outreach vehicles – e.g., the CSR website, our brochures and annual reports – while examining other forms of public education and outreach. We already have a potential partner at the Liberty Science Center, by virtue of Rutgers’ participation in their Delta Lab and their “Our Hudson Home” exhibit. Stevens Institute of Technology is currently in the planning stages of a renovation of buildings and grounds on the Hudson River waterfront along the east side of the campus. We will explore an opportunity to make use of a portion of the renovated space for a public education facility that is focused on the waterway, the national MTS, and the ongoing work of the CSR.

Research Overview

Research Area 1 - MDA Research
MDA Technologies
The MDA projects examine the basic science issues and emerging technologies to support the use of a layered approach to the problem. The layers include satellite-based wide area surveillance; HF Radar systems providing over-the-horizon surveillance; and nearshore and harbor surveillance systems centered on underwater acoustic technologies. Integration of these systems is aimed at achieving vessel detection, classification, identification, and tracking. The new knowledge and new and improved technologies and algorithms developed under this Research Area are aimed at achieving real-time, all-weather, day/night, multi-layer maritime surveillance from the open ocean to estuaries, harbors and inland waterways, all at high-resolution. One of the fundamental questions yet to be answered is the limit of resolution of each of the component sensor technologies (e.g., space-based, HF Radar, and underwater acoustic); or in other words: “how small is too small?” or “how far is too far?” This issue of resolution is driven by the concern for threats associated with small surface vessels, UUVs, and divers. Ultimately, this layered surveillance capability should provide the means to enable adequate surveillance-based
understanding of our waterways so that we can accurately define “the normal”, with all of its variability. Only then can we accurately define and detect the “departures from the normal”, or anomalies that can in concert with decision-support systems trigger a response.

The University of Miami’s Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) leads the space-base applications and is developing new understanding and new processes for receiving and analyzing large maritime area data from multi-satellite and multi-frequency sensors such as Synthetic Aperture Radar (SAR) and electro-optical (EO) sensors. Algorithms continue to be developed to employ the data to detect vessels, including small ships, in harbors, inland waterways, the coastal ocean and the high seas. Algorithms are also being developed to integrate this vessel detection information with ground-based systems such as Automatic Identification System (AIS).

Rutgers University’s High-Frequency Surface Wave Radar (HF Radar) team is developing robust detection algorithms that recognize ship-associated HF Radar signals above the background noise (e.g., surface waves). Algorithms continue to be developed to support vessel detection and tracking capabilities using compact HF Radars, demonstrating that ships, including small ships, can be detected and tracked by multi-static HF Radar in a multi-ship environment, while simultaneously mapping ocean currents. Further, Rutgers has been developing novel algorithms for improved ship position detection based on the use of multiple radar detection images. Hardware systems and software developed and tested in the CSR New York Harbor test-bed and at the Port of Miami are being transferred to the University of Puerto Rico for testing in Caribbean waters. The University of Puerto Rico at Mayagüez (UPRM) is focused on the installation and operation of HF Radar in remote areas such as the Mona Passage for the dual use applications of ship detection and tracking, and surface current mapping.

Stevens Institute of Technology leads the nearshore and harbor surveillance system portion of the MDA project. Much of the Stevens effort in Years 1 through 3 was devoted to the development of a passive acoustic array that can provide low-cost, highly portable acoustic surveillance capability. The signal processing is based on the cross-correlation of signals received by several hydrophones. The system was applied to measuring the travel direction and acoustic signature characteristics of vessels in the heavy traffic of NY Harbor as well in the Port of Miami, where many types of vessels (from jet skis to cruise ships) are typically present.

Stevens researchers are also conducting investigations of emergency response decision-making. We have found that emergencies can demonstrate both the strengths and weaknesses in human decision-making. When pushed to their cognitive limits, decision makers often fall back on overly simple reasoning strategies. It was found that common cultural practices can help overcome human weaknesses while supporting human strengths. Simply discussing a decision with a collaborator can help decision makers better see and understand complex relationships between decision variables and the
consequences of various decisions. The researchers believe that decision technologies can fill the need for greater computational power and extended memory.

Based on the successful transitioning of several MDA-related CSR technologies during the first 3 years, including satellite sensor algorithms, HF Radar systems, and a passive acoustic sensor system, we will continue our aggressive strategy to conduct field evaluations of the MDA systems, perform required systems integration, and facilitate their adoption by relevant organizations. This will require much closer partnership with stakeholders, including USCG, CBP Air and Marine, domestic port authorities, and possibly industry representatives, including MTS industry and sensor developers. We will also seek partnerships with relevant national labs, including, e.g., the Naval Research Laboratory. The Director of NRL, Dr. John Montgomery, is a member of the CSR Advisory Board. We will plan for more frequent and more challenging field experiments with MDA sensor technologies, with a view to expanding the geographical scope of our partners, as well as the range of harbor and coastal environments in which our various sensor types are tested and evaluated. Our milestones will center on transition and use of new technologies rather than the basic science-related milestones that were the focus of the Year 1 CSR Workplan.

In the case of our ongoing effort to enable HF Radar over-the-horizon vessel detection and tracking, we recently initiated a significant partnership that can both inform the technology development (by better understanding existing Government Off-the-Shelf capabilities) and accelerate the speed at which the technology can be fielded in an operational environment. This partnership was facilitated by DHS S&T and involves the multi-agency data sharing and information fusion effort known as Open Mongoose. The challenge for the CSR radar team is to develop and demonstrate a capability to provide real-time vessel detection data from the Rutgers prototype mono-static backscatter systems to the Open Mongoose aggregation center. Bi-static systems will also be employed, with the aim of enabling high-resolution, real-time vessel detection. Significant leveraging of existing and planned research programs and radar hardware will occur throughout, including ongoing programs with NOAA and with the State of New Jersey. If successful, we will be in a position to demonstrate the use of a multi-static HF Radar system distributed along a coastal ocean region for the purpose of vessel detection - initially in a realistic environment along the approaches to NY Harbor, then to a more remote location (e.g., Puerto Rico), and eventually in an operational environment as a component of Open Mongoose, most likely along the Alaskan coastline.

The passive acoustic method of surface and underwater threat detection has already been evaluated by various organizations for port security applications, including the US Navy at NUWC in Newport, RI in September 2009. Stevens has been examining various options for the commercialization of the system and its transition to use in the field – primarily in US domestic harbors and other waterside applications. Stevens has taken the following steps:
- A patent has been filed to protect the passive acoustic IP.
- The Office of Enterprise Development and Licensing at Stevens has actively engaged in discussions with several organizations to identify a commercial path forward.
- Stevens continues to improve the current prototype to facilitate transitioning, in part by soliciting and implementing recommendations from the user community.

These activities will continue in Year 4, and additional applications of the acoustic system will be identified and explored. One application that was recently identified and which will be examined in the near-term under the S&T Basic Ordering Agreement is the detection of Self Propelled Semi Submersibles (SPSS). For this and other threats, the concept of an acoustic buoy and supporting wireless communications has been developed, and we hope to design, build, test and evaluate a working prototype system over the next two years.

In the case of satellite-based sensing technologies, the Deepwater Horizon oil spill response demonstrated the ideal interplay and interactions between the U.S. Government and CSR. This was the result of a few visionary individuals in the U.S. Government who recognized the innovativeness and high relevancy of commercial satellite data that could not be filled by National Technical Means. This event demonstrated that the path to transitioning satellite imagery products to operational use in the field must include: 1) a contractual vehicle that allows the flexibility to respond to unconventional situations; 2) funding to cover the costs associated with the satellite imagery; 3) CSTARS-brokered agreements with all satellite vendors to apply the use of imagery data in the most flexible ways (licensing); 4) US government agency involvement in the coordination of image collects and distribution; and 5) regular background collections in areas of concern – this might include specific coastal regions during elevated security conditions, hurricane-prone regions, areas containing critical maritime infrastructure, etc. CSTARS is working closely with the National Geospatial-Intelligence Agency (NGA) to provide more and readily accessible satellite data from commercial systems. CSTARS is partnering closely with the U.S. Southern Command to respond to disasters in the Caribbean Basin as well as to other emergencies. They are working closely with the senior administration of the offices of the Vice Chair of the Joint Chiefs of Staff, and the Directors of the NGA and NRO to facilitate better utilization of commercial satellite data and deliver it to the user in a timely manner. CSTARS has very flexible and cost-efficient agreements with a diverse group of satellite image data providers that can readily and quickly be expanded and modified to obtain more access time to these satellites.

During Year 4, CSR and CSTARS will actively engage with additional federal stakeholders in order to better understand the specific needs and requirements for homeland security applications. CSTARS will develop and implement a Synthetic Aperture Radar (SAR) architecture that consists of a web-based collection management tool (CMT) and a Plug-In Mini-API (PIMA) for applications such as ship detection, change detection, various detected image formats, polarimetric analyses, etc. This system will allow any federal stakeholder to access the site for searching and browsing of archived imagery, and for ordering of new and historic images and products available
through PIMA. As our research products mature, they will automatically be integrated into PIMA as a smart phone application. As mentioned earlier, most research products have a successful transition because there is a demand. We will reach out to the federal stakeholders to learn more about their needs and issues, and work with them to focus product development in the areas of greatest need.

**Systems Integration and Field Test and Evaluation**
Since the CSR began its work, we have been demonstrating how individual MDA technologies work well by themselves (e.g., acoustics, HF Radar, and satellite surveillance) as well as combined in a layered approach. However, in order to facilitate the development and implementation of a complete surveillance system, we need to examine real-world, real-time detection, classification, and tracking of maritime threats including small vessels, while also addressing the question of identifying anomalous behavior through pattern recognition and machine learning. The experiment that was performed at the Port of Miami in April, 2011 will be used as the first step toward this goal. During the Miami experiment, we tested hand-offs between the various sensor technologies, and collected a large amount of small vessel data. In Year 4, we will aim towards performing an experiment that shows a system integration approach to detection, classification, and tracking. In order to accomplish this objective, we will continue to seek local, State, and Federal funding sources for support.

**Research Area 2 – MTS Resiliency Research**
The need for resiliency planning is greatest at the public enterprise tier because unlike private shippers, public agencies have generally avoided detailed resiliency planning in the MTS domain because most assets are privately owned. However, since the consequences of a Katrina-like hurricane or Japanese magnitude earthquake are regional and national in scale, it is only public agencies or major private stakeholders that can address the resiliency needs of the MTS and global supply chain. It is here that work must begin with individual customers that can guide the CSR research to practical ends that provide real direction before and after an incident. The value of this research will be guidance and tools provided to major MTS decision makers, in both the public and private sectors, in assessment of benefits from an array of security investments to achieve their preferred investment benefits. All of these projects must address a specific lack of resiliency in the terminal or port area from a systems perspective.

The knowledge gained during the data gathering and model development at the terminal and port level will be organized to explore the uses of the CSR sensor technologies under development in the MDA tasks to improve resiliency. Specific applications will be investigated as vulnerabilities and potential system failures at the MTS partner facilities are identified. As scenario-based assessments are performed, the use of MDA technologies will be discussed with researchers performing that work within the CSR in order to leverage potential research findings and to develop useful products that can be transitioned to the field.
The resiliency research products will be transitioned to the stakeholder community through the identification of specific customers and working with those customers to tailor the modeling and assessment methodologies to meet their particular needs. Coordination meetings and workshops will be conducted to gather input data and receive feedback as the tools are being developed. Two Port Authorities (Port Authority of New York and New Jersey and Weirton Area Port Authority) have been identified as potential partners and will be approached and offered the opportunity to work with the CSR Resiliency Team on resiliency plan development for their locale. As this effort continues, the research will be expanded to consider the national port network. The CSR Resiliency Team will begin by integrating their research outcomes from Years 1 through 3.
Appendix C

Miami Experiment Report