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

YEAR TWO REPORT

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

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Stevens Institute of Technology (lead institution)  
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Non-University Partners
Mattingley Group  
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 TWO 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 3rd 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 and Coastal Safety.

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 CSR efforts related to the support of MDA are fashioned around the notion of a layered approach to maritime surveillance, with the aim of providing real-time or near real-time information (as opposed to data) over regions of interest that can span from the Exclusive Economic Zone to harbors and inland
The individual MDA projects are therefore organized as inter-connected and collaborative efforts, with strong linkages among the partner university researchers, primarily via joint field experiments and student exchange. This multi-disciplinary activity seeks to provide information at the resolution and accuracy required by the Stakeholders while also minimizing the latency-of-response that has challenged previous efforts to support maritime, port and inland waterway security. The layered approach includes satellite-based wide area surveillance; HF Radar systems providing over-the-horizon surveillance; and nearshore and harbor multi-sensor and multi-tiered surveillance systems.

The University of Miami’s Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) leads the space-base applications, and is developing new tools and 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 are being 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). Tools are also being developed to provide high-resolution understanding of the maritime environment, a capability that CSTARS employed to great advantage in supporting the Federal response to the recent Deepwater Horizon oil spill in the Gulf of Mexico. Satellite imagery acquired by CSTARS was used to identify surface oil concentrations in the Gulf and thereby assist in the deployment of first responder assets. The CSTARS images, shared as Google Earth projections, were also used by the Rutgers CSR team to coordinate the U.S. Integrated Ocean Observing System (IOOS) assets, in particular the multi-institutional underwater glider fleet, in response to the oil spill.

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 ocean background noise (e.g., surface waves). Algorithms are being developed to support vessel detection and tracking capabilities using compact HF Radars, while simultaneously mapping ocean currents. Hardware systems and software developed and tested in the CSR New York Harbor test-bed are being transferred to the University of Puerto Rico for testing in Caribbean waters. The University of Puerto Rico Mayagüez (UPRM) efforts are focused on the installation and operation of HF Radar along the Mona Passage for the dual use applications of ship detection and tracking and surface current mapping. As the team continues to develop and refine the algorithms, more attention is being paid to the issues related to detecting and tracking small vessels. Parallel efforts have resulted in applications of the technology to the US Coast Guard’s Search and Rescue operations, with the integration of real-time HF Radar-derived surface currents into the US Coast Guard’s SAROPS. The DoD also is interested in applying new HF Radar vessel tracking capabilities in forward deployed areas from offshore wave-powered buoys. The CSR has leveraged the DoD investment in HF Radar infrastructure to expand the New York Harbor testbed beyond the immediate entrance to the Harbor. In Year 2, the Rutgers team was also involved in the Deepwater Horizon oil spill via the
coordination of information and resources through a web portal that consolidated many data streams to help response efforts.

Stevens Institute of Technology leads the nearshore and harbor multi-sensor and multi-tiered surveillance system portion of the MDA project. Stevens has developed and built the first version of the Stevens Passive Acoustic Detection System (SPADES) for the detection and tracking of underwater threats, including divers and unmanned underwater vehicles. The SPADES was successfully demonstrated during field tests at the Naval Undersea Warfare Center, Newport, RI, and is being integrated into a comprehensive underwater security system for use in Force Protection applications. Parallel efforts have been conducted to employ the passive acoustic system for the detection, characterization, and tracking of surface ships, including small vessels. The system has also been utilized as part of a novel navigation system for unmanned underwater vehicles, which will lead in Year 3 to the development of an integrated detect-and-respond system that will employ an unmanned vehicle to autonomously respond to a detected threat, thereby addressing the latency of response issue associated with existing maritime security systems.

Stevens researchers also conducted investigations of emergency response decision-making and emergency management. Security operations, and especially responses to emergencies, require collaborations among multiple agencies. Successful collaboration often hinges on the coordination of both divergent instrumental interests—resources and rewards—and divergent interpersonal interests—e.g. identity and status. Failure to coordinate interests at the interpersonal level can often lead to failures to coordinate instrumental interests. The long-term goal of this research program is to help DHS both anticipate and overcome some of the cognitive and interpersonal challenges to security and emergency response. CSR investigated what might be done to mitigate the impact of interpersonal discord on bargaining outcomes. Monmouth University’s contributions to this area of inquiry stem from work by two on-campus institutes: the Rapid Response Institute (RRI) and the Urban Coast Institute (UCI). RRI and UCI leverage their modeling and simulation capabilities to support the CSR research related to rapid decision-making in the event of a homeland security or all-hazard disaster.

**Topics in Global Policies influencing MTS Security and Coastal Safety.** This element of the CSR research 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. 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. A major effort at Stevens is aimed at developing a combined quantitative/qualitative framework to enable decision-makers to assess the resiliency of the MTS. We have learned that our ability to effectively capture multi-stakeholder perspectives requires grounding in systems thinking. Perspectives are representations of
an individual’s truths based on their knowledge of the world, and we use multiple tools to contextualize and communicate these perspectives (i.e. verbal, written, graphical). One form of systems thinking modeling is Systemigrams (Systemic Diagrams). Systemigrams are networks, having nodes and links, flow, inputs, and outputs, beginning and end. Through a series of modeling efforts supported by workshops with maritime stakeholders, a Systemigram that can articulate resilience was created. The effort to-date has demonstrated how to build a culture of systems thinking within an enterprise, thereby facilitating the accelerated absorption of principles and frameworks to embrace and deploy resilience in an enterprise.

The Massachusetts Institute of Technology (MIT) and the Mattingley Group (MG) have been investigating supply chain resiliency. The project objectives include the identification of the critical processes and systems of the MTS that need to be resilient; and the identification of methods for making critical MTS processes and systems more resilient. The MIT Port Resilience Survey of 525 shippers, carriers, port authorities, terminal operators, freight forwarders, customs brokers, and other 3rd parties and authorities associated with ports and port operations was completed during project Year 2. The respondent pool was collected using a convenience sampling method for the purpose of providing broad and general guidance in the domain. The survey solicited input on critical systems and actions to take towards making ports resilient. Additionally, the survey solicited respondent experience with delays in ports as well as opinions about regulations and their impact on port 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 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:

- Science, technology, engineering and mathematics (STEM) K-12 teacher workshops,
- Curriculum development and in-class testing and evaluation 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.

In June 2010, CSR offered its latest educational initiative - the Summer Research Institute – an 8-week, 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 and maritime system resilience.
I. INTRODUCTION
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), constitute 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.

- **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 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 achieve its vision centers 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 3rd 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, 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 1 illustrates how the CSR (MIREES) Vision Statement and associated research and education activities align with the implementation plans under NSPD-41/HSPD-13. Table 1 also lists the measurable outcomes – Performance Metrics - associated with the specific CSR activities that will be 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>
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</table>
| MDA                     | “...safe and secure use of our nation’s maritime domain..”  
“...advancement of the relevant sciences..” | 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 | “...safe and secure use of our nation’s maritime domain..”  
“...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. |
| Maritime Operational Threat Response | “...safe and secure use of our nation’s maritime domain..”  
“...advancement of the relevant sciences..” | 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. |
| 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 resilient US MTS. |
| | “..and a resilient MTS..” | Development of models and tools for use by the first responder community. |
| | “..advancement of the relevant sciences..” | 12. # of partnerships with the MTS community, including the port industry, shippers, carriers, etc. |
| | | 13. New data for the simulation of the various MTS elements of the supply chain. |
| | | 14. # of new risk and vulnerability assessment tools for the MTS. |
| | | 15. # of new systems engineering design tools. |
| | | 16. # of times direct assistance to the first responder community |
| | | Performance Metrics 3, 5 and 6 |

| **MTS Security** | “and a resilient MTS,..” | Examine the national and international policies and regulations that impact maritime security. |
| | “through advancement of the relevant sciences and development of the new workforce” | 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,..” | Develop models and tools for the analysis of the US supply chain, including vulnerabilities to disruption. |
| | “through advancement of the relevant sciences and development of the new workforce” | 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 1: Alignment of CSR Research and Education Activities with NSPD-41/HSPD-13 Goals; and Project Performance Metrics
In addition to these performance metrics, CSR partners agree that an essential metric of success of the overall Center of Excellence effort is the degree to which 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

All of the CSR research and technology development activities will be guided by a spiral development approach to solving the complex issues facing the MTS. This approach, illustrated in Figure 1, will require that the CSR research projects achieve the necessary fidelity to provide improved understanding and capabilities, as well as technology products where possible, that can be examined via field experiments in the real-world environment (initially conducted within the New York – New Jersey Harbor region). These activities, rooted in basic research and new knowledge development, will lay the groundwork for the transitioning of new technologies, systems and policy recommendations to full implementation.

Figure 1: Spiral Development Process for CSR R&D
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.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Academic Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>Mr. James B. Rice, Jr.</td>
</tr>
<tr>
<td>Monmouth University</td>
<td>Dr. Barbara T. Reagor (RRI)</td>
</tr>
<tr>
<td></td>
<td>Mr. Anthony Macdonald, Esq. (UCI)</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Dr. Scott Glenn</td>
</tr>
<tr>
<td>Stevens Institute of Technology</td>
<td>Dr. Jeff Nickerson (Decision-making)</td>
</tr>
<tr>
<td></td>
<td>Dr. Roshanak Nilchiani (Infrastructure Resilience)</td>
</tr>
<tr>
<td></td>
<td>Dr. Brian Sauser (Resilience Modeling)</td>
</tr>
<tr>
<td>University of Miami</td>
<td>Dr. Hans C. Graber</td>
</tr>
<tr>
<td>University of Puerto Rico</td>
<td>Dr. Jorge E. Corredor</td>
</tr>
</tbody>
</table>

The non-academic partners include:

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Academic Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Mattingley Group</td>
<td>Mr. Matt Mattingley</td>
</tr>
<tr>
<td>Nansen Envir. Remote Sensing Center</td>
<td>Dr. Johnny Johannessen</td>
</tr>
<tr>
<td>Pacific Basin Development Council</td>
<td>Ms. Carolyn K. Imamura</td>
</tr>
<tr>
<td>Port Authority of New York &amp; New Jersey</td>
<td>Ms. Bethann Rooney</td>
</tr>
</tbody>
</table>

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. 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

**c. Collaboration with other COEs**

The leadership and researchers at both the National Center for Islands, Maritime, and Extreme Environments Security (CIMES) and CSR believe that collaboration between the two centers is essential to meet DHS’s objectives. To that end, the two centers met 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 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 since.
The collaboration is ongoing between the two centers. In the last year, this has included joint sessions at the 2010 DHS S&T Annual Meeting, and collaboration in the conduct of the 2010 DHS University Programs – USCG Arctic Workshop (University of Alaska at Fairbanks, September, 2010). In addition, the Directors of CSR and CIMES have traveled together to meet with present and potential Stakeholders, including the US Coast Guard Academy, the USCG R&D Center, the Pacific Basin Development Council (Honolulu, Hawaii), and the Office of Naval Research.

Research collaborations are ongoing in the areas of Passive Acoustics; Time Reversal Acoustics; HF Radar; and remote-environment observing systems. We anticipate that these joint activities will lead to new joint research and joint proposals to DHS and other Federal agencies.

The CSR is already partnering with the newly-organized 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 teamed with the Center for Risk and Economic Analysis for Terrorism Events (CREATE) and CCICADA to develop a proposal on port resilience in response to a DHS Long Range Broad Agency Announcement. The proposed research was intended to build on and integrate the ongoing and prior work at CSR, CREATE, and CCICADA, with incremental tasks intended to help develop specific recommendations for building resilience within each operating port, as well as across the Network of Ports (NoP). The specific port resilience research would include system mapping, identification of port failure modes, gathering input from port operators and analyzing the results, developing resiliency metrics along with the corresponding evaluation methodologies for ports to use, and developing strategies for port authorities to improve their resilience by improving their processes and operations.

Also, CREATE invited CSR to present at its Maritime Risk Symposium that will be held in November, 2010 at CREATE. CSR will be presenting CSR capabilities as well as the findings from the port survey that CSR conducted under the leadership of MIT. The results of the presentation will be reported in next year’s annual report.

The leadership of CSR and CIMES is committed to exploring opportunities to support collaborative projects with these and other DHS COEs.
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

2. Topics in Global Policies influencing MTS Security, including Design for Resiliency

   Task 2.1 Resilient and Cognitive Port Infrastructure Systems and Enterprises

   Task 2.2 Resiliency Modeling

   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)

Project Abstract
As one of the nation’s leaders in the development of technology and technology products to enable space-based wide-area surveillance, CSTARS continues to develop the capability to employ space assets such as high resolution synthetic aperture radar (SAR) for a range of applications. Under the DHS CSR project, CSTARS is engaged in the use of SAR and other sensors in the detection and classification of maritime threats ranging in size from small boats to large vessels. During Year 2, this same capability was shown to have significant value in the monitoring of environmental pollutants such as oil spills that can have significant negative impacts on port and maritime commerce as well as posing health threats to coastal communities. We have leveraged ongoing studies and exercises with DOD agencies that have shown that wakes from small, fast moving boats can be detected, and large vessels can be tracked across ocean basins. This represents important new research directions that will be expanded during Year 3 under the DHS CSR funding. In collaboration with one of the primary companies operating a network of space-based Automatic Identification System (AIS) transponders, we engaged in the testing of the interoperability of SAR satellite data and space-based AIS for various scenarios. We have learned that a primary challenge to the use of space-based sensor data in maritime security applications is the provision of near real-time information to users on the ground. CSTARS has developed with the National Geospatial-Intelligence Agency (NGA) a Commercial SAR Architecture Center (CSTARS Pilot Project) which incorporates the new, high resolution SAR sensors such as Cosmo-SkyMed, TerraSAR-X, TanDEM-X and RadarSat-2 to support global and near real time acquisitions of image data. As part of the CSR series of joint field experiments (including the November, 2009 experiment in NY Harbor), satellite-based real-time monitoring of vessel traffic is continuing to be evaluated in order to better understand what is required to implement a comprehensive end-to-end surveillance of the global maritime domain. This capability does not currently exist, as a result of challenges that include the need for direct access to multiple satellite sensors to maintain persistence. During Year 2, CSTARS demonstrated its capability to rapidly respond and deliver large volumes of images to the maritime first responder community, during the DeepWater Horizon oil spill in the Gulf of Mexico. CSTARS will continue to participate in port and maritime security exercises and leverage other resources and projects to develop technology products that support safe and secure operations within the global and national maritime domain.

Project Objectives/Challenges in Year 2
a. Near real-time delivery of information
b. Examine the use of polarimetry in both vessel and vessel wake detection.
c. Explore the use of complex image data to extract information on vessel behavior.
d. Explore new high resolution and different frequency satellite radar sensors for the detection of vessels and the description of vessel movement.
e. Develop the capability to monitor maritime disasters such as an oil spill, with
sufficient resolution and low-latency to provide support to responders on the ground.

Research Milestones Met

Satellite Reception

Maritime surveillance with different satellite sensors during the CSR NY Harbor joint field experiment

As mentioned earlier, a primary challenge to the use of space-based sensor technologies in support of the maritime security community is the provision of near real-time information to professionals on the ground. In order to address this challenge, the CSR partner universities conducted on 9 & 10 November 2009 the second of a series of DHS-supported field experiments to demonstrate existing technical capabilities and evaluate potential new technologies and procedures for the multi-sensor surveillance of a large maritime area. The experiment was conducted in NY Harbor. The details of the experiment are provided in a later section in this report, but it is important to note here that CSTARS provided for the first time, near real-time collects of high-resolution satellite data from the COSMO-SkyMed constellation in support of a small boat detection exercise. The goal of this exercise was to test how small of a vessel could be detected by different surveillance systems such as satellites, HF radar and acoustic sensors. Figure 1 shows an overview of the Port of New York and New Jersey from Cosmo/SkyMed-2 on 9 November 2010 with 10 minutes duration of ship tracks using AIS. The positions of two small boats, Stevens’ research vessel and a Pilot boat are indicated by a red +.
Figure 1: Cosmo/SkyMed-2 stripmap image (5 m resolution) collected on 9 November 2009 at 10:50:15 UTC.

Figure 2 shows a zoomed in snapshot near the research vessel (dead in the water) and the inbound channel (markers visible in radar) toward the Verrazano Narrows Bridge. Visible is the signature of the container ship *Maersk Virginia* (inset).
Figure 2: Zoomed Cosmo/SkyMed-2 image collected on 9 November 2009 at 10:50:15 UTC showing channel markers, the Stevens’ research vessel (dead in the water) and the container ship Maersk Virginia.

Figure 3 shows a Cosmo/SkyMed-3 image over the same area, but taken on 10 November 2010 at 10:50:14 UTC. AIS positions for 5 minutes before and after the image collection time have been overlaid to highlight traffic patterns in this region. The image also shows a great deal of traffic through the Verrazano Narrows with the Stevens’ research vessel as well as the Pilot boat at the right edge of the image. Figure 4 shows the zoomed in image in the vicinity of the Pilot boat. In addition, two tug boats were detected, as well as an unidentified, fast moving vessel. Both tug boats exhibit a strong radar signature as well as the Pilot boat. Figure 5 displays several small boats detected during this exercise using both radar and electro-optical images. Most of these vessels are less than 50 feet long, with some even smaller than 30 feet in length.

The DHS-funded field experiments – planned to continue in Year 3 – have proven critical in supporting our efforts to develop and demonstrate the capability to provide near real-time high-resolution wide-area surveillance of coastal and harbor regions via satellite. Future efforts in Year 3 will include the integration of the satellite-based sensor information with other sensor data, including AIS, HF RADAR, and underwater acoustic data, with a goal of creating a CONOPS for the use of the integrated data to support coastal/harbor MDA.
Figure 3: Cosmo/SkyMed-3 stripmap image (5 m resolution) collected on 10 November 2009 at 10:50:14 UTC.

Figure 4: Zoom of the Cosmo/SkyMed-3 stripmap image (5 m resolution) collected on 10 November 2009 at 10:50:14 UTC.
Figure 5: Summary of detected small boats during the 2009 CSR joint field experiment using Cosmo/SkyMed satellites and FormoSat-2.

Figure 6 provides an example of a high resolution SAR image of a vessel approaching the Panama Canal. The SpotLight Cosmo/SkyMed radar image shows a great deal of detail of the ship deck which suggests either a cargo vessel or tanker. The very strong return is located at the bridge housing which is most likely caused by the marine X-band radar. Without access to global AIS we could not further validate the type of vessel and describe the various visible features on deck.

Figure 6: SpotLight high resolution Cosmo/SkyMed image of vessel approaching the Panama Canal. The 1 m resolution image shows great details of the vessel deck.
Developing new algorithms for vessel wake detection (work in progress)
ScanSAR and stripmap images in HH polarizations provide a high degree of detection of hard body targets such as ships of all sizes. On the other hand dual polarization images such as RadarSat-2 as shown in Figure 7 help to suppress the background noise or ocean waves to better emphasize the vessels. The preferable solution is the polarization combination of HH and HV. On the other hand, VV polarization is better suited to emphasize surface features such as wakes. This RadarSat-2 ScanSAR Narrow image of the Gulf of St. Lawrence (note the swath width of 300km) in the left image was taken in HH polarizations and shows a good deal of texture or “noise” from ocean surface waves. In contrast, the cross-polarization image on the right shows a drastically reduced background clutter and much better SNR of the two detected ship targets using the dual polarity.

**Figure 7:** RadarSat-2 image over the Gulf St. Lawrence was taken in dual polarity. On the left with HH polarization shows a good deal of ocean surface texture and on the right with HV polarization suppresses most of the background clutter.

Under the DHS grant, we are developing new algorithms to better detect ship wakes in a variety of sea states or noisy environments in SAR images. In particular, we are beginning to work more with image polarization as shown above, and sub-aperture stacking to better detect the motion of vessels even if the signal return is low. This effort will continue in Year 3, and we plan to apply these algorithms in the Year 3 CSR joint field experiment. Figure 8 shows an example of two ships in Chesapeake Bay that display very distinct wakes and Doppler shifts to determine the course, heading and speed of the vessels. This Cosmo/SkyMed stripmap with 3 m resolution provides a great deal of details of the wakes and Doppler shift. From the wake of Ship 2 we can clearly discern a course change in the middle of the image by about 18 degrees. The Doppler shift is readily measured in pixels and yields a displacement of the vessel target from the wake. The size of the displacement can be used to determine quite accurately the speed of the vessel. Also visible are the Kelvin arms of the bow wake of Ship 2 as well as the
transverse wake pattern.

Figure 8: Cosmo/SkyMed image of two vessels entering the Chesapeake Bay from the James River side. Significant details are easily visible of both wakes and vessel targets. Furthermore, Doppler displacements can be used to estimate ship speed.

The Doppler displacement can be calculated from the equation in Figure 9. With common parameters of the satellite readily available from the image metafile and with the help of the graphics shown in Figure 10, we determine the estimated speed over ground (SOG) of Ship 1 (Nightwing) to be 9.0 kts and its course over ground (COG) to be 60 degrees from true north. For Ship 2 (Charleston Express) we arrive at values of 15.8 kts for SOG and 78 degrees from true north for COG. These values compare very close to the numbers obtained from AIS (see Figure 10).

Equation:

Doppler Shift: \( \Delta x = \left( \frac{R}{V} \right) \left( v_w \cos \theta_a \sin \phi_{inc} + v_l \right) \)

<table>
<thead>
<tr>
<th>Common Values:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence Angle</td>
</tr>
<tr>
<td>Slant Range</td>
</tr>
<tr>
<td>Satellite velocity</td>
</tr>
<tr>
<td>Ship radial velocity due to pitching of vessel (for center of buoyancy)</td>
</tr>
</tbody>
</table>

Figure 9: Equation to compute Doppler shift and the common values of the satellite from the metafile.
CSR Support to the First Responder Community: DeepWater Horizon Oil Spill

The CSR team considers itself an important resource for DHS and its member agencies. As such, we are prepared to provide immediate support as needed during maritime emergencies, as was the case for two aviation incidents in the Hudson River during Year 1. During Year 2, a significant national maritime emergency occurred when the BP-owned DeepWater Horizon (DWH) platform in the Gulf of Mexico (GOM) exploded on April 20, 2010, killing 11 workers, and starting the largest oil spill in US history (Figure 11). Several attempts to cap the leaks (3) in the early days failed. Soon, oil continued to pour into the GOM from a blown-out undersea well. Following several phone calls among NGA, the CSR Director, and Dr. Graber, CSTARS began on 29 April to coordinate with the NGA on systematic collects of the oil spill in support of the first responder community. Daily telecons with NGA commenced in order to respond dynamically to the shifting appearance of the oil and to track its movement in the northern part of the GOM. By 30 April, the first Daily Brief was produced and satellite data was placed on a secure, password restricted ftp site within hours of downlink for DOD/IC community. CSTARS quickly recognized that the data could not be shared with DHS or USCG and other civilian federal agencies and by 2 May modified the image data licenses to include all Fed (Civ) and State and Local agencies involved in the oil spill response. This license upgrade assured that the data could be used freely by USCG, NOAA, and other responders to strategically position resources to prevent, as much as possible, oil from reaching sensitive wetlands, ecological habitats and beaches along the Texas, Louisiana, Mississippi, Alabama and Florida coastlines. By 9 May, upon request, CSTARS began to issue a separate Daily Brief to Florida Congressional Staffers of Senator Nelson, Congresswoman Ros-Lehtinen and Congressman Diaz-Balart.
CSTARS collected daily satellite imagery for NGA from 21 different satellite sensors which were downlinked and processed at CSTARS and the image data and value-added products were typically provided in near real time within 1 hour from the satellites with direct downlink to the CSTARS Miami station. Table 1 lists the satellite sensors available to CSTARS for the oil spill response.

![Figure 11: Photo of burning DeepWater Horizon platform on 21 April 2010.](image)

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Sensor Type</th>
<th>Number</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmo-SkyMed</td>
<td>Radar</td>
<td>3</td>
<td>Italy</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>Radar</td>
<td>1</td>
<td>Germany</td>
</tr>
<tr>
<td>RadarSat-1</td>
<td>Radar</td>
<td>1</td>
<td>Canada</td>
</tr>
<tr>
<td>RadarSat-2</td>
<td>Radar</td>
<td>1</td>
<td>Canada</td>
</tr>
<tr>
<td>Spot-4</td>
<td>Optical Sensor</td>
<td>1</td>
<td>France</td>
</tr>
<tr>
<td>Spot-5</td>
<td>Optical Sensor</td>
<td>1</td>
<td>France</td>
</tr>
<tr>
<td>MODIS on Aqua</td>
<td>Optical Sensor</td>
<td>1</td>
<td>USA</td>
</tr>
<tr>
<td>MODIS on Terra</td>
<td>Optical Sensor</td>
<td>1</td>
<td>USA</td>
</tr>
<tr>
<td>ALOS/PALSAR</td>
<td>Radar</td>
<td>1</td>
<td>Japan</td>
</tr>
<tr>
<td>ENVISAT ASAR</td>
<td>Radar</td>
<td>1</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>ENVISAT MERIS</td>
<td>Optical Sensor</td>
<td>1</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>ERS-2</td>
<td>Radar</td>
<td>1</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>FormoSat-2</td>
<td>Optical Sensor</td>
<td>1</td>
<td>Taiwan</td>
</tr>
<tr>
<td>EROS-B</td>
<td>Optical Sensor</td>
<td>1</td>
<td>Israel</td>
</tr>
<tr>
<td>RapidEye</td>
<td>Optical Sensor</td>
<td>5</td>
<td>Germany</td>
</tr>
</tbody>
</table>

*Table 1: List of satellite sensors utilized by CSTARS for the DWH oil spill response.*
During the 118 days of the oil spill in the GOM, CSTARS collected more than 800 images from a multitude of sensors listed in Table 1. Figure 12 displays the distribution of the number of images collected from these different sensors. It is obvious that synthetic aperture radar (SAR) was the most useful sensor for detecting and monitoring the oil spill. The SAR images were especially useful for the US Coast Guard to intercept oil heading toward wetlands and beaches.

**Figure 12: The table showing the diverse satellite sensors used for imaging the DeepWater Horizon oil spill to the Incident Command Post in Louisiana.**

Figure 13 shows a typical overview of image collections during a 24 hour period during the oil spill crisis. While some of these images overlay others, the imaging occurred at different times. A mixed strategy was applied using wide area ScanSAR coverage to monitor the overall spreading and movement of the oil spill and higher resolution stripmaps to focus on encroachments on wetlands and beaches.

Figure 14 shows an oil spill areal map using the RadarSat-2 and Envisat ASAR images from 2 July 2010 but collected 9 hours apart. The combined size of this part of the oil spill is estimated to be 10,661 square miles which is larger than the State of Maryland.

Figure 15 displays a shoreline impact map which was daily produced to indicate the encroachment of oil on coastal areas. The red line signified that oil was within 10 miles of land while blue was used when the oil was more than 10 miles offshore. This map was derived from a single ScanSAR image of Envisat ASAR taken at 15:57 UTC on 2 July 2010. At this instant, 300 miles of shoreline were vulnerable to contamination by the oil.
Figure 13: A typical collection scenario monitoring the oil spill over a 24 hour period.

Figure 14: Areal map of the oil spill derived from the RadarSat-2 and Envisat ASAR images collected on 2 July 2010. The total estimated size of the spill at this instant is 10,661 square miles.
Figure 15: Shoreline impact map displaying coastlines where oil either reached the land or was less than 10 miles away (red) from the Envisat ASAR image collected on 2 July 2010 at 15:57 UTC.

Figure 16 is a high resolution TerraSAR-X image showing the encroachment of oil on Perdido Beach, FL. Some of the oil is very close to the beach while along other parts of the coastline oil is washing up on the beach. This high resolution TerraSAR-X image emphasizes how detailed and accurate information can be obtained on oil spills.

Figure 17 is a ScanSAR Narrow RadarSat-2 image showing the spreading and encroachment of oil toward the north along the barrier islands. The large footprint always encompassed the entire oil spill in the early days. Wind, currents and local weather such as thunderstorm activity impacted the distribution of oil the most. Clearly SAR was able to detect and monitor the oil film on the ocean surface.

Finally Figure 18 is a high resolution (2.5 m) multispectral optical image from Spot-5 obtained on 25 May 2010 over Barataria Bay, LA. The white sheen is the oil engulfing Isle Grande Terre and spreading into bays. The image shows also phenomenological hydrodynamic patterns with flow splitting and flowing around the island as well as through the island gaps. This optical image confirmed early on the extent of encroachment by the oil into bays and ecologically sensitive wetlands.
Figure 16: High resolution SAR image from TerraSAR-X on 9 JUN 2010 at 23:40 UTC (19:40 EDT) shows detail of Perdido Beach oil encroachment. (1) oil streaks encroaching on shoreline south of Shelby Lakes; (2) oil encroaching on coastline from Little Lake to western Cotton Bayou (~ 2 miles); (3) oil encroachment on east side of shipping channel south of Terry Cove; and (4) oil made landfall on shoreline south of Old River from the state border to south of Rabbit Island (~3.5 miles).

Figure 17: Radarsat-2 image collected on 02 JUL 2010, 11:56 UTC (07:56 EDT) shows (1) main spill area drifting northward from the DWH site. (2) numerous visible filaments; (3) the denser and larger portion of the spill area heading toward Mobile Bay. (4) the location of local thunderstorm activity.
Figure 18: Spot-5 multispectral image taken on 25 May 2010 over Barataria Bay, LA.

The CSTARS response to this incident is a demonstration of the technical capabilities and significant partnering being generated under the DHS CoE grant. The existing CSTARS funding from, and relationship with NGA have been extensively leveraged to provide significant added value to DHS and its member agencies, not only in the development and demonstration of new technical capabilities and technology products, but also in the provision of immediate support in the field wherever and whenever needed by the Department.

CSR Annual Meeting in San Juan, Puerto Rico on January 21 & 22, 2010
Attended the “CSR All Investigator Meeting” at the Caribe Hilton Hotel in San Juan, PR in January 2010.

GCOOS meeting in New Orleans, LA on February 3 & 4, 2010
Attended and participated as panel member and speaker, to discuss CSTARS ocean observation capabilities and ongoing projects, including the DHS-supported activities under the CSR project.

Meeting with Sector Miami on 26 March, 2010
Attended meeting and gave briefing about CSTARS capabilities. Also initiated discussion of a future CSR joint field experiment in the area, planned to occur in Year 3.
Maritime & Port Security Sensing Technologies Course in Washington, DC on April 21 & 22, 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”

DHS Summer Institute at Stevens Institute of Technology, Hoboken, NJ on 7–9 June and 21 – 25 June, 2010
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. Using video camera recordings from the rooftop of the Babbio Center at Stevens, we validated the SAR images in addition to a live AIS data stream.

Collaborations
Contributed with Stevens Institute of Technology in the development of the DHS Summer Institute and participated in the teaching and exercises in June 2010. Two additional faculty from the University of Miami provided lectures and experimental support in July to the Satellite Team.

Working partnership with NGA on the development of a Commercial SAR Architecture.

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

Ongoing Projects and Future Plans
Literature review on the detection of small vessels via space-based and other technologies completed.

Commercial SAR Architecture Center
➢ Installed in 5 months three new SAR satellite systems for operational use.
➢ Developing a new front end to allow easy access to CSTARS data archive and permit a collection plan to provide persistent direct planning and ordering of new and old satellite image data.

European Collaborations - continuing
➢ MARISS – GEMES MARitime Security Services
➢ NATO La Spezia – remote ground station operation
Data analysis in support of CSR multi-sensor maritime surveillance

- Wake detection – continuing project to be accelerated during Year 3
  - i. Radon transform approach
  - ii. Examining dual and quad polarization data
  - iii. Pattern analysis of elementary shapes
  - iv. Speckle noise reduction

- Innovative antenna configuration - continuing
  1. Explore squinting algorithm for moving targets such as dynamic imaging or sub-aperture stacking
  2. 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 senior personnel from National Reconnaissance Office (18 February, 2010).
3. Visit by senior personnel from the Director National Intelligence (31 March, 2010).
4. Visit to USCG Sector Miami and presentation regarding CSTARS capabilities (26 March, 2010).
5. Presentation to Admiral Murrett, Director of the National Geospatial-Intelligence Agency, during the daily Director’s Oil Spill Updates at NGA HQ about CSTARS role and efforts in the DWH oil spill monitoring (28 May, 2010).
6. Presentation to General Fraser, USSOUTHCOM Commander, of CSTARS current and future projects and how goals of DHS CSR goals fit within MDA mission (28 June, 2010).
7. Hosted visit for General J. Cartwright, Vice Chair of the Joint Chiefs of Staff. Presentation on CSTARS SAR architecture plans included results from ship and wake detection and relationship to DHS CSR program (29 June, 2010).

Other Resources Leveraged

1. NGA’s CSTARS SAR Architecture Pilot Project
2. NGA’s Crisis Support Project
3. Cooperative maritime support from Immigration and Customs Enforcement and US Coast Guard
Table 2 presents a summary of presentations given during the year.

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Location</th>
<th>Date</th>
<th>Title of Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center for Secure and Resilient Maritime Commerce Annual Meeting</td>
<td>San Juan, Puerto Rico</td>
<td>Jan 21 - 22, 2010</td>
<td>“The Eyes in the Sky”</td>
</tr>
<tr>
<td>Port Security Sensing Technologies Course</td>
<td>Washington, DC</td>
<td>April 21, 2010</td>
<td>“Synthetic Aperture Radar (SAR)” “SAR Applications and Techniques” “Vessel Detection Exercise”</td>
</tr>
<tr>
<td>Briefing to Admiral Murrett, Director of National Geospatial-Intelligence Agency</td>
<td>Bethesda, MD</td>
<td>May 28, 2010</td>
<td>DeepWater Horizon Daily Briefing</td>
</tr>
<tr>
<td>Briefing to General Fraser, Commander, US Southern Command</td>
<td>SouthCom HQ, Miami, FL</td>
<td>June 28, 2010</td>
<td>CSTARS Brief Presented to General Douglas Fraser</td>
</tr>
<tr>
<td>Briefing to USCG Sector Miami</td>
<td>USCG Sector Miami</td>
<td>March 26, 2010</td>
<td>CSTARS Brief</td>
</tr>
<tr>
<td>Briefing to General Cartwright, Vice Chair of Joint Chief of Staff</td>
<td>CSTARS, Miami, FL</td>
<td>June 29, 2010</td>
<td>CSTARS Brief Presented to General James E. Cartwright</td>
</tr>
</tbody>
</table>

Table 2: presentations.
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)

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

Project Objectives and Significance to Stakeholders

- To provide a testbed for ship detection on the approaches to NY Harbor using high frequency (HF) radar
- To improve the capability of the SeaSonde HF Radar to detect vessels at sea

Research Milestones Met
The main focus of the year 2 effort was to increase the database of ship detection case studies using HF radar. Rutgers, Stevens and Miami conducted the second CSR joint field experiment on November 9, 2009. Rutgers operated four HF Radars in the vicinity of New York Harbor 1) Sandy Hook, NJ 5 MHz 2) Sandy Hook, NJ 25 MHz 3) Staten Island, NY 25 MHz and 4) Sea Bright, NJ 13 MHz. Rutgers personnel were present at the radar stations to ensure the radars were operating properly and to make on site observations of the ship signals in the HF Radar data. Rutgers collected Range series files and brought these files back to the main campus for processing. These files are then run through the ship detect Matlab code to produce possible ship detections. The detection rate results from the November 9, 2009 exercise are summarized in Table 1.

<table>
<thead>
<tr>
<th>Ship</th>
<th>Time</th>
<th>Length</th>
<th>Width</th>
<th>IIR Detection Rate (%)</th>
<th>Median Detection Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 YM Los Angeles</td>
<td>0600-0900 November 9, 2009</td>
<td>294</td>
<td>32</td>
<td>44.4</td>
<td>50.7</td>
</tr>
<tr>
<td>2 OOCL Thailand</td>
<td>0600-0900 November 9, 2009</td>
<td>277</td>
<td>40</td>
<td>36.2</td>
<td>47</td>
</tr>
<tr>
<td>3 CCNI Punta Arenas</td>
<td>0600-0900 November 9, 2009</td>
<td>215</td>
<td>32</td>
<td>33.3</td>
<td>28.5</td>
</tr>
<tr>
<td>4 Asphalt Seminole</td>
<td>1000-1600 November 9, 2009</td>
<td>108</td>
<td>19</td>
<td>31.6</td>
<td>26.7</td>
</tr>
<tr>
<td>5 Moscow Kremlin</td>
<td>1000-1600 November 9, 2009</td>
<td>243</td>
<td>42</td>
<td>25</td>
<td>45.9</td>
</tr>
<tr>
<td>6 Sand Master</td>
<td>0600-0900 November 9, 2009</td>
<td>110</td>
<td>10</td>
<td>16</td>
<td>24.7</td>
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<td>7 Bow Tone</td>
<td>1000-1600 November 9, 2009</td>
<td>170</td>
<td>26</td>
<td>9</td>
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<tr>
<td>8 Maersk Virginia</td>
<td>0600-0900 November 9, 2009</td>
<td>292</td>
<td>32</td>
<td>6.6</td>
<td>7.2</td>
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<tr>
<td>9 Barcarolle</td>
<td>1000-1600 November 9, 2009</td>
<td>177</td>
<td>32</td>
<td>5.1</td>
<td>18.4</td>
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<td>10 New York Express</td>
<td>1000-1600 November 9, 2009</td>
<td>294</td>
<td>32</td>
<td>3.9</td>
<td>15.6</td>
</tr>
</tbody>
</table>

Average 21 27
Max 44 51

The results from the highest detection rate are shown in Figure 1 (range, range rate and bearing) and Figure 2 (detections placed on a map). These detections were made on the YM Los Angeles, which is shown in Figure 3.
Figure 1: Range (top), range rate (middle) and bearing (bottom) of the YM Los Angeles as it approaches NY Harbor. The radar detections are the dark blue squares and the GPS data is the aqua line.
Figure 2: Detections made by the SeaSonde HF Radar placed on a map showing the detections (dark blue circles), gps track (aqua line), the location of the Sea Bright HF radar (center of radial grid) and the time of the track (green text).
The ship detection data is compared against GPS data sent via AIS to evaluate system performance. The AIS data collected on November 9, 2009 by all Rutgers AIS receivers is shown in Figure 4. The receiver at Tuckerton provided the most data due to the fact that the antennas are approximately 40 feet above sea level. Zooming in on NY Harbor is shown in Figure 5. The AIS data collected by the receiver at Sandy Hook was intermittent. We decided to move the antenna closer to the ocean to the Sea Bright HF Radar shore station. The AIS data collected for a similar time period after the receiver was relocated is shown in Figure 6. The position data for vessels entering NY Harbor is now more robust and continuous.
Figure 4: AIS data collected by the three AIS receivers operated by Rutgers University. They are located at Loveladies, NJ (LOVE), Sandy Hook, NJ (HOOK) and Tuckerton, NJ (Tuckerton).
Figure 5: AIS data in the vicinity of NY Harbor for November 9, 2009 exercise.
The work on the DHS CSR 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 13 MHz combined transmit/receive antenna and test if it was effective for current mapping and vessel detection. An exercise was conducted on May 4, 2010 using the new style antenna. The best ship detection plot is shown in Figure 7. Using the AIS data that was recorded simultaneously with the HF radar data, we are able to reduce the detections that are associated with a particular vessel. This is shown in Figure 8. A rudimentary association of the HF radar ship detections with the AIS data is shown in Figure 9. More work needs to be performed on the association algorithms. These initial results show that there is no loss in moving from the two antenna system to the one antenna system. This work will be continued in Year 3, including via a third CSR joint field experiment planned to be conducted in the Miami area. Among other challenges to be examined, we will be evaluating our capability to quickly deploy and operate our HF Radar system, in an area where we have no prior operating experience.
Figure 7: Association plot of HF Radar ship detection data (dark blue squares) associated with the GPS information from the vessel (aqua blue line).
Figure 8: Monostatic Pepper plot at FFT Length 128 and threshold 7dB using IIR background
Challenges and Progress: Vessel Detection Software Development

- **Background:** CODAR has been developing vessel detection software intended for dual-use with the U.S. IOOS national network of SeaSonde coastal HF radars; these efforts began in 2001 within a joint program with Rutgers funded by ONR. This MATLAB code ran offline on raw data (Range Files). Considerable success was demonstrated in these early programs. With the DHS CoE funding, and beginning in Year 1, these MATLAB codes were improved and work was begun converting them to C from MATLAB, so they could run in real time on the remote SeaSonde stations in the field, similar to the tools that produce radial currents and waves from the sea-echo data.

- **Bistatic Improvements:** Detection capability for multi-static radar configurations (where transmitter and receiver are separated, including buoy transmitters) had not been finished within the MATLAB code before the CSR Year 2 began. During Year 2, and with DHS support, this capability was completed and tested. This capability allows the code to output ASCII files with bistatic detections at the same time as the conventional backscatter ASCII files are produced, and in the same format. Thus the positions and velocities of candidate targets are available for multi-static geometries, allowing multiple detections of the same target. The latter capability is important in overcoming sea-clutter limitations that mask single-radar backscatter detections nearly 40% of the time.

- **Completion of RCS Addition to Code:** Within the ASCII output detection files, it had been intended to include the radar cross section (RCS) of the detected vessel, based on received signal level of its echo. This had not been completed in a way that would allow robust RCS estimation at all SeaSonde operating bands. With the DHS support, this work
was completed in Year 2. RCS is an important target descriptor that can aid in classification and identification of the vessel.

- Progress on Translation from MATLAB to C: Significant progress was made on this during Year 2. At the beginning of the year, a plan with schedule was organized that detailed the C-code blocks required to do this. There are many complexities in C that are not required for the offline MATLAB code, such as needing to run different spectral length and background scenarios in parallel rather than sequentially. The original plans called for the code to be ready for real-time beta-testing on SeaSonde field units at the end of Calendar Year 2010 (half way through CoE Year 2); that scheduled milestone is still on track. Details of other progress during Year 2 follow:
  - The MUSIC module to determine target bearing was completed using a C eigenvalue/eigenvector package from the Mac's Acceleration veclib framework.
  - Several "classes" (i.e., in C coding, these are like blocks or subroutines) have been completed: CrossSpectra; IIRBackground; MEDBackground. Other classes are underway: FindTargets; TargetDetection; UserPreference.
  - Initially the C code will create multiple ASCII detection files in parallel: those based on different spectra/FFT lengths; those based on different backgrounds used for thresholding (IIR or median); those based on different threshold levels; and those based on whether the receiver is seeing backscatter or bistatic echoes. After some real-time beta testing in early 2011, the MergeTarget class will combine all of these into a single ASCII detection file output.
  - Considerable thought and ultimate flexibility is being build into calculation of the IIR background. E.g., a single background going back in time can be interpolated to use for shorter time-series FFT spectra.
  - The median background is valuable as an alternative to the IIR background. However, calculation of this background uses 80% of the run time, with most of this time spent sorting data. A vector sort routine within the Accelerate/vDSP framework is to be tried, in order to improve performance considerably.

RiverSonde Test and Evaluation, April - June 2010.
During Year 2, students from a Rutgers/Stevens team won a RiverSonde Grant from CODAR that provided free use of a RiverSonde along with setup and training. Don Barrick and Pete Lilleboe of CODAR made a trip to Stevens in April to select a location for the RiverSonde unit and antenna so that it could observe an appropriate span of the Hudson River from the Stevens campus. A location was selected on the roof of the Babbio Center building.

The initial intention was to observe the radial component of surface flow across the river and analyze its utility within models, e.g, NYHOPS. The river at this point is 1200 m wide, to reach the other side at Manhattan. Prior RiverSonde experiences at 430 MHz UHF frequency had not achieved distances greater than 250 m. Theoretical calculations suggested that raising the antenna would increase the maximum range, something that does not happen at HF. Indeed, the RiverSonde -- radiating only 1 watt of power --
completely spanned the 1200-m wide river from the Babbio Center roof at a height 42 m above the water -- an exciting and welcome validation of theory.

Students quickly observed that -- in addition to the river surface echo used to derive flow velocities -- the RiverSonde was observing the vessel traffic on the Hudson, for which it had not been intended. As a result, a considerable amount of additional time and research energy on their part was devoted to vessel tests, both using the passing vessels of opportunity as well as controlled tests with a Stevens craft. These proved successful, and the enthusiastic students presented these results -- as well as surface flows -- at the Summer Research Institute while Dr. Barrick was present. These are being written up for publication.

Finally, the Stevens vessel was used with a transponder to measure antenna patterns before the RiverSonde experiment was concluded. These patterns allow more accurate calibration that enables much more precise bearing determination than the alternative: i.e., idealized patterns based on textbook or theoretical calculations. These calibrations were used to reprocess the data offline that were gathered during the summer.

The success experienced during these summer experiments is a dramatic illustration of how educational activities (in this case, the CSR Summer Institute) and research activities can come together in a very meaningful and productive way. We plan to continue this type of joint effort in the 2011 Summer Institute.

*Radar Surveillance Lectures for Summer Research Institute*

Dr. Donald E. Barrick put together lectures on HF radar that were presented within the CoE Summer Research Institute at Stevens. These covered fundamentals useful for college-level staff who have no background in radar, allowing them to understand the unique nature of HF - UHF coastal radars that are used for maritime domain awareness as well as mapping surface current and river flows, and monitoring sea state. These materials begin with first principles, but cover all important aspects of HF radar physics and signal processing, including: HF antennas; propagation beyond the horizon over the sea; radar cross sections (RCS) for vessel targets and sea echo; the role of noise in system performance; signal formats appropriate and used at HF; demodulation and digital signal processing; extraction of information from the echoes. Approximately 15 students and postdocs attended these lectures. These lectures applied both to the use of the CODAR SeaSonde as well as the RiverSonde.

*The Quest for Permanent HF/VHF Frequency Approvals*

a. **Background:** All of the HF/VHF SeaSonde radars -- as well as all prior HF radars used for ocean monitoring going back to the early 1970s -- have been operating under "experimental" secondary license authorizations. Nearly 400 SeaSonde radar units have been built and shipped worldwide. Even internationally, these must operate under the same "experimental" licensing procedure, as this is presently the internationally
agreed protocol that is managed by the ITU (International Telecommunications Union in Geneva). As the name "experimental" implies, the FCC grants these licenses on a temporary basis. As radars have proliferated and are becoming permanent as part of the U.S. IOOS HF radar observing network (with similar but less extensive networks in other countries), continued operation under this experimental licensing procedure is being curtailed. It became obvious several years ago that worldwide **primary allocations** must be sought and obtained for HF radar operations, regardless whether the agency needing the data is NOAA for environmental observations, or DHS/Coast Guard for maritime domain awareness / vessel surveillance / search and rescue. As a result, three years ago the U.S. delegation at ITU began a proposal for primary allocations under WRC Initiative 1.15, to be voted for approval in early 2012. Approved primary allocations will allow permanent operations for "HF Oceanographic Radars" as the category was named, for this radio spectral service. An agreed-on U.S. position must be approved by NTIA (National Telecommunications and Information Agency within the U.S. Dept. of Commerce). There are two parallel routes to obtaining NTIA endorsement of a U.S. proposal, and both are being pursued. In the meantime, the U.S. has enlisted backing from all other countries interested in this sensor technology; all of those delegations also meet in Geneva and are supportive. Details of status are given below:

b. **U.S. Government Route:** One route toward approval of new primary bands from ITU/WRC is a government proposal. This began three years ago within NOAA/ORFM (Office of Radio Frequency Management) under Jim Mentzer and Dave Franc. Several documents have been prepared in the meticulous formats demanded of that forum. Some of these have studied interference potential by or to the HF radars; these are called "Sharing Studies". The various government agencies who will benefit or be impacted by use of the radio spectrum for this purpose can criticize or demand changes to the proposal, before it is approved by NTIA as the official U.S. position at Geneva. The only government agency who has objected thus far is the U.S. Air Force, and this has been a problem in getting the unanimity desired by the NTIA in order to endorse a U.S. position. The AF has yet to list or defend their objections. Don Barrick attended the May ITU/WRC meeting as a delegate, hoping to move toward agreement on this important issue. However, the AF objections within the U.S. Government proposal has led to pursuit of a second route to reach an NTIA-approved position; this is described in the next section.

c. **FCC/Industry Route:** The FCC (Federal Communications Commission) is an agency of the U.S. Department of Commerce whose purpose is to assist and regulate U.S. industry and non-governmental bodies in use of the radio spectrum. As such, proposals can come through their IWG (Industry Working Group) process that will go to NTIA for approval as a U.S. position at ITU/WRC. Beginning a year ago, Dr. Don Barrick (President of CODAR Ocean Sensors) began preparing an industry-sponsored proposal to go up through this route. After many iterations within the IWG and much helpful assistance from relevant FCC personnel, this proposal is now nearly ready to be transmitted to NTIA. The positions in this proposal are nearly identical to those in the U.S. Government-Route documents: i.e., a request for primary allocations in four or five
HF/VHF bands. This will allow permanent coastal HF radar networks to operate without needing "experimental" licensing that is no longer relevant for operational needs, and that requires radar shut-down if a primary licensee complains. The hope is that this document can help strengthen the U.S. Government-Route proposal, so that together, these can overcome any continued Air Force objections or at least force a reasonable negotiated compromise and move toward a U.S. position for primary licensing. Without this, continued and expanded HF coastal radar operations for DHS and other established societal needs will be difficult.

RU27 TransAtlantic Glider Mission
In April of 2009, Rutgers University scientists and their undergraduates began their second attempt to fly an underwater glider across the Atlantic Ocean from New Jersey to Spain. Continuous monitoring of the flight was coordinated by professors (S. Glenn, O. Schofield, and J. Kohut) working with teams of undergraduate students in the Rutgers Atlantic Crossing research course during the Spring and Fall semesters, and with teams of undergraduate interns funded under the DHS CSR project via a 2009 Pilot for the Summer Research Institute. Typically 10 teams of 2-3 students were working in parallel on different aspects of the mission, from watching the weather for winds and waves, validating the ocean current models, monitoring the glider flight performance and its ability to communicate, analysis of the glider data, definition of a safe landing zone, and logistics for recovery. Over 25 multi-authored student research posters were constructed and presented at research meetings from the flight, including one summary student poster representing the entire team that was presented at the Ocean Sciences meeting.

Advances in Collaborative Glider Mission Planning Capabilities
A Glider flight across the Atlantic would require mission planning capabilities well beyond those available to students. We had operated several month-long ONR Coastal Predictive Skill experiments from a “collaboratory” located at a remote field station (Glenn et al., 2000; Glenn and Schofield, 2004), and recently completed a series of NSF studies of the Hudson River plume with an on-campus collaboratory (Chant et al., 2007). But both of these studies were relatively short duration, measured on time-scales of a few weeks. A Trans-Atlantic Mission would require planning tools that could be operated and sustained for many months.

Some of these capabilities were developed during the ONR Shallow Water 2006 Joint Experiment on the New Jersey outer shelf (Tang et al. 2008). In this experiment, a distributed team of collaborators was provided an online coordination portal that could be accessed over the Internet from shore or via HiSeasNet from a ship. At Rutgers, we developed the mission planning tools for coordinating a fleet of gliders and providing daily updates of the environmental conditions that we used to coordinate the glider fleet. The ability to produce your own data products locally from any location with a WiFi connection was critical for the success of the coordination activities. The difficulties arose in our inability to easily overlay datasets acquired from difference sources, and the
need for multiple layers of people to assemble and post new data products to be shared among participating scientists. With significantly fewer resources for the student Trans-Atlantic missions, a more efficient methodology would be required.

To accomplish these missions, collaborations would be required between a distributed team located on both sides of the Atlantic. The international team would require (1) common access to the variety of datasets acquired and forecasts generated on both continents, (2) the ability to overlay the datasets and forecasts in a common operational environment to create new composite analyses for mission planning, and (3) the ability to share our analyses, results and interpretations with our distributed team of partners. To accomplish the first task, we designed a collaborative web portal where access points to all existing analyses products and programs could be posted and shared. Rather than build our own set of software tools for overlaying the wide variety of available data and forecasts, we chose to use Google Earth as our mission planning tool for the second task. Many of the required datasets where already in Google Earth, and new datasets could be added with much less effort than that required to develop yet another dedicated path planning tool. The full capabilities to overlay and compare spatial maps, to zoom and pan, to pull off latitudes and longitudes, to measure distances and bearings, etc., was all provided by Google Earth once the new data was inserted. Major data layers added to Google Earth include global ocean forecasts (NCOM, NLOM, HyCOM), maps of sea surface height and the resulting geostrophic currents, satellite derived sea surface temperature and ocean color maps, and the glider tracks with depth averaged currents. The third piece was the ability to post the new analyses products along with an explanation in an open forum blog. The blog was used as our own mission log, but also as a means to share interpretations and comment on others. The blog became a textbook for students beyond our undergraduate classroom as the oceanographic concepts, and their relation to the glider mission, were discussed.

Real-World Applications – Fisheries & Oil Spills
The three collaborative tools developed for this undergraduate education project found immediate application in all of our glider activities. The educational tools were first applied in a semi-operational setting to the Mid-Atlantic Bight as part of our IOOS Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS). MARCOOS includes over 35 Co-PI’s from 22 institutions distributed around throughout the Mid-Atlantic. The specific application was to coordinate regional glider missions with NOAA fisheries surveys.

The next application was to help coordinate the IOOS response to the Deepwater Horizon Oil Spill in the Gulf of Mexico (Figure 10). The website was specifically targeted at the glider deployments conducted by iRobot, the Navy, SIO/WHOI, University of South Florida, Mote Marine Lab and Rutgers. The Deepwater Horizon web portal was used to introduce the purpose of the site, included a real time map of the tracks of the gliders and the location of the oil spill, links to all the raw products produced by others, and links to the Google Earth kml files so anyone could download them and produce their own planning products. The Google Earth interface displays only a small portion of the data
available, in this case an ocean model forecast, HF radar surface currents, glider tracks, buoy tracks, and the track of Tropical Storm Bonnie. Bonnie did not pass over the Loop Current Eddy that recently formed, and remained weak as it propagated northwest across the cooler waters of the Gulf and into Louisiana. The interactive Deepwater Horizon Blog shows the typical types of analyses generated, one focused on the vertical sections of data acquired by the gliders, and another focused on the horizontal maps produced by the composite analyses. The application to the Gulf of Mexico oil spill demonstrates the broader impact of education on research and applications. Because the collaborative interfaces were developed and refined during the 2008-2009 missions of RU15, RU17 and RU27 – some of which were funded under the DHS CSR project - the tools could be quickly repurposed to serve research and societal needs in an emergency response to an unexpected environmental disaster. This event, like several others during the initial two years of the CSR work, dramatically illustrate how leading-edge research coupled with education give rise to technology products that can directly support the maritime first responder community in the field.
Figure 10: Collaborative interfaces developed for the educational flight of RU27 now being applied to the Gulf of Mexico Deepwater Horizon oil spill for IOOS. (A) Web portal to organize access to a wide range of data products. (B) Google Earth interface to overlay ocean model results (HyCOM sea surface height and surface currents), HF Radar Surface current fields, glider and drifter tracks. (C) Public blog website to post and explain new results.
Highlights

- Participated in the CSR Joint Field Experiment on November 9, 2009.
- Participated in the COE review meeting in San Juan January 21, 2010 and gave presentation.
- Attended the DHS University Summit March 10-12, 2010.
- Gave Module 6 – High Frequency Radar of the Port Security Sensing Technologies course offered by Stevens Institute on April 21, 2010.
- Have begun conversations with USCG and DHS S&T about potential for HF Radar for over the horizon vessel detection.
- Led the High Frequency Radar group, one of four research groups within the Summer Research Institute which focused on the detection of small vessels.
- Created technology development road map for the use of HF Radar for search and rescue (SAR) and vessel detection (see Figure 11).
- CODAR Ocean Sensors made improvements to the ship detection code by adding bistatic capability, a Radar cross section calculation and porting the code from Matlab to C.
Future Plans

- We will be testing a beta version of the real time ship detection code on one of the 13 MHz HF radars this coming year
- We will be analyzing the ship detection data to determine why a detection is made on a particular vessel and not on another
- We anticipate that further applications of the RiverSonde will be examined during Year 3, including during the planned (third) CSR joint field experiment
- Un-attended HF Radar operation in remote environments such as Alaska and Puerto Rico will be examined, via our partnerships with the University of Puerto Rico and with CIMES

Collaborations

University of Puerto Rico Mayaguez (UPRM)
- Assistance in CODAR site operation and maintenance
- Assisted in antenna pattern measurements on trip to Puerto Rico October 2009
- Worked with 2 students from UPRM for DHS Summer Institute

Stevens Institute of Technology
- Collaborated with Stevens on November 9, 2009 field experiment
- Worked with Stevens technical staff on the maintenance and operation of the HF radar units in NY Harbor

CSTARS- University of Miami
- Collaborated with CSTARS on November 9, 2009 field experiment
- Worked with 1 student from U Miami for DHS Summer Institute

Ocean Power Technology on the LEAP Program

Michael Lovellette at the Naval Research Laboratory

Documentation

Publications


Schofield, O., Kohut, J., Glenn, S., Morell, J., Corredor, J., Orcutt, J., Arrott, M., Meisinger, M., Chao, Y., Chien, S., Thompson, D., Brown, W., Oliver, M., Boicourt, W. A regional Slocum glider network in the Mid-Atlantic coastal waters leverages broad community engagement. Marine Technology Society. (submitted)

Schofield, O., Glenn, S., Orcutt, J., Arrott, M., Brown, W., Signell, R., Moline, M. A., Chao, Y., Chien, S., Thompson, D., Balasuriya, A., Oliver, M. Developing and deploying automated sensor networks to advance ocean science. EOS, 91(39) pp.345-346.

Presentations
Table 2 presents a summary of presentations given during Year 2.

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<th>Meeting</th>
<th>Location</th>
<th>Date</th>
<th>Title of Presentation</th>
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<tr>
<td>Caribbean Regional Association for Ocean Observing</td>
<td>San Juan, Puerto Rico</td>
<td>Dec 1, 2009</td>
<td>Coastal Ocean Observing System - MARCOOS region</td>
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<tr>
<td>2010 Ocean Sciences</td>
<td>Portland, Oregon</td>
<td>February 23, 2010</td>
<td>Results from the Mid Atlantic High Frequency Radar Network</td>
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<tr>
<td>Port Security Sensing Technologies Course</td>
<td>Washington , DC</td>
<td>April 21, 2010</td>
<td>HF_Radar_DC_Course01_RUCOOL_Intro HF_Radar_DC_Course02_History HF_Radar_DC_Course03_Signals HF_Radar_DC_Course04_Waves HF_Radar_DC_Course05_Current_Mapping HF_Radar_DC_Course06_Vessel_Detection HF_Radar_DC_Course07_OPT HF_Radar_DC_Course08_NOAA</td>
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<tr>
<td>Scandinavian International Workshop on Coastal HF Radar for Oceanographic Applications</td>
<td>Goteborg, Sweden</td>
<td>May 3-4, 2010</td>
<td>Building a Regional Ocean Observatory for the Middle Atlantic Bight: Our View from the COOLroom</td>
</tr>
<tr>
<td>Briefing to NJ Governor</td>
<td>Trenton, NJ</td>
<td>May 27, 2010</td>
<td>Ocean Connections: Mapping potential pathways between the spill in the Gulf of Mexico and the Jersey Shore</td>
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CSR Year Two Report
October, 2010

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<tr>
<td>Basque Government Meteorology and Climatology Department Workshop - Azti Technalia</td>
<td>Port of Pasajes, Spain</td>
<td>May 18, 2010</td>
<td>Building a Regional Ocean Observatory for the Middle Atlantic Bight: Our View from the COOLroom</td>
</tr>
<tr>
<td>The Instituto Espaniol de Oceanographica's Workshop on Ocean Observing</td>
<td>Gijon, Spain</td>
<td>May 20, 2010</td>
<td>Building a Regional Ocean Observatory for the Middle Atlantic Bight: Our View from the COOLroom</td>
</tr>
<tr>
<td>The Balearic Islands Coastal Observing System's HF Radar Facility Implementation Workshop</td>
<td>Mallorca, Spain</td>
<td>May 27, 2010</td>
<td>Building a Regional Ocean Observatory for the Middle Atlantic Bight: Our View from the COOLroom</td>
</tr>
<tr>
<td>CSR Summer Research Institute</td>
<td>Hoboken, NJ</td>
<td>June 8, 2010</td>
<td>National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)</td>
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<tr>
<td>Homeland Security Summer Institute, Briefing to Pacific Northwest National Laboratory</td>
<td>Hoboken, NJ</td>
<td>July 29, 2010</td>
<td>Small Vessel Detection with UHF Radar in the Hudson River</td>
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**Resources Leveraged**

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<th>Details</th>
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<tbody>
<tr>
<td>Mid Atlantic Regional Coastal Ocean Observing System</td>
<td>Admin Assistance, electronic data processing, web support, technical support for the 30 site, operational, regional HF Radar network</td>
</tr>
<tr>
<td>NOAA IOOS Program National Surface Current Mapping Plan</td>
<td>CODAR loan brokering, data coordination with the U.S. National Network, operating frequency permissions</td>
</tr>
<tr>
<td>UCSD Coastal Observing Research and Development Center</td>
<td>Web hosting, Data quality control for the national HF Radar network.</td>
</tr>
<tr>
<td>NAVSEA LEAP Program</td>
<td>13 MHz SeaSonde deployed in NJ, 13 MHz bistatic transmitter deployed on shore and at sea</td>
</tr>
<tr>
<td>CIT – Funded</td>
<td>Additional support for vessel tracking test in Norfolk to evaluate the system for a Navy port.</td>
</tr>
<tr>
<td>NRL TOME - Pending</td>
<td>Continued development of bistatic transmitters on self-powered buoys for offshore operations on the U.S. coast and in denied access areas.</td>
</tr>
<tr>
<td>NJ Board of Public Utilities - Funded</td>
<td>Proposal Pending to Install Four 13 MHz CODAR SeaSondes along the south Jersey coast, extending the range of the NY Harbor testbed.</td>
</tr>
<tr>
<td>CODAR Ocean Sensors</td>
<td>RiverSonde equipment grant provided the instrumentation that was the centerpiece of the HF Radar group within the Summer Research Institute</td>
</tr>
</tbody>
</table>
Figure 12: Combined transmit and receive 13 MHz antenna at Brant Beach, NJ.

Task 1.2, Project 2, University of Puerto Rico Mayaguez (Dr. Jorge E. Corredor, PI)

Project Objectives and Significance to Stakeholders
- 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
- To supply 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)

Research Milestones Met
- A second CODAR 12 MHz HF radar installation was completed at the FURA Police station on Añasco Beach (see Figure 1).
Antenna pattern tests were implemented at FURA aboard a police go-fast boat and at CDDO (Club Deportivo del Oeste) aboard M/V BRASS BALLS in October 2009.
Field validation experiment
A surface current validation experiment was implemented jointly with CarICOOS in July 2010 within our HF Radar coverage footprint. The Lagrangian component of the experiment consisted of one Pacific Gyre Iridium satellite tracking-enabled Microstar drifter, two coastal buoys equipped with Garmin ASTRO GPS/VHF, and four nearshore visually tracked passive drifters. The Eulerian component consisted of one ADCP emplacement. Data are currently being analyzed and a second experiment is planned for winter.

Products served currently through the CarICOOS web page:
Surface current maps [http://www.caricoos.org/drupal/node/141](http://www.caricoos.org/drupal/node/141)

Highlights
- CSR-UPRM co-hosted the “CSR All Investigator Meeting” at the Caribe Hilton Hotel in San Juan, PR in January 2010.

- Dr. Corredor presented a conference entitled “CSR: Nationwide and CSR activities in Puerto Rico” at “Colegio de Ingenieros y Agrimensores de Puerto Rico” Jan 2010 by. Attendance ~60.

- CSR-UPRM co-hosted (with CarICOOS) an informal HF RADAR WORKSHOP delivered by Erick Rivera and Ethan Handel of Rutgers University in January 2010. Attendance 16. Attendees paid their own costs for the workshop, including travel.

- Participation in the 2010 Summer Research Institute (SRI) and further outcomes:
Four UPRM undergraduate civil engineering students (Jose Mesa, Lenny Llauger, Ariel Marrero and Omar Lopez) were selected to attend the SRI at Stevens Institute of Technology. UPRM students worked in the Acoustics, Systems and HF Radar groups. Dr. Miguel Canals spent a month at Stevens Institute supervising students, acting as faculty co-lead (week 2 with Dr. Tom Wakeman), lecturing on Maritime Domain Awareness in Island Environments, and collaborating with the HF Radar team. Mr. Lenny Llauger (SRI HF Radar team) has been recruited as a research assistant to work with the UPRM-CSR HF Radar. Mr. Omar Lopez, (SRI HF Radar team), has also joined our research group as part of the CariCOOS project. Mr. Jose Mesa (SRI Systems team) has been awarded the Puerto Rico Louis Stokes Alliance for Minority Participation Scholarship under which he will carry out a study of port resiliency at the Port of San Juan under the supervision of Dr. Canals.

Collaborations
- Maritime Security
  - FURA Fuerza Unida de Rápida Acción, Puerto Rico Police (Ship tracking, Maritime situational awareness)
US Coast Guard (Ship tracking, Maritime situational awareness, Search & Rescue Operations). The USCG is awaiting repair of the system (see below under issues) for deployment of a set of self locating data marker buoys (SLDMB used for search & rescue) for validation of HFR-derived current patterns.

- Maritime operations
  - Pilots at the Port of Ponce are using our AIS for to estimate time of arrival of vessels to their port.

**Future Plans**

Data analysis will be carried out for the HFR-derived surface currents validation experiment performed on 7 July 2010 in the “trade wind season”.

We intend to pursue implementation and data analysis of a second “northerly swells season” validation experiment.

We plan completion of a second AIS station located at the UPR campus in Mayaguez.

We will conduct site selection for a stand-alone bi-static HFR on Mona Island.

We will do high frequency radar ship tracking experiments to be validated with AIS

**Resources Leveraged**

<table>
<thead>
<tr>
<th><strong>Caribbean Integrated Coastal Ocean Observing System - CarICOOS</strong> At UPRM</th>
<th>Admin Assistance, data processing, web support, technical support, Site ID, site selection &amp; permitting</th>
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</thead>
<tbody>
<tr>
<td><strong>Rutgers University Coastal Ocean Observing Laboratory</strong></td>
<td>Technical assistance, technical support, technology transfer 12 MHz CODAR system loan</td>
</tr>
<tr>
<td><strong>Texas A&amp;M University</strong></td>
<td>12 MHz CODAR system loan</td>
</tr>
<tr>
<td><strong>NOAA IOOS Program National Surface Current Mapping Plan</strong></td>
<td>CODAR loan brokering, data coordination with UCSD-CORDC, site selection</td>
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<td><strong>UCSD Coastal Observing Research and Development Center</strong></td>
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<td><strong>Fuerza Unida de Rápida Acción – FURA Policia de Puerto Rico</strong></td>
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<td><strong>UPRM Department of Marine Sciences</strong></td>
<td>Logistic support, onsite labor for FURA installation</td>
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</tbody>
</table>
Task 1.3 Nearshore and Harbor Maritime Domain Awareness Via Layered Technologies (Note: there are three PIs on Task 1.3, A. Sutin, Stevens Institute of Technology, J. Nickerson, Stevens Institute of Technology, and B. Reagor, Monmouth University)

Task 1.3, Project 1. Stevens Institute of Technology (A. Sutin, PI)

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 threats detection, classification and tracking. Stevens researchers have applied the scientific approach to the problem, starting from an understanding of the main physical phenomena – the generation and propagation of sound from various threats. The Stevens Maritime Security Laboratory, or MSL, provides the capabilities of real-time experimental research of acoustic wave propagation in the Hudson River Estuary. Initially, the focus of MSL was on threats posed by surface and subsurface intruders including SCUBA divers and small boats by using passive acoustic techniques. Using these initial capabilities, MSL investigated the set of acoustic parameters fundamental to underwater acoustic threat detection including: diver acoustic signature, acoustic transmission loss, and acoustic environmental noise.

In 2009, under the DHS CSR project, the Stevens Passive Acoustic Detection System (SPADES) was developed and tested. The SPADES allowed for the real-world evaluation of our developed methods for target detection, classification and tracking. Significantly, the SPADES was successfully applied for the detection and bearing finding of NAVY divers in tests conducted at the Naval Undersea Warfare Center, Newport, RI. The system schematics and pictures are shown in Figure 1.

Numerous tests and associated enhancements and improvements to SPADES were performed during the CSR Year 2 effort. These enhancements include the use of the system as a primary component of an integrated, detect-and-respond underwater security
system that employs an unmanned underwater vehicle (UUV) that is directed to the detected sound source. The first tests of this application were conducted in Lake Hopatcong, New Jersey. Also as part of the Year 2 CSR effort, the SPADES application was extended to include surface vessel detection and bearing finding. Several joint tests demonstrated the advantages of the concurrent use of satellite imaging and passive acoustics for maritime domain awareness, including the 2nd CSR joint field experiment in November, 2009, and the DHS Summer Research Institute. To-date, the acoustic signatures of nearly 1,000 surface vessels have been recorded and logged into a database. Both of these applications and enhancements will be discussed later in this report.

Research Milestones Met

*Development of Hardware and Software of Stevens Passive Acoustic Detection System (SPADES) for Surface and Underwater Surveillance*

The Stevens Passive Acoustic Detection System (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.

The SPADES is based on the acquisition and analysis of sound generated by various threats; it does not radiate any sound itself. The system uses just four hydrophones and provides simultaneous acquisition and analysis of acoustical signals. The analysis function includes arbitrary digital filtering, spectral analysis and cross-correlation for simultaneous processing of signals from several hydrophones, acoustical source separation and determination of bearing for different targets relative to the central underwater mooring. The system also records and stores the complete raw acoustical data set, enabling further research and analysis of the acoustic signatures. The system components include a land-based computer and an in-water system (Figure 2). 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. The system uses hydrophones manufactured by International Transducer Corporation - Model ITC-6050C. They are sensitive in the band of up to 100 kHz and provide -157 dB re 1V/1μPa 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 sub-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 main method for acoustic source detection and bearing determination is based on the calculation of cross-correlation of acoustic signals recorded by various pairs of hydrophones. Let us consider how the measurements of cross-correlation can be used for estimation of bearing to a source of sound.

Figure 3. The noise radiated by a source reaches the hydrophones separated by distance L with a delay that depends on the direction, $\alpha$ of the source with respect to the line perpendicular to the hydrophone axis.

Let us consider the signals received by two hydrophones separated by a distance L. They record the noise radiated by a source whose direction makes an angle $\alpha$ with the normal to the line between the hydrophones. The distance between the source and the hydrophones is much larger than L. An example of such a configuration is illustrated in Figure 3. The noise radiated from the ship 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. Let us assume a single ship contributes to the acoustic field and that the signals \( h_1(t) \) and \( h_2(t) \) recorded by the two hydrophones are delayed versions of the same signal:

\[ h_2(t) = h_1(t - \Delta T) \]  
\hspace{1cm} (2)

and \( \Delta T \) is the delay introduced in Eq. (1). The cross-correlation of the signals is defined as:

\[ R_{12}(\tau) = \int_{-\infty}^{\infty} h_1(t') h_2(\tau - t') dt' \]  
\hspace{1cm} (3)

For two delayed signals of the form (2),

\[ R_{12}(\tau) = R_{11}(\tau - \Delta T) \]  
\hspace{1cm} (4)

The cross-correlation \( R_{12}(\tau) \) of the signals from the two hydrophones is the same as the autocorrelation \( R_{11}(\tau) \) of the signal from the hydrophone 1 but shifted to the time \( \tau = \Delta T \). Because the autocorrelation of a signal is maximum at \( \tau = 0 \), the cross-correlation is maximum at \( \tau = \Delta T \). This means that time location of the maximum of the cross-correlation can be used to estimate the direction to the ship. The SPADES system display shows the cross-correlogram of the signal for any hydrophone pair in the form of a floating chart representing the cross-correlation as a function of time. The time variations of the cross-correlation function are presented in the form of 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. A snapshot of the SPADES system cross correlation display is presented in Figure 4.

![Figure 4. SPADES system display showing cross-correlogram of the signal for hydrophone #0 and #2 (upper panel) and in color map form (lower display).](image-url)
The time delays in the cross correlation function can be recalculated to the source bearing angle using the Eq. (1).

\[
\alpha_1 = \arcsin\left(\frac{c\Delta T}{L}\right)
\]

\[
\alpha_2 = \pi - \arcsin\left(\frac{c\Delta T}{L}\right)
\]

(5)

It is seen that the same time delay takes place for two possible angles, which produces ambiguities in the process of the source bearing measurements by a single pair of hydrophones. This ambiguity can be solved using signal processing of several cross-correlation signals (see below).

The schema of SPADES signal processing is presented in Figure 5.

Figure 5. The schematic of SPADES signal processing.

The system has a graphical user interface that provides the following displays:
- 2 polar intensity displays; each shows two possible lines of bearing relative to the central mooring, but together they provide a unique bearing
- Correlograms of the processed data
- Spectrograms of the individual hydrophone outputs

These displays allow monitoring of the hydro-acoustic signals and estimation of bearing towards multiple simultaneous targets.

The electrical signals coming from the hydrophones are preamplifier and transferred to the digital signal using a National Instrument Data Acquisition system. Every channel is sampled at 200 kHz allowing analysis of acoustical signals in a wide frequency band up
100 kHz. The spectra of the received signals are shown in the form of a spectrogram that allows visual observation of the time varying frequency content of the signals. It is also possible to identify sources of acoustic interference, such as active sonar systems and depth-sounders, allowing for activation of appropriate filtering in the next step of the signal processing.

The cross-correlation is computed using a frequency domain Fast Fourier Transform algorithm by first taking the cross spectrum power density and then weighting with the processor of choice. To that an additional custom weight is added which accounts for relative spectral properties of emissions from various sources. The system operator can choose the frequency band for better detection and separation of various targets with different spectral content. Removal of the low frequencies reduces the interference due to ships. The filtering also allows the separation of radiated sounds in different frequency bands, e.g. SCUBA divers, Unmanned Underwater Vehicles, Diver Propulsion Vehicles, and surface swimmers.

Finally, as the distance between the hydrophones imposes a maximum possible delay between signals, only the information associated with the possible subset of delays is kept. As a result, a peak at a delay related to its direction is associated with every broadband source (diver or ship). If the frequency content is uneven, the cross-correlation peaks get modulated by high frequency. The representation of the correlation can be improved by computing its envelope using the analytic signal associated with the cross-correlation. This operation can be made at little cost by including it into the computation of cross-correlation. As the analytic signal is obtained by removing the negative frequencies of the signal, these frequencies can be removed during cross-correlation computation while in the frequency domain. The absolute value of the obtained complex cross-correlation is then taken to obtain the envelope. For each considered pair of hydrophones, the cross-correlation processing results in an image, as shown in Figure 6, that we call a cross-correlogram. Such images can be used for visual inspection, or can serve as a basis for further analysis.

Figure 6 shows an example of a recorded cross-correlogram in the Hudson River with a frame of the recorded video. The cross-correlogram shows the signals from three vessels and a diver. Only one moving vessel is visible on the recorded video (the vessel in the foreground was used for system deployment and was not moving or emitting noise during the experiment); the two other vessels were outside the area of the video recording.
Figure 6. Example of a recorded cross-correlogram in the Hudson River with the frame of the recorded video.

The polar intensity displays (Figure 7) show cross-correlation intensity mapped to estimated bearing from 2 pairs of hydrophones. The amplitude of the cross-correlation function is displayed using color, while its angle is recalculated from the time delays. The most recent data appears at the perimeter of the circle and moves toward the center with time. The system utilizes four (or more) low cost sensors placed in the shape of a convex polygon to automatically detect and localize divers, and alert the operator.

Figure 7. Polar intensity diagram.
The sensors do not have to be precisely placed to provide high accuracy target bearing, a great advantage over other systems, as precise sensor placement is very difficult due to tides and currents in underwater environments. Also, the hydrophones could be accidentally moved, in effect distorting the measurements. Because of the large hydrophone spacing considered (tens of meters or more), mounting them on a frame cannot be considered, particularly because we are interested in developing a highly portable, low-cost, easily deployable system. For these reasons, and for the purpose of knowing precisely the geographical coordinates of the system, an acoustical positioning of the hydrophones is required. Such a precision position locator was developed in Year 2, and is used as part of the deployment of the system. For the hydrophone positioning procedure, a supporting boat with GPS receiver, signal generator and acoustical emitter is employed. The boat has to move slowly and make 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 correlograms for various pairs of hydrophones and provides information about the time delay between acoustic signals at the hydrophones. A specially developed program calculates the hydrophone positions that provide least square root deviation of the calculated time delays to the measured values. Stevens researchers have developed automated diver detection algorithms based on the detection of the breathing rate of the diver. The Diver Indicator (DI) value is computed in a cumulative manner from a previously computed envelope signal. The envelope signal has a low sampling rate (e.g. 8 or 20 Hz) and is expected to present high values during certain phases of the diver breathing and low values otherwise. An example of such an envelope is shown in Figure 8.

Figure 8. Example of an envelope signal displaying a repeated pattern corresponding to a diver’s breathing.

This results from post processing of a cross-correlogram computed from the method described in the previous section (see Figure 9 below). The envelope signal presents a square-like pattern that corresponds to the diver breathing.
The idea behind the DI is to identify this square-like pattern and determine whether its rate is consistent with diver breathing. The first step consists in labeling the various samples of the envelope as low and high values, resulting in a binary signal. As the envelope can come from various sources (i.e. different processing and/or different sensors), it is advisable to determine the threshold from the envelope itself. A further advantage of this is that it allows for coping with slow variation in the background noise. The duration between the switching of the binary signal is then analyzed in order to assess whether it is consistent with a physiologically possible breathing rate.

Application of SPADES for Detection of Underwater Targets

The main interest in the CSR development of SPADES was to provide support to the protection of ports against underwater threats. It is assumed that terrorist organizations have been training individuals in scuba diving techniques [2]. The US Coast Guard is working actively on the development of techniques for port protection that includes the Integrated Anti-swimmer System [3]. There are numerous commercial diver detection sonar systems in production; a good review of these systems can be found in [4].

As mentioned earlier, the Stevens system employs passive acoustics as opposed to many existing underwater detection systems that employ active acoustics systems. We should here mention that in addition to high cost, there are several major disadvantages to active (sonar) systems. First, there is a high rate of false alarms. Objects with acoustic target strength similar to that of a diver, including fish, can be detected by active sonar systems. The problem is exacerbated in shallow water by multiple reflections from both the seafloor and the surface. Secondly, it is possible for an adversary to detect if an active sonar system is in use before dispatching a diver. Additionally, existing techniques that rely on active sonars may be prohibited in many domestic harbors due to their environmental effects (e.g. impact on marine mammals). These limitations of active sonar systems prompted our work in the development of passive acoustic diver detection methods, and under the CSR project, SPADES has been applied to several applications of underwater threat detection, including divers and UUVs. Several examples of the SPADES application for this purpose are presented below.

Figure 10 shows the SPADES display in a test of diver detection.
Figure 10. The SPADES display in a test for diver detection.

The upper panel shows the target bearing in polar diagram, the display in the middle shows a periodic signal produced by two divers and the lower panel shows the variation of the “diver indicator”. In the shown display the “diver indicator” exceeded the definite threshold and shows that divers are present.

Figure 11 shows an example of when a UUV signal was recorded. The upper panel shows the signal spectrogram where three types of signals are present: UUV radiation produced by motor and propeller, acoustic modem signal and UUV sonar. The lower panel shows the correlogram that allows UUV bearing determination.
Figure 11. Record and acoustic signal generated by UUV.

**Application of SPADES for Target Localization and Guidance of an Unmanned Underwater Vehicle – Reducing the Latency of Response**

The results presented in the previous section described the application of the SPADES for underwater target detection and bearing finding. Target localization can be provided by triangulation of bearings from two or more systems. Stevens has built one system with four hydrophones. An examination of the use of the system for target localization can be conducted by splitting of the hydrophones into two pairs as shown in Figure 12.
As was discussed earlier, the time delay of an acoustic signal produced by a target are connected with the bearing angle to the target by expressions
\[ \Delta T_1 = \frac{L_1 \sin \alpha_1}{c}, \]  
\[ \Delta T_2 = \frac{L_2 \sin \alpha_2}{c}, \]  

The time delays are measured using the cross-correlogram of the two signals. Knowing the spacing between the hydrophones, the time delay can be related to a direction of arrival of the signal relative to the line segment connecting the pair. The correlation between a pair of hydrophones is ambiguous in that it is not possible to determine on which side of that line segment the source is located.

Typically four hydrophones are deployed in a cross arrangement with the legs of the cross being about 10m. In this arrangement, there are six pairs of hydrophones whose signals can be correlated and processed to eliminate the ambiguity. Note that the time segment of the correlation function associated with the signal is an approximation to the autocorrelation function of the signal that may be used for classification. The four hydrophones in the system can also be deployed as displaced pairs. In this arrangement, a bearing line from each pair allows a source to be geodetically located if the hydrophone pairs are geodetically located. The pairs are usually arranged to cover an area of interest and the orientation and spacing of the pairs is chosen to provide coverage of that area. By choosing the orientation of the pairs and limiting the angles resolved, the potential for false locations associated with the ambiguous bearings can be eliminated.

In Year 2, the Stevens team conducted tests that not only provided target localization but also used this information for targeting of a UUV to the underwater source of sound. Our aim in this application is to overcome a primary weakness in maritime security systems by reducing the latency, or time to response, associated with virtually every existing threat detection system. This section of the report describes an experiment that used SPADES to detect and localize a source and simultaneously steer a UUV to intercept the source.
Stevens Institute of Technology conducted the experiment at the Lake Hopatcong Yacht Club (LHYC) on Lake Hopatcong in New Jersey, USA. The test was conducted over two days in August 2010 and was the third in a series.

The bathymetry surrounding the LHYC is illustrated in Figure 13. The four hydrophones and the central mooring to which they are cabled were deployed from a rigid-hull inflatable boat (RHIB). The figure indicates the locations of the deployed hydrophone pairs. The hydrophones are mounted on stands slightly less than 1m tall, so they were set at depth of 9-11m. The cable from the mooring to shore provides power and a fiber-optic data link. The mooring contains a data acquisition system and processor. The arrangement of the hydrophones was chosen to provide coverage for a 100m square box whose center was offset 100m from the mid-point of the two hydrophone pairs. The operators for the acoustic system and UUV were stationed in a sheltered work area at the base of the pier. There were two operators, one for the acoustic system and one for the UUV. During the testing, the RHIB was equipped with a programmable signal emitter (PSE). The PSE was capable of emitting various signals ranging from broadband noise, previously recorded signals of divers using various kinds of SCUBA, and recorded signals of ships and UUVs. The signal emitter was also equipped with a GPS receiver and a line-of-sight radio link so that the location of the emitter could be transmitted back to the operator of the acoustic system.

The Stevens passive acoustic system was modified for this test. One of the processing functions computes the correlation function between the signals received at pairs of hydrophones. The correlation function will have a peak when the time delay corresponds to the time that it takes a signal in the water to propagate between the pairs. The time
delays can in turn be related to directions of arrival (provided the distance to the source is more than 3-4 times the hydrophone spacing). Figure 14 shows one of the ways that data is displayed on the acoustic system’s operator console. In this display, the magnitude of the correlation function is mapped to a level indicated by the color bar. The display is oriented so that the level at the top of the disk indicates the level of the correlation function corresponding to a signal coming from true North. The newest data is plotted farthest from the center of the display and is propagated toward the center as new data is processed. The display also indicates the orientation of the hydrophone pair and the pair in the figure corresponds to the SE pair in Figure 14.

![Figure 14. Correlogram display for the SW hydrophone pair.](image)

In order to localize and track the intercepting UUV, the system must be able to uniquely identify and track the UUV signature. The UUV used during the tests was equipped with a small pinger operating at 72kHz with a 1Hz repetition rate. Previous testing had shown that the pinger often could not be detected in the presence of background noise. An energy detector was developed that isolates a 1kHz band around the pinger’s 72kHz center frequency. A threshold is determined by estimating a level from neighboring portions of the spectrum with the 1kHz sub-band removed. Additional processing makes sure that the pulse has the proper duration. A delay and corresponding direction of arrival are computed by locating the leading edge of the pulse from two hydrophone channels. The most recent detection of the UUV pinger is indicated in the display in Figure 15 by the yellow triangular cursor. Past detections are indicated by yellow rectangles on the display and move toward the center as the display updates. The data displayed in the figure also includes a diver signal. In this case, a pre-recorded signal of
a diver using open-circuit SCUBA gear was being transmitted by the PSE. The direction to the diver is indicated on the display by the triangular blue cursor. The bearing to the diver is currently updated manually by the operator.

Figure 15. Display showing geodetic locations of hydrophone, diver, and UUV.

The image in Figure 15 shows the most recent locations of the diver and UUV as well the locations of each hydrophone pair. The display updates in real time as detections are made by the signal processing algorithms and results are overlaid on an image of the operational area. Nautical charts can also be used when available. The operator interface for the UUVs is shown in Figure 16. The controls allow the operator to issue commands to the UUV by an acoustic communication link. The display shows the positions of both the sound source and the UUV as determined by the passive acoustic system. When the diver’s location is updated on the server, the UUV interface uses the last location of the UUV to compute a new heading for the UUV and then transmits that heading to the UUV. The UUVs position in Figure 16 is indicated by the green line and cursor. The purple line indicates the UUV’s internal estimate of its position. The red line indicates the position of the source. The jagged appearance of the line is a result of the fact that the operator is periodically updating the location of the diver manually and not on each detection, which would produce a smoother result. Future work in Year 3 will include research into techniques to enable the integrated system to operate more autonomously.
Passive acoustic methods for small boat detection and classification
Passive acoustic methods are based on the detection of sound produced by moving boats. Passive acoustic methods have been applied for submarine detection for many years. There is a limited amount of publicly available publications covering the parameters of submarine sounds: many results were published just after World War II [5] and some parameters of Russian submarines are presented in [6]. Results of ship noise measurements can be found in many publications. Much research has been conducted on the impact of the noise generated by ships on marine life and a good review of this work can be found in [7]. A detailed description of the mechanisms of sound generation by ships can be found in [8,9]. According to [9], the main sources of vessel sound include:

- The prime movers - typically diesel engines.
- Shaft-line dynamics
- Propeller radiated pressures and bearing forces.
- Air conditioning systems.
- Maneuvering devices such as transverse propulsion units
- Cargo handling and mooring machinery
- Vortex shedding mechanisms
- Intakes and exhausts.
- Slamming phenomena
The noise radiated by small vessels can be applied to small vessel detection and classification. Measurements of acoustic signatures of ships can be used for ship classification. During our Year 2 CSR effort, it was found that one of the most reliable acoustic parameters for ship classification is the spectrum of the ship noise envelope. 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, that can be used for ship classification. The method for estimation of the envelope modulation is known as DEMON (Detection of Envelope MOdulation on Noise) [10,11]. The signal processing of the DEMON is simple: The envelope of the recorded signal is calculated by using a Hilbert transfer and the spectrum of the envelope is used as a basis for ship classification. Stevens has developed a cross-correlation method for DEMON ship signature extraction [12]. This method is based on measurements of the cross-correlation function with relatively fast repetitions. The energy of the cross-correlation signal around any peak is proportional to the energy of the noise radiated from the definite direction. Time variation of this signal represents the envelope of noise energy. The spectrum of the energy around the cross-correlation peak is the same as the DEMON spectrum.

Examples of DEMON and full spectra analysis of passing boats are presented below for signals recorded in the Hudson River by students during the Summer Research Institute on July 3, 2010. In this test, the hydrophones were deployed in the Hudson River near the Stevens campus, and the acoustic signals were recorded over a week. Figure 17 presents results of the 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, Stevens Research Vessel Savitsky, and a DEP barge) moved along the river. Figure 17a presents the cross-correlogram of the signals recorded by two hydrophones. Figure 17b shows the spectrogram of the signal and Figure 17c presents the DEMON spectrogram of the ship noise.
Figure 17. Cross-correlogram (a), full spectrogram (b), and DEMON spectrogram (c) for three ships shown at the upper panel of the Figure

It is seen that the whole spectrum of the acoustic signal (Figure 17b) has a wide band random spectrum without a clear narrow band spectral component that can be used for ship classification. The DEMON spectrogram (Figure 17c) contains several stable narrow band signals that are seen as horizontal lines. These frequencies in the DEMON spectra can be used for ship classification.

References

Collaborations

a. **USCG Sector New York** via information-sharing, and permits for in-water sensors in NY Harbor, and HF RADAR on Staten Island.

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

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

d. Improvement of automated diver detection algorithms was done in collaboration with **Advanced Acoustic Concepts**.
**Future Plans**
1. Novel algorithms for ship signature extraction based on a joint signal processing of DEMON signals from several hydrophones will be developed. The suggested method will require 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.

2. Continue development of vessel classification methods using a library of acoustic signatures collected by Stevens.

3. Develop and build new passive acoustic system optimized for small vessel and go-fast boats detection, classification and tracking.

4. Participation in the diver detection test in NUWC (Newport, RI) where the Stevens automated diver detection and characterization algorithm will be tested in conjunction with the Advanced Acoustics Concepts passive acoustic array for diver detection.

5. As part of a collaboration we are leveraging with 4D Security, we will explore fusion of SPADES data with radar and AIS data as part of a permanent installation on the Hudson River.

**Documentation**


Resources Leveraged
The SPADES was developed in close collaboration with the Stevens Maritime Security Laboratory supported by the Office of Naval Research.

The work for development of automated algorithm of passive acoustic diver detection was partially supported by Advanced Acoustics Concepts.

The improvement of SPADES and tests in Panama City and Key West Florida were conducted under support from ONR and other DoD agencies (Blue Dart project).

Task 1.3, Project 2. Stevens Institute of Technology (Dr. Jeff Nickerson, PI)

Project Description and Significance to Stakeholders
Security operations, and especially responses to emergencies, require collaborations between multiple agencies. The Department of Homeland Security is responsible for promoting and facilitating such collaborations among its subsidiary agencies and between federal, state, and local authorities. Successful collaboration often hinges on the coordination of both divergent instrumental interests—resources and rewards—and divergent interpersonal interests—e.g. identity and status. Failure to coordinate interests at the interpersonal level can often lead to failures to coordinate instrumental interests. Consequently, inter-agency collaborations can sometimes devolve into parallel single agency efforts; the benefits of collaboration are lost. The long-term goal of this research program is to help DHS both anticipate and overcome some of the cognitive and interpersonal challenges to security and emergency response.

As part of the Year 2 effort, CSR investigated whether and when the divergence of instrumental and/or interpersonal interests leads to breakdown of collaboration. We found that collaboration fails when partners either contribute unequal resources towards the collective effort or identify with differing social groups. More importantly for DHS, CSR investigated what might be done to mitigate the impact of interpersonal discord on bargaining outcomes. We found that perspective taking and sometimes empathy can dampen differences of investment or identity. For all of these investigations, we relied on human-subjects experimentation as our primary method of investigation. In designing these experiments, we synthesized insights from behavioral game theory and both cognitive and social psychology.

Throughout the process of collaboration, collaborators bargain over their interests. Instrumental interests include money, tools, and other tangible resources. Interpersonal interests include identity, status, and other “social realities.” Bargaining often entails explicit and face-to-face efforts to coordinate interests, though success often depends on tacit agreement on what is fair to all collaborators. With regard to collaborative responses
to emergencies, one can conceive of the problem of coordinating interests (whether instrumental or interpersonal) as a “public goods” game in reverse. Previous public goods research considered what motivates contributions towards that good. Often, though, people cannot or do not choose whether (or how much) they will contribute to collective efforts. These are distributive problems, where people instead bargain on how to allocate the resulting goods.

CSR used human subject experiments as our primary tool for investigating the coordination of interests. For these experiments, we designed a tacit bargaining game (a game played without communication and little to no knowledge of one’s opponent/collaborator). Negotiating positions in tacit bargaining often represents the “invisible lines in the sand” beyond which one or the other negotiator, when engaged in explicit bargaining, will not concede his or her interests. Many theorists have argued that an equitable distribution of a common good stands out amongst the solutions to the distributive problem. In other words, negotiators should tacitly agree that a “fair” share of a common good means an equal share of that good. This argument assumes that negotiators either think alike or automatically take one another’s beliefs and feelings into account. Our experiments challenged this assumption; social-cognitive skills must be primed for equity to stand out.

In our first study, we compared various instrumental effects on tacitly bargained solutions to distributive problems. We also investigated what social-cognitive factors that might shift the invisible lines towards greater equity. We modeled tacit bargaining as a card game in which a four-ace hand wins a prize (see Figure 1). 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 agree on how to share the prize. Prior to bargaining, some subjects played one of three social-cognitive games: one that primed perspective-taking skills, another that primed empathic skills, and a third that primed general social intelligence. The remaining negotiators performed no priming task.
Figure 1 - The tacit bargaining game

Absent any social-cognitive priming, we found that bargaining often fails when one player contributes more instrumental resources (more aces) to the common pool than their partner; both partners often demand the larger share of the rewards. Nevertheless, we found that encouraging players to take one another’s perspective reduces the effects of lopsided contributions; partners are more likely to demand fair shares and, consequently to strike a bargain. Empathy did not help players as much perspective taking; social intelligence did not help at all. Figure 2 summarizes these results.
In our second study, we examined the interplay of instrumental and interpersonal interests, and how these two factors together affect tacitly bargained solutions to distributive problems. We modeled tacit bargaining using the same card game as before, except that players were informed of the social identity (i.e., ethnic background) of their alleged partner. Like study one, bargaining fails when players focus on social identity; the likelihood of a “fair” (50/50) bargain depends on whether or not partners share a
social identity. Again, though, social cognition mitigates the impact of interpersonal
discord on bargaining outcomes. Interestingly, while perspective taking increases the
likelihood of fair bargains among partners who do not share an identity, empathy
increases fairness among partners with a shared identity.

These findings are here deemed critical for DHS stakeholders because they offer
empirical clues as to why inter-agency collaborations can sometimes devolve into
multiple parallel efforts, lacking collaborative force and utility. Our findings can serve as
the basis for metrics and protocols towards more productive inter-agency negotiation and
collaboration. Thus, the benefits are two-fold: awareness of various psychological effects
on collaborative efforts, and ways to dampen or, even, harness those effects.

Research Milestones Met
The milestone that were met during the year include the development of the experiments
on one shot bargaining games, the design of social-cognitive games, the design of social-
identity games, and the preparation of conference papers on extant results (Association
for Psychological Science) that were presented on May 27-30, 2010.

In addition, we conducted experiments on dampening conflicts of interest, conducted
experiments on dampening regional identity, and prepared conference papers comparing
extant results (Psychonomics Society, Society for Judgment & Decision Making). These
papers are currently under review.

Other milestones include the ongoing experiments on dampening gender identity, the
ongoing design of power-conflict games, and the preparation of a report on one shot
bargaining and dampening conflicts of interest. The preparation of the report on
dampening social identity is in process.

Future Plans
Coordinating Interests: Tacit bargaining games allow for fine-grained experimental
control. With this control we were able to test the impact of specific factors and specific
combinations of factors on the coordination of interests and the success of collaboration.
Consequently, we have learned a great deal about what creates conflict among
collaborators and what skills might help them see beyond the conflict. At the same time,
we need to increase the naturalism of the bargaining tasks before we can apply our
findings to the actual negotiations between those engaged in coordinating security and
emergency response efforts.

We will use explicit bargaining games (games with communication and increasing
knowledge of one’s partner) to investigate how players negotiate the boundaries between
their interests during a collaborative task. We will use observational field studies to
inform and bring greater naturalism to our laboratory work. In both laboratory and field
work, we are especially interested in whether, when, and how often players concede their
own interests for the greater good. We plan to systematize the mechanisms of concession into metrics and protocols for more productive inter-agency negotiation and collaboration.

Harnessing the Crowd: Our general goal is facilitate and improve collaboration in security operations and emergency response. At least for certain aspects of security and collaboration, that collaboration might include the public. Public collaboration goes beyond the "see something, say something" campaign in New York City and, now, the nation as a whole. The public can provide more than just many eyes in many places; they can also contribute the cognitive skills to interpret what they see.

Our CSR collaborators have been developing a number of interconnected detection technologies. Making sense of the data will require decision technologies that can emulate the best human detection expert working under the best conditions. Obviously, human experts will play a major role in training the decision technologies with which they will work everyday. The public can also play a role in the training process.

For instance, protein researchers at University of Washington have harnessed the collective cognition of human puzzle solvers to help train protein folding algorithms. Similarly, researchers at Carnegie Mellon University and, later, at Google Inc. have used crowds of gamers to train image categorization systems to recognize semantic relationships between images. In large measure, these systems rely on the fact that human beings are exceptional pattern recognizers and that crowds of people see things from diverse perspectives and make uncorrelated errors. We will explore possibilities for using crowds to train detection algorithms.

Another skill at which people excel is developing explicit rules from the patterns they recognize. Rules make problem solving more efficient. Rules are also easy to communicate. Small groups that rely on constant, rapid communication to coordinate their problem-solving efforts tend to develop conventions (explicit rules) for talking about problems and problem solving procedures. We will also explore the use of crowds of small-groups to train decision technologies on the use of such rules.

Task 1.3, Project 3. Monmouth University (Dr. Barbara T. Reagor, PI.)

Project Objectives and Significance to Stakeholders
The Rapid Response Institute (RRI) led by Dr. Barbara T. Reagor, 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, 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’s relevant initiatives including the Summer Research Institute, workshops, outreach, and training. During Year 2, we contributed to the CSR and its DHS stakeholders in several areas.

- The MU faculty were active participants in the planning and conduct of the CSR Summer Research Institute (SRI). The MU faculty provided presentations and exercises for SRI Students on Emergency Management, Trustworthiness and Credibility in Emergency Response, Critical Infrastructure Protection, Public and Private Emergency Management Partnerships in the maritime environment, and maritime policy issues.

- RRI conducted 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. The team developed a web portal for Emergency Preparedness, Emergency Management and Flood Prediction utilizing real-time sensor data (Floodview) and created a prototype software system, Emergency Responder (ER) Locator using RFID technology coupled with a building software visualization product (FloorView).

- MU Assisted local communities’ adaptation strategies to address the climate change and sea level rise issues that impact our National Security. UCI Participated in several workshops on Green Ports and Blue Harbors, Sea Level Rise and Coastal Inundation.

- MU continues to work with CSR and their Stakeholders to identify user needs, societal benefits and improved links between coastal monitoring and ocean observations networks.

Research Milestones Met

MU’s RRI & UCI have participated in all of the Year 2 activities of CSR, including:

- MU provided a Faculty Research Mentor for the CSR Summer Research Institute from June 7, 2010 through July 28, 2010.
- RRI made presentations and contributed to outside speaker coordination for the CSR SRI.
- 2 MU Seniors (Mr. Walter Seme – Software Engineering major and Mr. Joseph Bongi - Math major) successfully participated in the Inaugural CSR Summer Research Institute at Stevens.
- The MU team made a presentation of their research and education activities at the CSR midyear conference on January 21, 2010 in Puerto Rico.
• MU participated in meetings at Stevens and conference calls as needed.
• RRI/UCI conducted a 2010 STEM Summer Research Program at MU that was funded by CSR, the US Army and MU from June 28 through August 26, 2010
• Ms. Lauren Landrigan has begun her PhD Research program at Stevens Institute working for Dr. Jon Wade in support of RRI Rises and Stevens CSR.

STEM HS Summer Research Program
During the summer of 2010, RRI conducted its third HS Student/Teacher STEM integrated program with funding from the CSR project, the MU School of Science and US Army contract W011-SR-09-C-0056. The RRI HS Summer Research Program is an applied research/education program, with 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.

The 2010 Rapid Response Institute High School Summer Research Program (HSSRP) focused on applied research in Dynamic Information Visualization (DIV) in the emergency management domain. DIV addresses issues in the viewing of rich data sets related to objects that move or change value over time. The work involved the development of system prototypes in two areas.

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 named Floodview. The second prototype called Emergency Responder (ER) Locator involved multiple advanced technologies: RFID, robotics, and electronic floor plans integrated into a solution. The solution addressed the display of the location of first responders in a building displayed on floor plans through the detection of RFID tags on their persons. A robot was dispatched to visit a first responder based upon that individual being motionless for a specific length of time.

This work was performed by nine high school students guided by a University professor and two high school teachers. Four students from Freehold Borough High School, four students from Middletown High School South, and one student from Allied Health and Science High School worked in teams to develop these solutions in nine twenty hour weeks. The following summarizes the activities.
Floodview and ER Locator

*Floodview*

*Objectives:*

- Floodview (Figures 1 and 2) provides a prototype web site that displays data from five deployed flood sensors. It can define users of the web site, determine how they would use the web site, determine how best to show the information the users need, and discover algorithms for predicting water levels and flood stages.

- The users of Floodview include Public (to take precautionary measures, evacuate, and for recreation conditions), Emergency Management (to declare evacuation and determine evacuation routes), and Researchers for trend analysis.

*Figure 1. Floodview System Architecture*
Figure 2. Floodview Web Portal Shots
**ER Locator**

**Objectives**
The Application may be describes as follows:
Imagine a building catches fire and emergency responders arrive to extinguish the fire and evacuate any civilians trapped inside the building. Upon retreating from the building, all civilians safe, the incident commander takes roll call. There is an absence of one fireman. Normally a specialized Search and Rescue (SAR) Squad would be deployed to find this fireman and escape the building as fast as possible. The job of finding an individual in a collapsing building is obviously life threatening and for the safety of the stranded fireman and the SAR Squad you want this done as quickly as possible.

- It is preferable that the incident commander didn’t have to take roll call.
- It is clearly preferable that the SAR Squad knows where the stranded fireman is.

The Mission is described by the following steps:
- Research Passive RFID Tags.
- Explore tracking/pinpointing the location of a Passive RFID Tag.
- Develop a GUI (graphical user interface) for an incident commander to see the location of his men.
- Enable the deploying of a robot to a location of a selected tag.

**Collaborations - Leveraging Existing Programs:**

**Joint Mobile Command and Training Center**
Together, the RRI and UCI develop and coordinate the delivery of exercises, workshops and training “On-Site” to Stakeholder Communities utilizing the RRI Joint Mobile Command and Training Center. The JMCTC Truck (Figure 3) was developed under US Army Contract W911SR-06-C-0007.
During CSR Year 2, the JMCTC truck was used in several state exercises. RRI conducted these exercises as part of our research on the effectiveness of Technology Insertion and Rapid Information Sharing in support of Emergency Preparedness, Response and Training. The work is supported by current US Army Contract W911SR-09-C-0056 “Rapid Information Sharing for Event Decision Support” (RISES). A list of demonstrations, exercises, and events that were supported over the past year appear below. Demonstrations of emergency response capabilities leveraging IT Technology Insertion are denoted by a D, exercises denoted by an X followed by an L, C, S, F, or M representing local, county, state, federal, or military participation, and with Real-time event support denoted by a single E.

<table>
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<tr>
<th>Date</th>
<th>Name of Event</th>
<th>Location</th>
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<tr>
<td>September 26, 2009</td>
<td>Joint MRC/CERT Hurricane Exercise w/Monmouth County OEM</td>
<td>Wolfe Hill Recreational Area, Oceanport, NJ</td>
<td>XC</td>
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<td>June 10 – 24, 2010</td>
<td>JUICE Live Shooter Exercise Support to FBI, Military – Civilian Communications Exercise</td>
<td>Fort Monmouth, NJ</td>
<td>XF</td>
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</table>
Stevens PhD Program in support of Trustworthiness and Credibility
Prompted by the work performed under the CSR project, and supported by US Army Contract W911SR-09-C-0056, RRI researcher Ms. Lauren Landrigan has begun a PhD Research program under the direction of Dr. Jon Wade, Associate Dean of Research, School of Systems and Enterprises at Stevens.

As a precursor to research at Stevens, a paper was presented in May 2010 at ISCRAM, “Determining Credible Sources During an Emergency Situation” by Ms. Lauren Landrigan, Dr. Allen Milewski and Ms. Jennifer Baker. The abstract of the paper states that an important aspect of working in an emergency operations center (EOC) is determining what information is credible and what actions to take based on that information. Information during an emergency may come from various sources and EOC workers may not know the information providers personally. Information may come from electronic sources where the exact source of the information may be unknown and credibility may be affected.

For this study, ethnographic interviews were conducted with emergency management subject matter experts to gain insights on credibility. The interviews included a series of questions to learn about the current processes of an EOC, what sources generally provide information about the situation and what factors determine credibility. These interviews are ongoing and this paper provides a summary of the interviews completed at this point. The expected outcome of this study is a potential software system with features to enhance credibility despite weak source information.

Trustworthiness and Credibility of information sharing are key issues associated with Ports and Harbor security and research in this area directly supports CSR and its Stakeholders.

Collaborations from the Urban Coast Institute
The UCI Director worked with the NOAA Coastal Services Center, other federal agency representatives, and Ocean Research and Resources Advisory Committee (ORRAP), to plan a Sea Level Rise-Inundation Community Workshop for December 3-5, 2009 in Leesburg, VA. The workshop brought together leaders from a range of these communities to discuss and develop a framework on coastal inundation and sea level rise.
that can help guide where investments should be made to enable states and local
governments to assess impacts and initiate adaptation strategies over the next decade.
The UCI Director prepared a report and made a presentation to the workshop
summarizing “Coastal Community Stakeholders Needs for Addressing Sea Level Rise
and Inundation.”

UCI is a participant in the New Jersey Coastal Community Resilience Demonstration
Project funded by the NOAA/National Sea Grant Office, Coastal Communities Climate
Adaptation Initiative (CCCAI). The goals of this demonstration project is to work with
selected local communities to develop a Coastal Vulnerability Visualization mapping
tool, and refinement of a “Getting to Resilience” community characterization survey for
use by coastal communities. Partners include the NJ Department of Environmental
Protection, and NJ Sea Grant Coastal Hazard extension at Stevens Institute of
Technology.

UCI worked with the American Association of Port Authorities to convene a Green Ports
and Blue Harbors: A National Ocean Policy Framework for Maritime Transportation
workshop in Washington, DC on August 11, 2010 the objectives of the workshop was to
Identify how a National Ocean Policy will facilitate marine transportation, and identify
opportunities to increase collaboration among ports, federal agencies and the
environmental community to support stewardship of ocean resources and the expansion
of sustainable ports and maritime commerce. Senior Administration, port and
environmental representatives attended the meeting. Topics included The Significance of
National Ocean Policy and Marine Spatial Planning to Maritime Transportation, and
Climate and Shoreline Change: Mitigation and Adaptation Strategies for Ports.

These activities of the Urban Coast Institute directly support CSR and its Stakeholders.

Benefits to DHS
This research is directly applicable to CSR research goals and initiatives. Specifically, the
research being conduct by Dr. Nickerson on the complexity of human coordination for
decision support is a complementary component to the technology and systems research
being conducted by RRI. The research can be leveraged directly into CSR research
directions for Cognitive and Resilient Port Security.

The 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
community’s needs.

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

<table>
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<tr>
<th>Project ID</th>
<th>Project Description</th>
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| W911SR-09-C-0056 | Rapid Information Sharing for Event Decision Support  
Provide key learnings, procedures and methodologies useful to CSR – provided assistance from professors and students |
| W911SR-08-C-0083 | All Hazards Exercise Training Tool  
Technology transfer, evaluate the Mobile Trainer in a Trunk prototype for use with Decision Support Systems |
| Monmouth University’s Joint Mobile Command and Training Center | Provide use of the JMCTC at cost for vehicle operation (fuel and driver and technical support) plus leverage students, PI's and Professor support |
| Monmouth University’s Urban Coast Institute | Director Tony MacDonald will be a Co-PI with Dr. Reagor and will leverage the Coastal and Oceans Policy work of the UCI for Community Outreach |

### Year 2 Accomplishments, Monmouth University

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<th>Categories of Accomplishments</th>
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<td>Students matriculated - Emergency Response</td>
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<td>Papers - Emergency Response</td>
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<tr>
<td>Requests for assistance or advice from DHS/FEMA</td>
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<td>Congressional Testimonies or Briefings</td>
<td>3</td>
</tr>
<tr>
<td>Projects Completed - Other sources</td>
<td>2</td>
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Task 1 (Joint) Results from the 2nd CSR Joint Field Experiment – “How Small is Too Small”. November, 2009

Detection, classification and tracking of small vessels are considered critical tasks in support of port security and the security of coastal and offshore operations. DHS issued the Small Vessel Security Strategy [1] with one of the goals “to enhance maritime security and safety based on a coherent framework with a layered, innovative approach.” As mentioned earlier in this report, the CSR research follows a layered approach utilizing above water and underwater surveillance techniques. The 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 vessel detection, classification, identification, and tracking. In this section we present some of the results of the second of a series of DHS-supported joint field experiments, conducted in NY Harbor in November, 2009, where satellite imagery was combined with concurrent passive acoustic surveillance. The use and evaluation of the HF Radar system during the same field experiment was described in the HF Radar section earlier in this report.

Satellite sensors used for ship detection include Electro-optical (EO) and Synthetic Aperture Radar (SAR) systems. High-resolution EO satellites provide the clearest images, but these sensors can be obstructed by clouds and fog. SAR satellites can operate day and night and in all weather conditions providing reliable surveillance, but interpretation of these images is more challenging. SAR sensors also offer a variety of modes which allow collection at a variety of resolutions. Higher resolution comes at the cost of reduced areal coverage. This gives the user the opportunity of choosing spotlight modes (highest resolution/smallest area) for monitoring ports and choke points in different ocean basins, as well as strip map modes (lower resolution/larger area) for monitoring vessel traffic inbound and outbound of ports and harbors. The recently launched satellite SARs have spotlight modes that provide spatial resolutions comparable to high-resolution optical sensors.

Satellite sensors can detect ships directly or indirectly by observing the resulting wakes. In many cases, both the vessel and wake are observable. The size of a wake is typically much larger than the size of the ship often making the wake more easily detectable than the ship itself. Even very small boats can create a wake detectable from space though the actual vessel is too small to be observed. Difficulties can arise in the detection of even large boats that are moving slowly or are adrift with engines off. A wide range of factors determines the detectability of vessels from satellite sensors, including environmental conditions, vessel material, size and speed.

Results from the November, 2009 field experiment during three tests where satellite images and acoustic surveillance were conducted at the same time and place are presented below.
The satellite image shown in Figure 1 was received from the EO system Formosat-2 collected at 15:22:13 UTC on November 9, 2009. The magnification of several ships and their ground photographs are presented. Note that the ground photographs were not taken at the time of the satellite image and in no way reflect environmental conditions or vessel movements at the time of the satellite image. From the first glimpse of the image, vessels underway, especially at higher speeds, are very noticeable. This is primarily due to the strong optical reflection of the vessels’ wakes. The Stevens Research vessel “Savitsky” with the deployed Stevens Passive Acoustic Detection System (SPADES) was moored and produced no wake; it was barely observable in the satellite image. In addition to location information, vessel heading is apparent in the EO image from the wake characteristics. Clearly the wake is the primary signature for small vessels in an EO image.

Also in Figure 1, two of the boats that were captured in the EO image were also detected earlier in the morning by COSMO SkyMed-2 at 10:50 UTC (5:50 AM local time) on November 9, 2009. These boats were known to be the same in each image by correlation with Automatic Identification system (AIS) data. The vessels themselves provide much stronger returns in the SAR image than in the EO image. In contrast, wakes, while visible in the SAR, tended to be faint relative to the bright reflections from the vessels.
Therefore, vessels dead-in-the-water would likely be more detectable by a SAR system, depending of course on material from which the vessel was constructed. In SAR imagery, direct detection of radar returns from the vessel appears to be the primary signature. In cases where both wake and vessel are observable, Doppler offsets in the image can provide estimates of the vessel’s speed. As mentioned earlier, CSTARS will continue to work on this aspect of detection during the CSR Year 3 effort.

The SPADES hydrophones were placed at Latitude 40032.596° and Longitude -74000.116°. The depth at the point of measurements was about 10 m. Figure 2 shows the orientation of hydrophones that was estimated based on signal processing of the noise radiated by ships with known GPS coordinates that were received using the AIS system.

![Figure 2. SPADES hydrophone orientation](image)

The main signal processing was the cross-correlation of the signals recorded by various pairs of hydrophones. An example of the calculated cross-correlation between two hydrophones #0 and #2 is shown in Figure 3. The cross-correlation was computed for a time window of 500ms duration. It is seen that the cross-correlation has several peaks. These peaks happen at time delays that are correlated with the bearing angle to the ship via the techniques described earlier in this report.

![Figure 3. Example of the cross-correlation envelope showing three peaks of signals produced by ships](image)
The time variation of the cross-correlation function in the form of a cross-correlogram is shown in Figure 4.

![Cross-correlogram showing peaks of variation with time. The yellow line indicates time when cross-correlation shown in Figure 3 was taken.](image)

**Figure 4. Cross-correlogram showing peaks of variation with time. The yellow line indicates time when cross-correlation shown in Figure 3 was taken.**

For ship tracking, an automated program of cross-correlation peak detection was developed. The time delays of the detected peaks were recalculated to the ship bearing. The results of this recalculation are presented in Figure 5. As noted earlier, any time delay peak in the cross-correlation function can be associated with two bearing angles. This means that recalculation of the time delays to the target bearing produces twice as many tracks as there are real targets. Half of the tracks are imaginary targets. The satellite image allows simple separation of imaginary targets from the real targets – a significant benefit of the use of multiple sensors. Target #1 is a SeaStreak ferry moving from South to North. This ship provided its GPS position through AIS, which allowed us to verify the maximal distance of detection as 7 km. Target #2 is a fast boat moving from West to East. It is seen that this boat changed direction at 15:23:00 and moved from East to West. Target #3 is a boat moving to the south of the array. It was not identified at the time of the test and its track shows that this boat moved from East to West.
Figure 5. Acoustic tracks of water traffic at time of satellite flyover. The red lines indicate the real targets.

As discussed earlier in this report, measurements of acoustic signatures of ships can also be used for ship classification, using estimation of the envelope modulation via DEMON (Detection of Envelope MOdulation on Noise). The recorded DEMON spectra of five ships are presented in Figure 6. It is seen that every ship has its own acoustic signature.
Several tests combining acoustics with satellite imaging were also conducted by the student team in the CSR Summer Research Institute. One of the tests was conducted during the TerraSAR-X Satellite Pass on 7/13/2010 at 11:13:21 [GMT]. The satellite image (Figure 7) captured 3 distinct vessels in the Hudson River. Judging from the wake the vessels left behind and their location in time, the three vessels are the Savitsky, a NY Waterway ferry heading north and another NY Waterway ferry heading south. Additional vessels can be seen at the south end of the image. While the Savitsky had its engine turned off awaiting its launch into a particular route, it drifted south due to currents in the Hudson. The Savitsky engaged its engine for a short time to readjust to a northern location. The engagement of the engine during this short time left a clear acoustic signature.
The cross correlogram shown in Figure 8 allows us to record various boat movements before and after the satellite flyover. The spectrogram of the full acoustic noise shown in Figure 8 indicates the acoustic level of various boats. The highest noise level was observed from Savitsky because Savitsky was closer to the hydrophone array than the other ships. The DEMON spectra shows various distinctive frequencies that can be used for ship classification. Variation of the DEMON frequencies from Savitsky is connected with movement of the ship – Savitsky started and stopped during the signal recording. It is seen that DEMON spectra allowed us to observe variation of the ship motor RPM.
Figure 8. Cross-correlogram (a), full spectrogram (b), and DEMON spectrogram (c) during satellite flyover

Figure 9 presents several DEMON spectra for various ships recorded during the satellite flyover.
Figure 9. The DEMON spectra for various ships recorded during the satellite flyover.

An optical satellite image of the Hudson River was taken by Cosmo Sly-Med2 Satellite. The satellite pass on 7/13/2010 at 22:46:57 [GMT] accounts for three vessels in the waters (Figure 10). Our log from that day indeed acknowledges the sailboat near the NYC coast moving from north to south. The additional larger vessel seen in the satellite image is a barge dead in the water that had been on this location from the previous day. The NY Waterway ferry seen to the South, although out of our log view, is on track with the ordinary schedule of the ferry transportation from downtown Manhattan into Hoboken NJ. The sailboat appearing on the far side of the Hudson is recognized by cross correlation diagrams (Figure 11).
Figure 10. Satellite images recorded during Cosmo Sky-Med-2 flyover.
Let us consider what advantages can be received from a combination of acoustic and satellite surveillance. As shown above, passive acoustic surveillance can provide continuous bearing to sources of sound. The acoustic signature of a target can also be applied for target classification.
The first benefit of satellite imaging for the passive acoustic system is the opportunity for accurate location of hydrophone positions. Knowledge of the hydrophone positions is required for accurate target detection. Usually, the location where SPADES hydrophones are dropped in the water is measured by GPS that provides relatively rough position estimation. After dropping the hydrophones in the water, they sink in the ocean in a possibly non-vertical way and their coordinates on the bottom are not the same as the coordinates at the point of release. Getting information about the position of various acoustic sources at the time of satellite flyover allows the calculation of the hydrophones position. Knowledge of the coordinates of two separated sources and the approximate coordinates of the hydrophone center allows finding of the hydrophone axis angle and the distance between hydrophones. Determination of the bearing of other sound sources during a satellite flyover will improve the accuracy of the hydrophone positioning.

The satellite imaging provides an exact instantaneous picture of the sea area at definite moments, and the passive acoustic system can provide a continuous track of boats that were detected by satellite. Acoustics also shows the ship track history. The ship tracking can be performed from the moment when the noise from the ship is detected.

Acoustic signatures of ships can be used for ship classification. Satellite imaging can assist in this regard, and in fact can be very useful in developing a cause-and-effect relationship between the recorded signature and the vessel type (and perhaps speed). The satellite images can provide knowledge of the position of the vessels in relation to the passive acoustic system. This knowledge can be used to calculate the acoustic source level of the ship, which provides additional parameters for ship classification.

Underwater acoustics is the main tool for the detection of underwater targets, including submarines, UUVs, SCUBA divers, etc. In many cases, it is not clear if the detected sound belongs to a surface or an underwater target. Satellite imaging can exclude surface targets, and what is invisible for a satellite may be detected as a source of sound from an underwater target using the acoustic system.

References
2. Topics in Global Policies influencing MTS Security and Coastal Safety

Task 2.1 Resilient and Cognitive Port Infrastructure Systems and Enterprises
Stevens Institute of Technology (Dr. Roshanak Nilchiani, PI)

Project Objectives and Significance to Stakeholders
The objectives of this project are two folds. Building on and going beyond year one objectives, the group aimed at developing a combined quantitative/qualitative framework allowing decision-makers to assess the resiliency of the maritime transportation system. The group also explored 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.

Research and Education Milestones Met
The approach adopted included the development of a qualitative/quantitative model for maritime and port infrastructure systems resiliency on the one hand, and development of a conceptual framework for cognitive ports on the other hand.

i. Networked Infrastructure Resiliency Assessment Framework Application to MTS
The resiliency assessment process utilizes a network model that includes the biggest ports on both sides of the Pacific Ocean as well as information about the tonnage flow between the ports. Since resiliency deals with how the system responds to threats, hypothetical disruptions are imposed on the network model in terms of the port’s capacity to process goods. The network model is used to identify the critical links in the network as well as to test the effectiveness of the resiliency strategies. The network model (Figure 1) was applied to the MTS network connecting Asian ports with U.S. Pacific ports.
The research shown in Figure 2 demonstrated that a multi-day disruption in one port (in this case LA/LB) will reduce the processing capacity of the Pacific MTS system by 35%, and have substantial impacts on freight time and freight cost. However should the ports of Oakland and Seattle be able to accept freight destined for LA/LB and transfer goods over land to LA/LB the resiliency of the system increases dramatically.

**Figure 1: Pacific Port Network Map**

**Figure 2: Resiliency Metric Values for Multi-Day Closure of LA/LB**
ii. Cognitive Ports
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.

Within our research, we developed an initial set of physical and logical architectures for integrating MDA sensors into an integrated system allowing a holistic management of port security and resiliency (Figures 3 and 4). The research has been presented at multiple conferences and is being submitted to the MTS Journal special issue on Maritime Homeland Security.

Figure 3: Cognitive Port Logical Architecture
iii. Summer Research Institute Activities
The research group provided SRI students with the latest updates on their work on cognitive port infrastructure and designed exercises allowing students to incorporate cognition into their projects. The student groups did outstandingly well, allowing some of the presentation materials produced to be used to further research.

Future Plans
a. Development of Advanced Network Model for International Maritime Transportation System with Pacific Ports as an in-depth Case Study
b. Development of a Cognitive Meta-Architecture for Port Infrastructure Enterprises
c. Development of a Cognitive Logical Architecture for Port Infrastructure Enterprises
d. Development of a Cognitive Integrated Architecture for Port Infrastructure Enterprises
e. 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.
f. The design requirements for graphical user interfaces that incorporate understanding of decision-making under stress will also be explored.

g. Risks and threat scenario databases for the cognitive port systems will be explored and integrated into the cognitive response.

Documentation

Journal Publications

Omer, M., Mostashari A., Nilchiani, R. ““Measuring the Impact of Inter-port collaboration on Maritime Transportation Systems Resiliency”, Special Issue: Critical Infrastructure Systems and Enterprises, American Journal of Engineering and Applied Sciences, Accepted and to be published, January 2011.

Omer, M., Mostashari A., Nilchiani, R. “Measuring the Resiliency of the Manhattan Points of Entry in the Face of Severe Disruption”, Special Issue: Critical Infrastructure Systems and Enterprises, American Journal of Engineering and Applied Sciences, Accepted and to be published, January 2011.

Conference Publications


Project Objectives and Significance to Stakeholders

The 2008 Strategic Plan for Department of Homeland Security (DHS) states as their mission to “sharpen operational effectiveness” and use “performance measures at all levels to monitor our [DHS] strategic progress and program success.” To accomplish this it must “coordinate centralized, integrated activities across components that are distinct in their missions and operations.” Furthermore, the 2010 DHS Quadrennial Homeland Security Review Report (QHSR) states that solutions to DHS challenges must consolidate the “national enterprise” via a “collective effort and shared responsibility … composed of multiple actors and stakeholders whose roles and responsibilities are distributed and shared.” Enterprises exist in webs of alliances, partnerships, and co-operatives, and must necessarily reflect their strategic intent at the level of these networks. This is fundamental to developing security strategies and operational policies that consider emergent, decentralized behavior (actions of spontaneous individuals) of the enterprise as a positive contribution to ensuring resilience in enterprise service. Recently it has become apparent that the utilization of what we call Zeroth Responders could become a key contributor to national security enterprise solutions. Zeroth Responders are individuals acting spontaneously prior to the arrival of coordinated response groups, e.g. First Responders.

Some examples of the influence of Zeroth Responders:
- Nimitz Freeway collapse during the Loma Prieta earthquake where of the 150 people on the freeway, 49 were rescued by bystanders and workers in an industrial facility below freeway [1];
- 1979 tornado in Wichita Falls, TX where 13% of rescued people said they were rescued by emergency officials; 59% of all uninjured victims interviewed had given aid to someone else within minutes, and roughly 10,000 people were helped [2];
- 1989 San Francisco Bay Area Earthquake where surveys indicate that more than 31,000 residents were involved in search and rescue activities immediately after the disaster.

The objective of this project is to better understand the influence of Zeroth Responders in order to close the gap between disaster mitigation requirements and response capabilities for resilience of the maritime supply chain. 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.

This project has a five-year goal of being able to lay the foundations for an enterprise governance framework/guidance that can allow for effective use of Zeroth Responders in Maritime Resilience. Figure 1 is a synopsis of this five year plan. The long-term goal 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.

This report presents the results of the second year of this long-range plan.

Figure 1: Plan for an Enterprise Governance for Zeroth Responders in Maritime Resilience

Research Milestones Met
Through Year 2, this effort has involved two major research efforts: Systemigram Modeling for Understanding Resilience and Enterprise Strategy and the initial development of Agent-Based Modeling for Modeling and Simulation.

i. Systemigram Modeling
The capturing of a multi-stakeholder perspective is about systems realization, and our ability to effectively capture these perspectives requires grounding in systems thinking. Perspectives are representations of an individual’s truths based on their knowledge of the world, and we use multiple forms to contextualize and communicate these perspectives (i.e. verbal, written, graphical). One form of systems thinking modeling are Systemigrams (Systemic Diagrams). Systemigrams are networks, having nodes and links, flow, inputs, and outputs, beginning and end. The nodes are noun phrases specifying people, organizations, groups, artifacts and conditions. The relationships
between these nodes are verb phrases (occasionally prepositional phrases) indicating transformation, belonging, and being. In Year 1 we examined resilience using Systemigrams to capture a collective understanding of resilience. Through a series of modeling efforts supported by workshops with maritime stakeholders, a Systemigram articulating resilience was created (see Figure 2). The effort to-date has demonstrated how to build a culture of systems thinking within an enterprise, thereby facilitating the accelerated absorption of principles and frameworks to embrace and deploy resilience in an enterprise.

Figure 2: What is Resilience Systemigram

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.

The inclusion of multiple viewpoints, from multiple participants of a network is generally important and valuable as it increases the richness of perspective in analysis. It is also essential to include knowledge and perspective of all the constituent systems in making decisions and adopting strategies regarding security or resiliency of the entire system.
Systemigrams enable the stakeholders to explore diversity in their perspectives while maintaining a single objective, such as making a specific decision or adopting a resilience strategy, on which the stakeholders can share thoughts and make a resolution. We will utilize Systemigrams to capture systemic intent of port resilience for the small vessel security enterprise so we may better understand the influence of Zeroth Responders on enterprise resilience.

Thus, in Year 2, we first utilized the Systemigram modeling technique to begin to better understand the Small Vessel Security challenge before we moved into any agent-based modeling and simulation of Small Vessel Security. Our first model was that of the DHS Small Vessel Security Strategy as defined by the respective strategy document. The following Figures 3-14 represent 12 scenes from the Systemigram model. Each scene is a representation of a defining topic within the document. That is, Figures 3-6 define the Purpose, Scope, and Relationships; Figures 7-10 define the Strategic Environment; and Figures 11-14 define the Strategic Vision. Collectively, these scenes represent a systemic description of the Small Vessel Security Strategy (document) and are represented by the Systemigram model in Figure 15. Keeping in mind, that this model is our interpretation. It still needs to be validated with key stakeholders.

Figure 3: DHS Small Vessel Security Strategy Purpose
Figure 4: DHS Small Vessel Security Strategy Scope

Figure 5: DHS Small Vessel Security Strategy Relationship to Other Strategies and Plans
Figure 6: DHS Small Vessel Security Strategy Methodology

Figure 7: DHS Small Vessel Security Strategy Importance to Maritime Domain
Figure 8: DHS Small Vessel Security Strategy Maritime Governance

Figure 9: DHS Small Vessel Security Strategy Small Vessel Community
Figure 10: DHS Small Vessel Security Strategy Small Vessel Risk

GUIDING PRINCIPLES (A)

Figure 11: DHS Small Vessel Security Strategy Guiding Principle A
Figure 12: DHS Small Vessel Security Strategy Guiding Principle B

Figure 13: DHS Small Vessel Security Strategy Guiding Principle C
Figure 14: DHS Small Vessel Security Strategy Guiding Principle D
Further development is necessary with these Systemigram models. We still intend to begin a validation effort with these models and develop a unified Small Vessel Security Systemigram Model with relevant subject matter experts in the field of maritime security. This effort will follow a similar approach as that in the development of the “What is Resilience?” Systemigram where a series of iterations with relevant stakeholders yielded a refined model that articulates more closely the perspective of its stakeholders.

ii. Agent-Based Modeling
Before we can integrate the knowledge and information deciphered from the Systemigram modeling into an agent-based model (ABM) we needed to build a prototype ABM to verify that we could use ABM to demonstrate the influence of Zeroth Responders. Thus, we used an ABM to investigate the impact (positive or negative) Zeroth Responders could bring to a First Responder situation. The ABM provides a computational model for simulating the actions and interactions of autonomous individuals in a network, with a view to assessing their effects on the system as a whole. The model can simulate the simultaneous operations of multiple agents, in an attempt to re-create and predict the actions of complex phenomena. The individual agents are presumed to be acting with limited knowledge in what they perceive as their own interests. This will be used in order to observe the interactions with regards to Zeroth
Responders and how they may influence a First Responder situation. This initial prototype model builds upon previous work conducted by the PI, thesis work by Chen-En James Chou, and dissertation work by William Baldwin.

iii. ABM Scenario
Because ABM is founded upon modeling behavioral interactions, we propose an approach to modeling the First Responder system using a set of system of systems (SoS) behavioral characteristics which have shown to be able to model the behavior of SoS [3-6]. The scenario is based on a fictional First Responder crisis setting, and the model is simulated using ABM software. The First Responders consist of a fire department, an EMS, and the police officers of law enforcement. While the firefighters and EMS medics are stationed until dispatched to a crisis, the police patrol the area.

An emergency crisis randomly occurs involving a random number of civilians and structures. These civilians may include bystanders, destructive rioters, injured victims, and helpful Good Samaritans, e.g. Zeroth Responders. Injured civilians require medical help while rioters require police intervention. Existing structures may incur damage requiring the fire department. Any injured victim or damaged property will be lost eventually without the proper help.

The SoS behavioral characteristics of autonomy, belonging, connectivity, and diversity are modeled in the simulation (Table I). The fifth characteristic of emergence is present in part due to the other characteristics. The characteristics manifest themselves in accordance with the scenario. Diversity is inherent in the different First Responders, including the so-called Zeroth Responders. Connectivity represents the ability to call for help or dispatch the appropriate responders. Belonging represents the ability of a First Responder to address situations outside of their domain. For example, when the police or fire fighters respond to a medical emergency, they are exhibiting belonging. Finally autonomy manifests as the ability to address an emergency without receiving orders from the appropriate department chief or dispatcher. The lack of autonomy requires a responder to seek instructions for each new incident.

<table>
<thead>
<tr>
<th>SoS Characteristic</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Autonomy</td>
<td>the ability to complete one’s own goals within limits and without the control of another entity.</td>
</tr>
<tr>
<td>Belonging</td>
<td>the acceptance, ability and need to make a valued contribution to the goal of the larger entity.</td>
</tr>
<tr>
<td>Connectivity</td>
<td>the capability to form connections as needed to benefit the entity.</td>
</tr>
<tr>
<td>Diversity</td>
<td>the distinct or unlike elements or qualities in a group; the variation of social and cultural identities among people existing together in an operational setting.</td>
</tr>
<tr>
<td>Emergence</td>
<td>the appearance of new properties in the course of development or evolution</td>
</tr>
</tbody>
</table>

Table I: System of System Characteristics [7]

Upon receiving word of an incident, the dispatcher sends appropriate First Responders to the scene. If the appropriate responder is unavailable, the dispatcher may send an
alternate responder, such as the police to a medical response. In addition the police patrol and may stumble upon an incident if not already reported. After an incident is resolved, police resume patrolling and fire and medics return to their stations.

The First Responder scenario was simulated as an ABM using NetLogo [8]. A new incident occurs at random, and a random number of agents may be involved. These agents represent civilians and properties. Some civilians are healthy enough and may or may not help others, and some property is not severely damaged. On the other hand, some civilians may be injured, some property may be on fire, and some civilians may start rioting. Rioters may harm civilians and burn properties. The interface provides adjustable settings and displays the agents interacting (see Figure 16).

![Figure 16: First Responder ABM Interface](image)

All civilian agents have a set health-level, which deteriorates with time when injured or damaged. All agents can see as far as their eight neighboring patches. To summon appropriate help, a Zeroth Responder must call the emergency services dispatcher. However, Zeroth Responders are effective enough to maintain a victim’s health-level, prevent a fire from spreading, or restrain a rioter until help arrives. However professional treatment is the only means to save a victim or property. Furthermore a rioter may end up hurting a Zeroth Responder in the process.

As modeled, connectivity is the probability a dispatcher will receive the notification of an incident. Failed connectivity requires a Zeroth Responder to go for help before returning to the incident. A residential property will try periodically to communicate, although less
frequently when involved. This added delay attempts to simulate the lack of time available to call continuously. If a responder tries to call in an incident and fails, an unavailable First Responder will try again periodically also, and the autonomy variable comes into play. Autonomy is a probability that a First Responder can deal with a situation without getting orders from the dispatcher. If there is no autonomy and no connectivity, the First Responder will report in-person for orders. If autonomy but no connectivity, the First Responder will attempt to deal with the situation alone. The belonging variable models the probability a First Responder will address an incident outside of its specialty. If belonging fails, the First Responder notifies the dispatcher to send an appropriate response. Exhibiting autonomy and belonging, the First Responder will attempt to handle every incident within view. Although connectivity between a Zeroth Responder and a First Responder is not modeled explicitly, the Zeroth Responder continues to help after the arrival of the First Responders.

Each simulation was run for 15,000 ticks with settings of 0%, 50%, and 100% probabilities for autonomy, belonging, and connectivity. A tick represents some arbitrarily short length of time where each agent performs some action, such as moving a finite distance. Similar settings modeled the probability of a civilian assuming the role of Zeroth Responder. For each combination of variables, we ran 30 repetitions resulting in a total of 2,430 simulation runs. Hence each combination of variables produced 30 trials in an attempt to get significant samples.

iv. ABM Results
The NetLogo ABM saved the results of the simulations to a comma-delimited file. We wrote a script to read the file and process the data using the statistical package R (R Development Core Team 2009). Various combinations of the variables were examined. First we examined the average percent of “saves” given all the variables set to zero, which is equivalent to turning them off. This setting provides a baseline as it indicates 30% of victims are saved with standard deviation (sd) 0.05 primarily through the patrolling police officers. Conversely when all three characteristics are set to full, the mean “saves” is 80% (sd 0.07), which indicates approximately 20% are lost due to response time or overburdening of the system.

Since connectivity in the form of communication is a major concern of crisis planners, we focused our analysis on different connectivity values. When connectivity is set to full without any other characteristic, the mean “saves” is 56%. If communication is cut to 50% effective, the mean “saves” falls marginally to 53%. When autonomy and belonging are added to the 50% connectivity, the “saves” jump back to 79% (see Figure 17). In other words, decreasing the communications without eliminating it had minimal impact on the “saves” as long as the responders exhibited autonomy and belonging.
Figure 17: Connectivity Analysis

The next interesting result involves the bystanders that are willing to help, also known as Zeroth Responders. The connectivity results of Figure 7 do not consider bystander participation at all. If the bystanders do not help and connectivity is lost, the mean “saves” is 33%, and this result includes total autonomy and belonging of responders. This result makes sense since the responders need to find out about a situation in order to address it regardless of their abilities. Altering 50% of the bystanders to help, either by administering first aid, holding a criminal or going for help, improves the mean “saves” significantly to 49%. Adding 50% connectivity is almost the same as full connectivity with mean “saves” of approximately 84% (sd 0.10). The surprise of this result is the significant contribution of Zeroth Responders when connectivity is greatly diminished (see Figure 18).
Although numerical results are presented, the reader is cautioned to ignore the specific numerical results and focus on the changes produced from different input variables. We are not asserting that 84% is a maximum limit of “saves,” but rather reduced connectivity may be mitigated to levels close to full connectivity with the presence of Zeroth Responders and First Responders who exhibit autonomy and belonging.

**Figure 18: Bystander Analysis**

According to the given simulation, communication plays a major role in successful first response, as well as the value of civilians willing to help, which we call the Zeroth Responders. While this simulation does not claim there is a substitute for good communication, the risk is mitigated through autonomy and belonging of First Responders and the presence of Zeroth Responders. Reducing communications in half resulted in a minimal impact when the First Responders were allowed to make their own decisions and cross-trained enough to deal with incidents outside of their specialty. Furthermore the contributions of bystanders improved the efficiency of the First Responders.
The simulation contains many assumptions that may affect the resulting statistics, such as the location of responders as well as response times. These assumptions include the characteristics’ values of autonomy, belonging, and connectivity. Yet most if not all of the assumptions can be modified in future studies. Therefore this experiment demonstrates the usefulness of modeling a First Responder system as a SoS with appropriate behavior.

**Summary of Work Accomplished**

For Year 2, CSR was able to:

- Develop tools to enable the understanding of the small vessel security strategy via multiple Systemigram models.
- Develop a prototype ABM that quantitatively verified that Zeroth Responders can have a positive influence on a First Responder situation.

**Collaborations**

**Key Collaborator (current)**

- Ali Mostashari, Stevens Institute of Technology (CSR, infrastructure resiliency)
- Jeff Nickerson, Stevens Institute of Technology (CSR, decision-making)
- Jim Rice, MIT (CSR, supply chain)

**Key Collaborators (future)**

- Adam Rose, USC (CREATE)
- Fred Roberts and Paul Kantor, Rutgers, The State University of NJ (CCICADA)
- United States Coast Guard (e.g. Robert Gauvin, Technical Advisor, Office of Vessel Security Activities)
- Homeland Security Institute (e.g. Drs. Charles Brownstein and Margaret Velardo)

**Future Plans**

In Year 3 of this research, the plan is to:

a. Refining Systemigram models of the DHS small vessel security strategy as they relate to port enterprise resilience. For the refinement of our small vessel security strategy Systemigram, we will engage stakeholders so the model and reality can be compared and contrasted for refinement of the model.

b. Use data mining from the Systemigram model of small vessel security to begin to build agent-based models to begin to study the temporal and special characteristics of the small vessel security enterprise as executed by its stakeholders.

c. Identify the types of Zeroth Responders for each of the four small vessel security strategy scenarios as described in the DHS Small Vessel Security Strategy, and a) build into the agent-based models the performance behaviors of these zeroth responders.

d. Run simulations of the agent-based model to indicate qualitative and quantitative impacts of Zeroth Responders in a small vessel security scenario.
Documentation

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

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

**Project Objectives and Significance to Stakeholders**

The key objective of the work in this component of the CSR effort is the development of methodologies (tools) that ports can use to evaluate their resilience, and strategies for port authorities to improve their resilience. The strategies 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 resiliency of port operations design and management. Under the DHS-supported CSR project, the MG Group will assist in the preparation and development of evaluation tools and strategies through direct and indirect interaction with port and supply chain stakeholders.

**Research Milestones Met**

i. **Continued literature review and analysis for lessons learned of real-world port disruptions**

This effort built upon the Year 1 effort, most notably the disruption in operations in the Port of Kobe following the 1995 earthquake. Representative reviews included Port of New Orleans (Hurricane Katrina), West Coast Port Closures (Labor), Port of Mumbai (Ship Collision), Port of Miami (Airplane Crash), Port-au-Prince (Earthquake), Port of Paranagua Brazil (Government Shutdown), Port of Morehead City, NC (Hazmat), Port of Houston (Oil Spill). 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.

ii. **Analyzed 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. 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.

iii. Contributed to the development of an initial draft survey instrument as part of a team under the overall management of MIT
The Mattingley Group provided content based on field experience in conducting numerous port and supply chain security studies in national and international ports. Additional input was secured through consultation 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 to identify concerns, actions, trends, challenges for port operators, shippers, carriers, importers, trade associations, port authorities, local government, etc. They refined initial draft through informal testing, followed by distribution of first survey edition to the maritime community. Widespread dissemination was achieved through the active support of the Journal of Commerce. Over 450 responses were received from a wide variety of maritime system operators and stakeholders. They participated in survey result analysis to direct future research efforts.

Contributions were made to the development of the 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. Contributions were also made to the development of failure mode analysis to identify supply chain vulnerabilities to disruptions, impact on port operations, communications, infrastructure, and personnel.

The Mattingley Group performed field visits to key US ports to identify key port systems for resiliency evaluation, 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. Included 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. They participated in port recovery exercise with Port of Los Angeles with an aim to providing business continuity in the event of a major disruption by restoring functioning of the Harbor Department, restoring landside port infrastructure, restoring waterway navigability, and restoring cargo operations.
Collaborations

- Port Authority of New York & New Jersey
  a. Identification of port operations, processes, and systems vulnerable to disruption with Marine Transportation System Recovery Unit (MTSRU)
  b. Enhance understanding of the dynamics of port operations as they relate to resiliency.
  c. Obtain feedback on initial survey instrument
- Massachusetts Institute of Technology
  a. Perform field visits to Ports of Los Angeles, Long Beach, Hueneme, Houston, Boston, New York/New Jersey.
  b. Develop, distribute, and analyze draft survey instrument for industry and government input
  c. Develop supply chain failure mode analysis
  d. Develop port capacity study
- University of Minnesota
  Draw upon lessons learned by National Center for Food Protection and Defense
- US Coast Guard
  a. Identification of port resiliency issues
  b. Responsibilities of the Captain of the Port
  c. Implementation and enforcement of Safety and Security Zones
  d. Command and control authority in directing vessel movement within US territorial waters and navigable waterways
  e. Interagency Operations and Planning with Maritime Security Stakeholders

Resources Leveraged

- Port Authority of New York & New Jersey
  a. Provided first hand experience on development of port recovery plans
  b. Provided real world expertise on port disruption scenarios
  c. Provided lessons learned on first response capabilities, stakeholder coordination and involvement, dealing with multiple political jurisdictions, and business continuity
  d. Organized meeting for CSR team with MTSRU to exchange ideas, suggestions, criticisms, and lessons learned
- Massachusetts Institute of Technology Center for Transportation and Logistics
  a. Provides expertise in supply chain efficiency and security studies
  b. Provides extensive background in data analysis and modeling and simulation capabilities
  c. Capability to bring research resources to bear on resiliency issues and identify mitigation strategies
- Port of Los Angeles
  a. Identification of port operations, processes, and systems vulnerable to disruption.
b. Enhance understanding of the dynamics of port operations as they relate to resiliency.
c. Participate in Port Recovery Plan exercise with POLA stakeholders.
d. Obtain feedback on initial survey instrument

• Port of Long Beach
  a. Identification of port operations, processes, and systems vulnerable to disruption.
  b. Enhance understanding of the dynamics of port operations as they relate to resiliency.
  c. Understand operation of Los Angeles-Long Beach Port Security Committee
  d. Obtain feedback on initial survey instrument

• USCG Sector Los Angeles-Long Beach
  a. Review issues of Captain of the Port, Federal Maritime Security Coordinator, Federal On-Scene Coordinator, Marine Inspections, SAR missions, Maritime Safety and Security Team
  b. Understand areas of concern specific to LA-LB
  c. Review efforts to establish security standards, enhance maritime domain awareness, improve deterrence, improve response and recovery capabilities

• Port of Houston Authority/USCG Sector Houston-Galveston
  a. Identification of port operations, processes, and systems vulnerable to disruption with Port Coordination Team, Marine Transportation System Recovery Unit (MTSRU), and Area Maritime Security Committee
  b. Enhance understanding of the dynamics of port operations as they relate to resiliency.
  c. Review issues of Captain of the Port, Federal Maritime Security Coordinator, Federal On-Scene Coordinator, Marine Inspections, SAR missions, Maritime Safety and Security Team
  d. Understand areas of concern specific to Houston-Galveston
  e. Review efforts to establish security standards, enhance maritime domain awareness, improve deterrence, improve response and recovery capabilities

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

Future Plans
  a. Continue review and analysis for lessons learned from real-world port disruptions
  b. Continue review of laws and regulations impacting port resiliency capabilities and effectiveness
  c. Continue effort to define maritime supply chain operations in terms of failure modes to identify vulnerable points and devise mitigation strategies
d. Refine port capacity study to determine ability of maritime system to absorb port disruptions

e. Refine and validate survey of port resiliency issues

f. Accomplish additional port visits for representative sampling of port resiliency issues and feedback on initial survey results

g. Expand collaboration efforts to include University of Southern California and National Center for Risk and Economic Analysis of Terrorism Events

h. Expand collaboration efforts to include University of Maryland and National Consortium for the Study of Terrorism and Responses to Terrorism

Documentation

a. City of Los Angeles Harbor Department, Port Recovery Plan, The Port of Los Angeles, June 2009


c. MG Group Presentation, “Supply Chain Security Issues and Recommendations,” 8 July 2010


e. Center for the Commercial Deployment of Transportation Technologies, “Port Disruption Model Program,” June, 2007


Task 2.3, Project 2, Massachusetts Institute of Technology (J. Rice, PI)

Project Objectives and Significance to Stakeholders
The project objectives for Port and Supply Chain Resiliency research conducted under the CSR project have not changed since Year 1, and they stand 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 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.

Based on our studies to date, there is no single assessment of port capacity in the US, and therefore there is no method for assessing how cargo volume could possibly be distributed among the 300+ ports in the US in the event that one or more ports were disrupted or shuttered. Given that over $2b of the $13b GDP is associated with global trade volumes, and that 77% of the cargo (by weight) comes into the US by seaports, one can see that the US economy is dependent upon global trade – imports and exports – in order to maintain the US economic productivity. It is therefore critical to understand how to make the US ports capable of handling various disruptions to maintain economic activity.

Research Milestones Met
i. Port Resilience Survey
We completed the MIT Port Resilience Survey of 525 shippers, carriers, port authorities, terminal operators, freight forwarders, customs brokers, and other 3rd parties and authorities associated with ports and port operations. The respondent pool was collected using a convenience sampling method for the purpose of providing broad and general guidance in the domain. The survey solicited input on critical systems and actions to take towards making ports resilient. Additionally, the survey solicited respondent experience with delays in ports as well as opinions about regulations and their impact on port resilience.

ii. Capacity Study
A second milestone achieved was conducting a capacity study assessing the ability of the 310+ ports in the US to handle disruptions. Two approaches were used. Method #1 – entailed estimating the current capacity utilization of ports and identifying the ability of the 310+ domestic US ports to absorb the volume of any one port closure. This method assigned the displaced volume to nearest ports in order of proximity to the disrupted port. Capacity estimations were extrapolated from the MergeGlobal port utilization data for top 10-12 ports in 2006. The 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 considered absorption ability at 3 levels: 1st with no
constraints, 2\textsuperscript{nd} require matching commodity class, 3\textsuperscript{rd} require minimum volume/stop (min 4000 TEU). The analysis observed that the ports do not have capacity to withstand a disruption at the largest ports when considering the required commodity match and the system had even less ability to absorb when considering the minimum volume/stop requirement. There are many limitations on the utility of this analysis as the Army Corps of Engineers (ACOE) data set used only presented annual volume data and the most recent data set was for 2007. Further study is necessary but the finding raises concern about the ability of the 310 ports to handle disruptions.

A second method was used which sought to identify the maximum current capacity utilization in order for the remaining ports to absorb the volume from any one port closure. This analysis used recent handled volume at each port as the base volume for the port. The analysis entailed removing the port with the largest volume in each commodity class. 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 showed a surprisingly low level of maximum capacity utilization in several commodity classes.

iii. \textbf{Summer Institute Education}
This past summer, a disruption simulation was conducted with the CSR Summer Institute Students, and this apparently inspired the students to adopt a similar approach in their subsequent project work.

iv. \textbf{Field Visits}
In the course of conducting the analysis for the survey and capacity study, field visits to various parties in several ports were used to supplement the work. This included visits to:

a. Port Authority New York/New Jersey MTSRU
b. Port Authority of Long Beach site visit.
c. Port Authority of Hueneme site visit.
d. US Coast Guard Visits and Tours at various facilities:
   i. Sector Los Angeles
   ii. Sector Boston
   iii. Sector Houston
e. Port Authority of Los Angeles Simulation Exercise
f. Visits to terminal operations in Port Hueneme, Port of Los Angeles, Port of Long Beach, Port of Houston, Port of Oakland.
g. Driving port visits to Port of San Juan, Port of Miami.

v. Brief Commentary:
Each of the analyses is less than perfect given the dearth of data available for study. But the data is enough to suggest that there are serious constraints in the system. Even starting with the concept of port resilience, we recognize that the concept of port resilience is new, and therefore there is no agreed-upon definition and further this concept is not well-understood. Additionally, the definition of this concept varies depending on
one’s perspective, and therefore the actions one might take to make a port resilient would be different depending on one’s perspective. Obviously this is not a desirable condition as this means that different parties would not be working towards the same objective and therefore investments would potentially be competing against each other. We believe that our work in Year 2 has helped improve the understanding of the concept of port resilience by virtue of recognizing the different perspectives and the need to consider port resilience as a function of resilience of key components of the MTS – resilience of the navigable waterways, the terminals and the intermodal connections. Still at a conceptual level, there is more work remaining to make this a more operational and actionable concept.

The capacity studies reveal an apparent capacity constraint at least at a high level. The MergeGlobal capacity utilization estimates may be inaccurate. Yet even if that is the case, the calculated maximum capacity utilization (Method #2) shows low levels that most would agree are below the current capacity utilization. In fairness, one needs to actually calculate these to genuinely know. It is therefore necessary to further study ‘port capacity’ by considering the capacity of the navigable waterways, the terminals and the intermodal connections of each port to get a full understanding of the real capacity of the system. These initial observations should not be discounted.

Collaborations
a. Primary collaboration with Mr. Matt Mattingley on the preparation of the port resilience survey, and in weekly team meetings with the 2009-2010 MIT Port Resilience Team which included discussions on the capacity study and port resilience survey.
b. Secondary collaboration with Stevens Institute of Technology colleagues Brian Sauser and Ali Mostashari

Resources Leveraged
• Port Authority of New York/New Jersey MTSRU
• Port Authority of Long Beach
• Port Authority of Hueneme
• US Coast Guard:
  a. Sector Los Angeles
  b. Sector Boston
  c. Sector Houston
• Port Authority of Los Angeles
• Terminal operators:
  a. Wallenius Willhelmsen Logistics in Port Hueneme
  b. APL in Port of Los Angeles
  c. California United Terminals in Port of Los Angeles
  d. Wallenius Willhelmsen Logistics in Port of Long Beach
  e. APL in Port of Oakland
  f. Intermarine near Port of Houston
  g. Maher Terminal in Port of New York/New Jersey (Port Elizabeth)
Future Plans
The future plans include continuing to harvest insights from the survey data and the capacity study, and the Year 3 workplan includes the following milestones:

a. Port Resilience Survey – initial draft report on observations from initial port resilience survey
b. Port Capacity Study – Submit an analysis that assesses annual capacity of domestic US ports to absorb volume in the event of port capacity loss (annual volume only)
c. Port Case Study Database – prepare an initial draft listing of potentially interesting port disruptions
d. Prepare framework for a follow-on port resilience survey (subject to data collection needs after Q3)
e. Plan and host a roundtable discussion focused on Port Resilience.

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
There are several papers in process that document some of the work:

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.

In June 2010 CSR offered its latest educational initiative - 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.

Year Two of the Center’s operation marks several new educational initiatives, notable accomplishments, and the hiring of a full-time Director of Education.

This section of the CSR Year Two annual report highlights the Center’s educational activities and achievements for 2010.

Director of Education
In November 2009, CSR confirmed its commitment to providing a continuum of education and outreach programs by hiring a full-time Director of Education. Ms. Beth Austin DeFares, formally the Director of Communications and Outreach for the School of Systems and Enterprises at Stevens Institute of Technology, joined the CSR team with
over 15 years of experience in academic administration, program development, student recruitment and advisement, and industry and government sponsor outreach.

In her capacity as Director of Education, Ms. DeFares has actively developed CSR program brochures and collateral, collaborated closely with faculty from each of the six CSR partner schools and served as the lead administrator and coordinator for the CSR’s eight-week intensive Summer Research Institute, held June 7 to July 30, 2010, on the Stevens Institute of Technology campus in Hoboken, NJ.

Ms. DeFares also contributed to the preparation of a winning joint proposal between CSR and Stevens for the university’s first DHS Career Development Grant. The grant award will provide support for three full-time Master’s Degree Fellowships in Maritime Systems with a Graduate Certificate in Maritime Security, starting spring 2011. Ms. DeFares will serve as the primary coordinator of the Fellowship program, while resuming planning and preparation for the CSR’s 2011 Summer Research Institute.

**K-12 STEM Teachers Workshop**

The CSR in collaboration with the Center for Innovation in Engineering and Science Education (CIESE) offered a week long teachers workshop focused on Underwater Detection Technologies and Port Security, August 2 – 6, 2010, at the Stevens campus in Hoboken, NJ. The workshop leveraged an innovative research project being conducted by CIESE and sponsored by the National Science Foundation (NSF), Information Technology for Students and Teachers (ITEST) program. The goal of the 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 Underwater Detection Technologies and Port Security teacher’s workshop was developed to expand on the already successful Build IT program and introduce 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, lesson plans and activities within a maritime security-centric context, that they could bring back to their classrooms.
Using LEGO building blocks, waterproof motors, IT software cabling, and sound, touch and light sensor devices, the teachers built their own submersible “Bots”. Upon submerging the Bots in a large rubber pool of water, the teachers learned how to read sensors and log their data. Through a series of exercises that included “Nervous Bots” a sound sensor activity, “Water Roomba” a touch sensor activity and “Find the Light” a light sensor activity, the teachers explored and experimented with the various signal detections.

To provide a maritime security context, CSR affiliate faculty member, Dr. John Dzielski, Deputy Director, Maritime Security Laboratory (MSL), provided an in-class seminar discussing the real-world utility of sensors technologies in the detection of maritime security threats and the use of these technologies in the development of cognitive maritime systems.

Twenty middle and high school teachers representing the following school districts attended the five-day workshop:

- Aviation High School, Queens, NJ
- Bridgewater-Raritan High School, Bridgewater, NJ
- Dickinson High School, Jersey City, NJ
- Great Meadows Middle School, Great Meadows, NJ
- High Point Regional High School, Sussex, NJ
- Hoboken High School, Hoboken, NJ
- Lincoln Park Middle School, Lincoln Park, NJ
- Middle School 88, Brooklyn, NY
- Morgan Village Middle School, Camden, NJ
- Passaic County Technical Institute, Wayne, NJ
- Renaissance I.S. 192Q, Saint Albans, NY
- Robbinsville High School, Robbinsville, NJ
- Saint Augustine School, Union City, NJ
- Veterans Memorial Middle School, Camden, NJ

CIESE is a non-profit education organization founded in 1988 by Stevens Institute of Technology to improve K-12 science and mathematics education through the use of technology. Since its inception, CIESE has received more than $22 million in grants, contracts and awards from the National Science Foundation, the Department of Education and the New Jersey Department of Education among other public and private organizations.

Maritime Domain Awareness Curriculum Development and Education
In collaboration with and sponsorship by CSR, The Institute for Marine and Coastal Sciences (IMCS) at Rutgers University has developed curriculum aimed at enhancing maritime domain awareness (MDA) education. The MDA curriculum was delivered
during the spring 2010 semester as part of Rutgers' Communicating Ocean Science for Informal Audiences (COSIA) college course, led by Janice McDonnell, Director of Education and Outreach, IMCS, and Dr. Scott Glenn, Professor of Oceanography, Director of the Coastal Ocean Observation Laboratory (COOL) and CSR faculty member. The intent of the COSIA course is to encourage undergraduate and graduate science majors to become more aware of K-12 and public science education, and to introduce students to public outreach and the “broader impact” of their work as prospective ocean scientists and educators. By employing topics related to the marine transportation system and port security, students in the spring 2010 course learned how
global climate change and other environmental and man-made factors influence and impact the maritime domain. Through in-class discussions and exercises students gained a broad perspective on how changes and disruptions in the maritime domain can affect the safety, security and economy of our nation.

As part of the course curriculum, COSIA students were required to develop lesson plans and activities involving MDA topics intended for K-12 students and general public audiences.

This year’s student projects included:
* Oil Spills Mitigation - How do oil spills affect local biology and clean up?
* Cargo Ships - Effects of tides on ships coming into port.
* Marine reptiles and mammals - Effects of marine transport on migratory animals.
* Invasive species in estuaries.
* Oil spills - Single vs. double hull tankers.

Figure 1. COSIA students demonstrate their projects at the Liberty Science Center.

COSIA students applied and demonstrated their lesson plans and projects by hosting exhibits and presentations for hundreds of visitors at the Liberty Science Center located in Jersey City, NJ, and at the Rutgers University annual “Rutgers Day” (Figure 1).

Student interviews and examples of the COSIA spring semester projects can be viewed in a YouTube video located online at: http://www.youtube.com/watch?v=pYMzXcPQauI
1.4. Maritime Security Online Graduate Certificate Program
Stevens Institute of Technology has expanded the delivery of its four-course Maritime Security Graduate Certificate program to include online distance learning via Stevens award-winning WebCampus. By providing the program online, current and prospective Maritime Security students will be given greater flexibility and convenience to pursue a Stevens Graduate Certificate or Master’s Degree whether they are on a vessel in the Indian Ocean or stationed at a military base on the west coast.

Current Graduate Certificate students include representatives from the U.S. Navy and U.S. Coast Guard.

The four-course Maritime Security program includes the following courses:

- OE 529 Maritime Safety and Security
- OE 560 Fundamental of Remote Sensing
- OE 628 Technologies for Maritime Security
- OE 629 Advanced Maritime Security

Online courses contain the same curriculum as on-campus courses and are taught by the same Stevens faculty members.

Port Security Sensing Technologies – Professional Development Course
Faculty from CSR partner universities teamed together to deliver a one-week graduate-level module course in Port Security Sensing Technologies delivered April 19-23, 2010 at the Stevens Institute of Technology’s campus location in Washington, DC. Student participants included representatives from the U.S. Coast Guard and the Army Corps of Engineers.

The objective of the five-day course was to enable a broad base of maritime industry and government practitioners with minimal to moderate technical expertise to understand the basic technologies used in port security applications and to provide them with a basis to make informed managerial decisions regarding relevant technology-based solutions.

Student participants learned the principal aspects of relevant sensor technologies including HF Radar, Satellites, Acoustics and Electro-Optics, that serve as the foundation for port security applications.

Student survey feedback highlighted the usefulness and utility of the course to the student’s current job responsibilities. When asked what they liked best about the course, students mentioned the subject matter expertise of the faculty and learning about the capabilities of the various sensor technologies.

Instructors for the April 2010 Port Security Sensing course included:

- Dr. Michael Bruno, Director, Center for Secure and Resilient Maritime Commerce,
- Dr. Thomas Wakeman, Deputy Director, Center for Maritime Systems,
• Dr. Scott Glenn, Director, Coastal Ocean Observation Laboratory, Rutgers University,
• Dr. Hugh Roarty, Coastal Ocean Observation Laboratory, Rutgers University,
• Dr. Barry Bunin, Research Professor, Stevens Institute of Technology,
• Dr. Alexander Sutin, Research Professor, Stevens Institute of Technology,
• Dr. John Voiklis, Stevens Institute of Technology, and
• Dr. Hans Graber, Director, Center for Southeastern Tropical Advanced Remote Sensing, University of Miami.

CSR will deliver a three-day version of the same course October 18 – 20, 2010, at the Stevens Washington, DC campus location. Eight students from the U.S. Coast Guard are currently enrolled to attend.

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.

**DHS Career Development Grant Award**

The CSR has recently been awarded its first DHS Career Development Grant. Funding received from the grant award will be used to provide greater access and full-tuition support for U.S. students to pursue a homeland security focused Master’s Degree in Maritime Systems with a Graduate Certificate in Maritime Security. The fellowship program will create enhanced experiential opportunities and direct pathways for highly skilled students to obtain technical leadership positions in the maritime security domain.

Stevens’ objectives in pursuing the DHS HS-STEM fellowship were to:

1. Leverage Stevens existing graduate curricula in maritime security, and the research capabilities of Stevens’ research centers to provide extensive and diverse maritime security-centric opportunities and experiences for HS-STEM fellows.
2. Increase the number of undergraduate STEM discipline students interested in maritime security and related homeland security fields.
3. Provide students with greater opportunities for research and experiential learning through mentorship and summer internship placement.
4. Encourage high-potential students to pursue advanced academic study and PhDs in maritime security.
5. Increase the number of students seeking careers and job placement in the private and public homeland security sectors.
6. Increase the number of women and underrepresented minorities entering STEM and maritime security related fields.

Commencing spring 2011, qualified applicants will be selected according to a rigorous application and interview process.
Summer Research Institute (SRI) Program Overview

In June 2010 CSR offered its latest educational initiative - the Summer Research Institute - a multi-disciplinary, highly-collaborative summer research program designed to provide qualified undergraduate and graduate-level students with the unique opportunity to learn about the maritime security domain by conducting hands-on research in collaboration with CSR faculty to address critical issues in maritime domain awareness, emergency response and preparedness, and maritime system resilience. The inaugural offering of the Summer Research Institute (SRI) was held June 7 to July 30, 2010 at the Stevens Institute of Technology campus in Hoboken, NJ.

Developed as a collaborative effort across the entire CSR research enterprise the SRI was created with the following program objectives:

- Expose a diverse group of students from a variety of academic disciplines to MDA, the MTS, and the sensor technologies used in Port Security applications.
- Encourage students to think along the same lines as public and private, industry and government stakeholders and homeland security practitioners to understand the complex challenges in maritime and port security operations.
- Engage students in rigorous research activities that produce innovative work and quality research outcomes that result in published papers and presentations.
- Cultivate a strong and active alumni network to promote and support future SRI offerings.
- Enhance the interest of students to pursue advanced academic study and/or careers in the homeland security and maritime systems domain.

Faculty members from each of the six CSR partner universities, including Stevens Institute of Technology, Rutgers University, University of Miami, University of Puerto Rico, Massachusetts Institute of Technology and Monmouth University, participated at various stages throughout the eight-week program contributing their teaching talents and subject matter expertise to expose students to the marine transportation system (MTS) and 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.

Altogether twenty-six students were admitted into the eight-week intensive summer research program. Twenty-two of the student participants represented the CSR’s partner universities including eight students from Stevens Institute of Technology, four from Rutgers University, four from the University of Miami, four from the University of Puerto Rico, and two from Monmouth University, and four additional students were selected from other U.S. university’s including two students from the University of Guam, one student from John Jay College of Criminal Justice, and one student from Morgan State University. Eleven of the students were Master’s and/or PhD students and 15 were undergraduate students in their junior and/or senior year of study. Collectively the student participants represented a broad base of academic disciplines including Biology, Computer Science, Criminology, Electrical Engineering, Marine Policy, Maritime Systems, Mathematics, Oceanography and Systems Engineering.
Students participated in weekly lectures by CSR faculty and maritime industry and homeland security experts including:

- Dana Goward, SES & Director, Marine Transportation Systems Management, USCG
- Richard Larrabee, Dir. of Port Commerce Port Authority of NY & NJ (PANYNJ),
- Mitchell Erickson, Director, DHS Northeast Operations Interagency & First Responders Programs,
- Bethann Rooney, Manager Port Security, PANYNJ,
- John Gilmore, Sales Director, Maersk Line, Inc., and
- Thomas Betro, Senior Advisor Law Enforcement and Security, 4-D Security

Rounding out their experience, the students also attended the Annual Joint Conference of Harbor Safety Committees and Area Maritime Security Committees in Jersey City, NJ, and engaged in field visits and tours of APM Terminals and Port Authority of New York and New Jersey facilities located in Newark, NJ, and the Office of Emergency Management of New York City.

The students were organized into four research teams mirroring the research arms of the CSR in Acoustics and Electro-Optics, HF Radar, Satellites, and Systems Thinking. Working closely with designated faculty mentors the students were given the collective challenge to research the utility of their respective sensor technologies to detect small vessel threats, using the Hudson River Estuary as their test bed. In the case of the Systems Thinking team, students were given the challenge to develop a detection, response, and resilience strategy focusing on vessel threat scenarios outlined in the 2008 DHS Small Vessel Security Strategy.

The Stevens Institute of Technology campus provided an exceptional research venue for the Summer Research Institute, allowing students and faculty access to a robust suite of research assets and facilities including the Maritime Security Laboratory (MSL), a Stevens-based research laboratory that develops and evaluates technologies aimed at detecting and characterizing current and emerging maritime threats. The geographical location of the Stevens campus, located opposite New York City and adjacent to New York Harbor also provided tremendous opportunities for students to conduct field experiments and hands-on research.

**Student Recruitment and Admission Criteria**

The CSR’s student recruitment efforts began in mid-October of 2009 with the development of a program brochure, dedicated program web pages and an online application system on the CSR website. For the preliminary offering of the SRI, the CSR relied on its academic partners to disseminate and circulate the SRI program brochure to their respective university colleagues and students. Extended program outreach was also conducted through the DHS S&T academic channels to generate program awareness and to peak the interest of qualified students for the SRI 2010 and future program offerings. To be considered for admission, students had to be currently enrolled in an undergraduate and/or graduate degree program. 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. The CSR received 52 student applications and selected the top 26 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>
<thead>
<tr>
<th>UNIVERSITY</th>
<th>STUDENT</th>
<th>MAJOR &amp; DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Jay College of Criminal Justice</td>
<td>Leonid Lantsman</td>
<td>Criminology, PhD</td>
</tr>
<tr>
<td>Monmouth University</td>
<td>Joseph Bongi, Walter Seme</td>
<td>Mathematics, Undergrad</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computer Science, Undergrad</td>
</tr>
<tr>
<td>Morgan State University</td>
<td>Tanaira Cullens</td>
<td>Biology, Undergrad</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Blake Ciganerella, Danielle Holden, Dakota Goldinger, Shankar Nilachantan</td>
<td>Industrial Systems Eng., Undergrad Marine Sciences, Undergrad Oceanography, Undergrad Electrical Eng., Graduate</td>
</tr>
<tr>
<td>Stevens Institute of Technology</td>
<td>Waleed Alsaedi, Nazanin Andalibi, Hardik Gajjar, Qing Li, Talmor Meir, Saiyam Shah, Catherine Strez, Michael Trent</td>
<td>Electrical Eng., Graduate Systems Eng., Graduate Maritime Systems, Graduate Systems Eng., Graduate Ocean Eng., PhD Computer Science, Graduate Systems Eng., PhD Maritime Systems, Graduate</td>
</tr>
<tr>
<td>University of Guam</td>
<td>Wojciech Czerwonka, Felisa Fernandez</td>
<td>Computer Science, Undergrad. Computer Science, Undergrad.</td>
</tr>
</tbody>
</table>

*Table 1. SRI Admitted Student List*
Stipends and Accommodations
Admitted students received summer stipends of up to $5,000 and were provided free accommodations at Stevens’ off-campus residential complex located at 800 Madison Street, Hoboken, NJ. Participants were also provided with access to the Stevens’ Maritime Security Laboratory, the S.C. Williams Library, the Schaefer Gym, Computer Services, Health Services, and the Babbio Center and Edwin A. Stevens academic buildings.

Program Administration
The day-to-day administration and coordination of the SRI was a team effort largely supported by Beth Austin DeFares, CSR Director of Education and Dr. Thomas Wakeman, CSR Deputy Director, under the executive direction of Dr. Michael Bruno, CSR Director and Dean of the School of Engineering and Science at Stevens Institute of Technology. Ms. DeFares and Dr. Wakeman were assigned complementary roles with Dr. Wakeman serving as the lead faculty facilitator and curriculum developer, and Ms. DeFares as the primary program and student coordinator.

CSR “Faculty Leads” and “Faculty Mentors” also played an essential role in the coordination and administration of the research program. Faculty mentors were assigned to each of the four research teams. Faculty mentors were instrumental in helping to shape the strategy and research agenda for their students and facilitating opportunities for field tests and experiments. 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.

Program Format and Curriculum
The eight-week program format was designed to provide a balance between in-class lectures, research project time, professional skills development, and experiential learning opportunities through field exercises, field visits and tours. Figure 2 illustrates the generalized SRI weekly schedule format.
The first two weeks of the program were devoted to providing a contextual framework in which the 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 MTS in global trade and to the US economy, and the significance of MDA 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.

During this time students were also assigned to one of the following four research teams; Acoustics and Electro-Optics, HF Radar, Satellites, and Systems Thinking, and were given the collective challenge to research the utility of their respective sensor technologies to detect small vessel threats using the Hudson River Estuary as their test bed. In the case of the Systems Thinking team, students were given the challenge to develop a detection, response, and resilience strategy focusing on four small vessel threat scenarios identified in the 2008 DHS Small Vessel Security Strategy and two developed internally by the team. Paired with their designated faculty mentors, the teams went to work immediately, developing their research agenda.

**Weeks One and Two** also provided the opportunity for students to participate in research vessel tours of the Hudson River and the Port of New York and New Jersey. Using Stevens’ research vessel the RV Savitsky, student teams were able to assess first hand the vulnerability of the region’s critical infrastructure and national landmarks to small vessel threats and the inherent security challenges posed by the high volume of vessel traffic moving in and about this urban estuary.
Starting **Week Three**, in-class lectures began to delve deeper into the science, engineering and technical applications and Systems Thinking tools used by the CSR to conduct research and develop new knowledge and technologies to enhance our nation’s MDA.

Dr. Hans Graber, Director CSTARS, University of Miami, served as the faculty lead for **Week Three**, providing an in-depth overview of the use of satellites in vessel detection and wide-area surveillance of maritime areas and harbors. During **Week Four**, Dr. Scott Glenn and Dr. Hugh Roarty from Rutgers University, led in-class lectures and experiments in the application of HF Radar in near-shore and over-the-horizon detection and vessel tracking.

Dr. Brian Sauser from Stevens Institute of Technology and Mr. Jim Rice, from MIT, participated as faculty leads for **Week Five**, introducing students to Systems Thinking tools and techniques used to understand and architect the extended enterprise of the maritime systems domain and the systems of systems inherent within the overarching enterprise. Group exercises focused on the effects of disruptions to the maritime transportation system and supply chain security and resilience.

During **Week Six**, Drs. Barry Bunin and Alexander Sutin, from Stevens Institute of Technology introduced students to the uses of Acoustics and Electro-Optics in detecting threats posed by waterborne vessels and underwater divers and unmanned underwater vehicles (UUV’s). SRI students learned about sound waves and acoustic signatures, and the properties of long-wave and short wave infrared imaging. Students also engaged in a comprehensive field test that demonstrated how the integration of sensors can be leveraged to enhance MDA.

Dr. Ali Mostashari, Stevens Institute of Technology, and Dr. Barbara Reagor, from Monmouth University, served as the faculty leads for **Week Seven**, discussing topics related to emergency management, response and preparedness, and novel research being conducted in the area of “cognitive ports”. The concept of cognitive ports refers to a system of sensors and data fusion processes that over time become capable of reacting to security threats and events as they occur in the port environment.

At the start of **Week Eight** of the program, students showed tremendous creativity and leadership by staging a student-directed crisis simulation that integrated and tested the detection capabilities of the Acoustics and Electro-Optics, HF Radar and Satellite teams. Organized and led by the Systems Thinking team, the crisis simulation was intended to demonstrate the varied roles of stakeholders in a maritime crisis situation, and the challenges in coordinating multi-agency emergency response efforts and the sharing and dissemination of information among the stakeholders and jurisdictions.

Throughout the eight-week program, students participated in weekly writing and technical communications workshops aimed at enhancing the development of their professional skills. Led by faculty from Stevens’ Writing and Communications Center,
students were introduced to fundamental concepts and tools necessary for written communications and oral presentations within the professional work environment. The workshop sessions included:

- Introduction to Professional Communications
- Creating and Delivering Presentations
- Technical Writing
- Conveying Technical Data to Your Audience
- E-mail Distinctions and Approaches
- Adding Value with PowerPoint

On the last in-class day of the SRI program, the four student teams presented their final research findings in the form of oral presentations and written reports to the CSR faculty and invited guests. The student presentations clearly demonstrated the maturity and growth of the student teams throughout the program and highlighted their keen understanding and research capabilities as it related to their respective research projects.

The student’s achievements and hard work were recognized in an SRI commencement ceremony. Each student was acknowledged for their contributions to research in port security and received a certificate of completion.
Table 2. below illustrates the detailed eight-week schedule.

<table>
<thead>
<tr>
<th>SCHEDULE</th>
<th>TOPIC</th>
<th>FACULTY LEADS</th>
<th>GUEST SPEAKERS</th>
<th>SRI ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 7 – 11</td>
<td></td>
<td></td>
<td>Richard Larrabee, Dir. of Port Commerce PANYNJ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mitchell Erickson, Dir., DHS NE Operations Interagency &amp; First Responders Programs</td>
<td></td>
</tr>
<tr>
<td>WEEK TWO</td>
<td>Marine Transportation System (MTS) Physical Environments</td>
<td>Thomas Wakeman, Stevens Institute of Technology</td>
<td>John Gilmore, Director of Sales, Maersk Line Inc.</td>
<td>Tour of APM Terminals and Port Authority of NY &amp; NJ facilities in Newark, NJ</td>
</tr>
<tr>
<td>June 14 - 18</td>
<td></td>
<td>Miguel Canals, University of Puerto Rico – Mayaguez</td>
<td>Thomas Betro, Senior Advisor Law Enforcement and Security, 4D Security</td>
<td></td>
</tr>
<tr>
<td>WEEK THREE</td>
<td>Satellite Sensors in Maritime and Port Security</td>
<td>Hans Graber, University of Miami</td>
<td></td>
<td>Student team research vessel tours of the Hudson River Estuary</td>
</tr>
<tr>
<td>June 21 - 25</td>
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</tr>
<tr>
<td>WEEK FOUR</td>
<td>HF Radar Applications in Port and Maritime Security</td>
<td>Scott Glenn, Rutgers University</td>
<td>Bethann Rooney, Manager Port Security, PANYNJ</td>
<td>Student team experiments and research vessel tours of the Hudson River Estuary</td>
</tr>
<tr>
<td>Jun. 28- July 2</td>
<td></td>
<td>Hugh Roarty, Rutgers University</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEEK FIVE</td>
<td>Systems Thinking Tools and Techniques</td>
<td>Brian Sauser, Stevens Institute of Technology</td>
<td></td>
<td>Student team experiments and research vessel tours of the Hudson River Estuary</td>
</tr>
<tr>
<td>July 6 - 9</td>
<td></td>
<td>Jim Rice, MIT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. SRI 2010 Program Schedule

Student Teams and Research Projects
The four research teams were organized to ensure relative balance between school representation, degree status and academic major. Each team was tasked with conducting research and real-time experiments leveraging sensor technologies and systems thinking tools to develop strategies and applications for detecting small vessel threats.

A. Acoustics and Electro-Optics Team
The goal of the Acoustics and Electro-Optics team was to conduct research aimed at detecting, classifying and tracking of small vessels in the Hudson River estuary opposite New York City. The team leveraged Steven’s acoustic system, infrared and CCTV cameras to conduct their research. Test paths with Stevens’ research vessel, the RV Savitsky, were conducted to understand the limitations and benefits of such technology. The team successfully collected small vessel acoustic signatures but recognized ambient noise in the urban estuary as a limiting factor in their research. Student Team: Wojciech Czerwonka (U. of Guam), Andreas Graber (U. of Miami), Qing Li (Stevens), Ariel Marrero (U. of Puerto Rico), Talmor Meir (Stevens), Walter Seme (Monmouth Univ.), and Saiyam Shah (Stevens).
Faculty Mentors: Dr. Barry Bunin (Stevens) and Dr. Alexander Sutin (Stevens).

B. HF Radar Team
The HF Radar team used a high frequency radar system to determine the utility of this sensing technology in detecting small vessels in the Hudson River along New York City.
Utilizing radar antennas they assembled and mounted on the 6th floor balcony of the Babbio Center at Stevens Institute in Hoboken, NJ, the team conducted comprehensive detection tests of vessels traveling the river. Leveraging Stevens’ research vessel, the RV Savitsky, the students collected data and made assessments on the benefits and shortfalls of HF radar in detecting small vessel threats. Students found that they could successfully detect vessels as small as 15 feet high above the water surface, traveling at different velocities. **Student Team:** Dakota Goldinger (Rutgers), Danielle Holden (Rutgers), Lenny Llauger (U. of Puerto Rico), Omar Lopez (U. of Puerto Rico), Shankar Nilakantan (Rutgers), and Angelica Sogor (U. of Miami).

**Faculty Mentors:** Dr. Scott Glenn (Rutgers) and Dr. Hugh Roarty (Rutgers).

C. Satellite Team
The Satellite team paired satellite imagery against Automatic Identification System (AIS) data to identify vessels in the Hudson River estuary opposite from New York City. The purpose of the research was to examine the use of satellite imagery and its applications toward the detection of small vessel threats. The team’s goal was to determine the capabilities of satellites in the detection of small vessels, defined as those vessels of ten meters or less in length. The technology used involved a combination of Synthetic Aperture Radar imagery, Google Earth software overlays, traditional photography, and AIS data provided by equipped vessels. The team’s research results indicated that the commercial satellites used were not applicable to the detection of small vessels, but were instead useful for port security and resilience applications. **Student Team:** Waleed Alsaeedi (Stevens), Joseph Bongi (Monmouth Univ.), Felisa Fernandez (U. of Guam), Blake Picolo (U. of Miami), Michael Trent (Stevens), and Catherine Strez (Stevens).

**Faculty Mentors:** Dr. Hans Graber (U. of Miami), Dr. Shahrair Negahdaripour (U. of Miami), and Dr. Roland Romeiser (U. of Miami).

D. Systems Thinking Team
The Systems Thinking team utilized systems thinking tools and techniques to address small vessel threats to the Marine Transportation System (MTS). The Systems Thinking team was challenged to create a resilient system strategy incorporating the concept of cognition to augment detection, deterrence, defense and mitigation capabilities. The goal of the team was to design a novel resilient security system that would address the threats posed by small vessels and tailored for the urban estuarine environment of the Port of NY and NJ. As a result, the team developed a comprehensive Systemigram and causal loop models illustrating the interconnections in small vessel security and the complex network of resilience strategies. The team also took leadership in conducting a crisis simulation exercise that integrated and tested the detection capabilities of the Acoustics, HF Radar and Satellite teams. **Student Team:** Nazanin Andalibi (Stevens), Blake Cignarella (Rutgers), Tanaira Cullens (Morgan State Univ.), Hardik Gajjar (Stevens), Leonid Lantsman (John Jay College), Jose Mesa (U. of Puerto Rico), and Tiffany Walter (U. of Miami).

**Faculty Mentors:** Dr. Ali Mostashari (Stevens) and Dr. Brian Sauser (Stevens).
Research Experiments
During Week Six of the program the student teams participated in a collaborative multimodal data gathering experiment on the Hudson River opposite New York City, to test the applicability of their respective sensor technologies in detecting vessels. Students utilized the 6th floor patio of the Stevens’ Babbio Center to set-up their equipment and to conduct real time observations. The teams leveraged the use of Stevens’ research vessel the RV Savitsky, together with Stevens Passive Acoustic Detection System (SPADES), the Maritime Security Laboratory’s CCTV cameras, still photography cameras, long wave infrared cameras, and a 360 degree IR camera provided by the United States Army Armament Research, Development and Engineering Center (ARDEC), located at the Picatinny Arsenal in Dover, NJ. The Rutgers HF Radar system, the Riversonde, was deployed and Satellite flyovers and images were arranged by the University of Miami’s Center for Southeastern Tropical Advanced Remote Sensing (CSTARS). Students collected data and maintained data logs that they would later organize and use in their final project analysis and team reports.

In a separate exercise held during the last week of the summer research program, the Systems Thinking team took leadership in organizing a crisis simulation that integrated and tested the detection capabilities of the Acoustics and Electro-Optics, HF Radar and Satellite teams. In the crisis simulation, the Systems Thinking team members acted out the roles of civilians, law enforcement, government and Port Authority officials and the media in the midst of a terrorist threat in the Hudson River opposite New York City. The role-playing demonstrated the varied roles of the stakeholders in a maritime crisis, and the difficulties in coordinating multi-agency emergency response efforts, and the sharing and dissemination of information among the stakeholders and jurisdictions.

To stage the simulation, representatives from the Acoustic and Electro-Optics, Satellites, and HF Radar teams were assembled in the Stevens Maritime Security Laboratory and were informed of a substantiated threat of a waterborne improvised explosive device (WBIED) on a cruise ship in the harbor. The teams were instructed to use their respective sensor technologies to detect and locate the threat before a crisis incident occurred.
As the teams readied their sensors, the Stevens research vessel, the RV Savitsky and a small rubber fast boat were deployed in the Hudson River and acted the role of the terrorist vessel. Each boat pilot was given a pre-determined travel pattern and told to head toward a specified buoy within the harbor that represented the mock cruise ship in jeopardy. As the boats ascended on their respective routes traveling at varying speeds, the teams were instructed to begin their detection exercise.

Minutes into the simulation, the Acoustics and HF Radar teams were able to detect two vessels traveling from opposite directions toward the buoy (target cruise ship). Communications between the two teams intensified as they tried to exchange critical information on the traveling speed and path of vessels. Before the teams could gather all of the necessary intelligence to intercede, the RV Savitsky and the rubber fast boat reached their intended target.

Following the simulation, the students held a recap session where they discussed the key issues and challenges that constrained their ability to successfully pinpoint and intercede in the mock terrorist attack. While the students were able to pick up the two vessels, their respective sensors also captured other vessel traffic in the Hudson, making it difficult to assess which of the vessels intended to do harm. Communications within and between the teams also posed issues as the attack became eminent and the need to rapidly process information became more challenging. Students acknowledged that with better-defined team member roles and responsibilities, the flow of communication and the processing of data would have been more efficient and fluid. The teams all agreed however, that detection of a threat is only one component of the overall picture and that without the proper law enforcement resources or capabilities to intercede, detection has less value.

SRI Assessment
An assessment of SRI outcomes and lessons learned was performed at the conclusion of the program in the form of a student and faculty survey. Feedback from the survey responses, together with the final student team research reports and presentations all reflect the SRI’s success in meeting its program objectives.

Student Survey
Overall, a majority of the students rated the SRI “Very Good” to “Excellent” in the following areas:
- Helpfulness of faculty mentors
- Quality of Teamwork
- Quality of the Classroom Facilities
- Program coordination and administration

When asked how their knowledge and understanding of port security improved during the course of the program, all students reported positive improvement with 64% (16 students) reporting substantial improvement and advanced knowledge, and 32% or 8 students reporting adequate improvement.
Relative to the skills they learned, students rated their oral presentation skills as “Excellent”, and writing, literature reviews and teamwork skills as “Very Good”. Twenty-two out of 24 students said that the SRI had enhanced their interest in pursuing advanced study and/or a position within homeland security, and 100% of the respondents said that they would recommend the SRI to their peers and colleagues at their respective schools. When asked about the strengths of the program, students collectively remarked on the knowledge and expertise of the faculty, the resources and support that were provided to them, and how the diversity of the student participants contributed to the unique experience of the SRI.

**Faculty Survey**
When asked to rate the program across several dimensions including “Quality of Student Participants”, “Quality of Student Work and Outputs”, “Program Organization & Administration” a majority of the faculty said that the program “Exceeded Expectations”. In all dimensions relating to the structure and format of the program, a majority of the faculty said that the program had “Satisfied and/or Met the Program Objectives”.

The one area in which the faculty ratings varied greatly was the role of the “Faculty Leads”. While 67% said that the Faculty Leads “Satisfied and/or Met the Program Objectives”, 22% said that they were either “Unsatisfied” or “Somewhat Satisfied”, and 11% said that the Faculty Leads “Exceeded Expectations”.

When asked what they considered the strengths of the SRI program, one faculty member commented: “One of the most impressive accomplishments I have seen in years, given the diversity of students, backgrounds, expertise, etc.”

**Outcomes and Lessons Learned**

Overall, the SRI was effective in achieving the following outcomes.
- Student research reports, field experiments and weekly presentations demonstrated the student’s knowledge and understanding of the MTS and MDA.
- Students enhanced their professional skills by attending writing and technical communications workshops and providing weekly research status updates and oral presentations.
- Students took initiative and leadership to create a student directed crisis simulation exercise, including input and participation by all four of the research teams.
- Students developed obvious strong bonds and friendships with each other.
- Students expressed interest in pursuing advanced academic study and enhanced interest in pursuing a position within homeland security as a result of the SRI.

The most salient lesson learned during the eight-week program was the need to engage students in their research earlier on in the program and to provide them with more time to engage in hands-on research and field experiments. Conversations with students and faculty, together with their survey feedback, each suggest that student research productivity and outcomes were constrained by too much time spent in in-class lectures. Student and faculty comments suggest that if the student teams had had more time to
conduct their research, their final reports would have been more substantive and conclusive.

Recommendations
Based on the student and faculty survey responses and conversations held between the CSR faculty and administrators the following recommendations have been made for future SRI program offerings.

Admission Criteria: Some faculty members have recommended that the criteria for admission become more rigorous and that students submit letters of recommendation from faculty advisors together with their applications and statements of interest.

DHS Career and Internship Opportunities: As reflected in this year’s SRI student survey, many students expressed enhanced interest in pursuing advanced 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 next year’s summer program include representation from DHS who can discuss next step internships and/or career opportunities for motivated and interested students.

Location: Several of the CSR faculty members have suggested that the SRI program remain at the Stevens Institute of Technology campus because of its robust research assets and its geographical location next to the Hudson River Estuary.

Program Format: Faculty and student feedback strongly recommend that students be given more time to conduct their research and participate in field experiments earlier on in the SRI program. Faculty and student comments suggest that a better balance be achieved between in-class lectures and team research project time.

Research Teams and Topics: CSR faculty recommend that a “Data Fusion” team be included in next year’s SRI program and that the student teams be given “narrower” more defined research projects.

Conclusion
The student and faculty responses to the SRI program survey overwhelmingly confirm the success of the Summer Research Institute. The SRI was by all accounts a true collaborative effort across the entire CSR research enterprise, leveraging the teaching talents and research expertise of its faculty and the contributions of its maritime industry and homeland security partners to provide students with a unique, real-world, multi-disciplinary research experience.

The collaborations in and among the student teams and the faculty proved to be a key feature of the program. Students were kept motivated as they engaged in innovative and rigorous research activities centered on the technologies, tools and techniques used to enhance our nation’s maritime domain awareness and the security of our ports, inland waterways and coastal borders. Students developed new skills and knowledge that were
clearly demonstrated in the quality of their research reports and the analysis of their findings.

Student survey responses reflected the enthusiasm for the SRI program and highlighted their enhanced interest in pursuing advanced academic study and/or positions within the maritime homeland security domain.

The momentum of the SRI program renewed synergies among the CSR faculty as they collaborated in the classrooms and labs, and casual conversations in the hallways spurred new ideas for future research projects and student research opportunities.

**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:

3. CSR will seek to host DHS Scholar & Fellow interns during the summer of 2011
4. Include students from CIMES partner schools and other DHS CoE’s to participate in the annual Summer Research Institute
5. Provide new professional development course offerings.
6. Create a global CSR faculty seminar series
V. SUMMARY OF ACCOMPLISHMENTS IN YEAR 2

a. Table 1: List of Accomplishments

CSR Accomplishments: July 2009 through June 2010

<table>
<thead>
<tr>
<th>Categories of Accomplishments</th>
<th>Number/Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students matriculated</td>
<td>12</td>
</tr>
<tr>
<td>Papers</td>
<td>27</td>
</tr>
<tr>
<td>Software Products Developed</td>
<td>9</td>
</tr>
<tr>
<td>Patents</td>
<td>0 granted; 1 patent application</td>
</tr>
<tr>
<td>Requests for assistance or advice from DHS</td>
<td>7</td>
</tr>
<tr>
<td>Requests for assistance or advice from Federal, State, Local Government</td>
<td>20</td>
</tr>
<tr>
<td>Presentations</td>
<td>75</td>
</tr>
<tr>
<td>Congressional Presentations</td>
<td>4</td>
</tr>
<tr>
<td>Projects Completed</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: There were no patentable inventions resulting from Year 2 work.
VI. APPENDICES

Appendix A – SRI Faculty List
Summer Research Institute
June 7 to July 30, 2010

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. Alan Blumberg, Director, Center for Maritime Systems
Dr. Barry Bunin, Research Professor, Maritime Security Laboratory
Beth Austin DeFares, Director of Education, CSR
Dr. Thomas Herrington, Associate Professor, Civil, Environmental and Ocean Engineering
Dr. Ali Mostashari, Director, Infrastructure Systems and Associate Professor, School of Systems and Enterprises
Dr. Julie Pullen, Director, Maritime Security Laboratory
Dr. Jose Ramirez-Marquez, Assistant Professor, School of Systems and Enterprises
Dr. Hady Salloum, Director Port Security Initiatives, CSR
Dr. Brian Sauser, Assistant Professor, School of Systems and Enterprises
David Silverstein, Director, Writing and Communications Center
Dr. Alexander Sutin, Research Professor, Center for Maritime Systems
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
Dr. Tony MacDonald, Director, Urban Coast Institute

Rutgers University
Dr. Scott Glenn, Professor, Coastal Ocean Observation Laboratory, Department & Institute of Marine and Costal Sciences
Dr. Hugh Roarty, Director, Operations Center, Coastal Ocean Observation Laboratory
Dr. Josh Kohut, Assistant Professor, Coastal Ocean Observation Lab, Institute of Marine and Coastal Sciences
Ms. Janice McDonnell, 4H Agent, Science, Engineering and Technology, School of Environmental and Biological Sciences.

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-3 Plans

**Introduction**
The CSR will continue its research efforts in two basic areas:
- Maritime Domain Awareness (MDA), and
- Topics in Global Policies influencing MTS Security, including Design for Resiliency

We expect that in Year 3, 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. In addition to these publications, presentations, and advising activities, we expect to provide the following products:
- prototype underwater passive acoustic sensors for use in the detection of small surface and underwater objects;
- computer algorithms for the analysis of passive acoustic sensor data;
- database of signatures of small surface and underwater vehicles and threats, including small powered surface vessels, unmanned underwater vehicles, and divers;
- visualization algorithms to support decision-making using the passive acoustic system;
- algorithms to support the use of space-based sensor information in the detection and characterization of surface vessels;
- algorithms to support the use of HF Radar data in the detection and characterization of surface vessels;
- 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;
- analytical models of the national and international MTS, including Systemigrams and other modeling, simulation, and visualization tools;
- metrics and procedures for the assessment of MTS resiliency;
- database and analysis of decision-making in complex environments; and
- visualization algorithms and training tools for decision-makers.

**Education and Outreach Overview**
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.

Each of the research projects described in the section following this section contains activities and funding for the participation of undergraduate and graduate students. These activities constitute one of the primary vehicles by which the CSR partner universities plan to achieve their mission of educating the nation’s future maritime security workforce.

The CSR partners have developed several important initiatives to address the educational needs of university students both within and outside of the CSR member universities (the Summer Institute), and the specialized training needs of working professionals (the CSR Maritime Security courses in Washington, DC).

Education Area 1: CSR Maritime Security Summer Institute
In 2010, CSR created a uniquely collaborative, multi-disciplinary, academic-industry-government enterprise, the **CSR Maritime Security Summer Institute**. As described earlier in this report, the Institute consisted of an 8-week focused research and education activity in which undergraduate and graduate students selected via a highly-competitive application process will work hand-in-hand with world-class science and engineering faculty and MTS professionals to:

• conduct transformational, multi-disciplinary research in support of the needs of the marine transportation community;
• employ the research activities as a vehicle for the conduct of undergraduate, graduate, and professional education, and;
• develop and strengthen the international personal and professional ties that will sustain and expand the collaborative activities initiated under the auspices of the Institute.

The Summer Institute will once again be conducted in the summer of 2011 on the campus of Stevens Institute of Technology, using funding received via other DHS, government, industry, and foundation support.

Education Area 2: CSR Maritime Security Courses in Washington DC
In a unique and significant initiative, the CSR partner universities have teamed to develop and implement 1-week, intensive courses in maritime security. These courses are intended for delivery to the maritime security technology workforce, including designers, operators, and acquisition personnel. The second of these courses, to be offered in October, 2010, deals with Port Security Sensing Technologies. See Figure 1. The course will be delivered by the CSR PIs responsible for each sensor type being developed under the present grant, thereby giving the students the benefit of having the most up-to-date information regarding the present state-of-the-art and future trends in maritime security surveillance technologies.
This three-day professional development course uses selected topics from the Stevens Institute of Technology’s graduate level courses in Port Security Sensing Technologies and Technologies for Maritime Security (OE-810 and OE-628).

**COURSE DESCRIPTION**

The objective of this course is to enable participants to understand the basic sensor technologies used in Port Security applications, to engage in discussions of these at a management level, and to make informed management decisions in their areas of responsibility regarding relevant technology-based solutions.

**INSTRUCTION AND ORGANIZATION**

This course is led by experienced and highly qualified former maritime industry and government practitioners and by nationally recognized scientists and senior researchers from the DHS National Center for Secure and Resilient Maritime Commerce (CSR), the Center for Maritime Systems (CMS), and the Office of Naval Research (ONR) sponsored Maritime Security Laboratory (MSL).

Participants are exposed to case studies and illustrative examples. The course is designed to facilitate an open dialog and the sharing of relevant experiences and lessons learned in port security.

**COURSE MATERIAL**

Participants will receive a binder containing notes and additional readings specifically organized for this course.

**AUDIENCE**

This course is tailored to maritime security professionals and practitioners who engage in management-level decisions and acquisitions as they relate to security technology and applications in port and maritime environments.

**REGISTRATION**

To register visit: [http://dc.stevens.edu/course-schedule](http://dc.stevens.edu/course-schedule)

(Click on Maritime Security under Academic Program Schedule.)

**GENERAL INFORMATION**

For information on course delivery, tuition & fees, please contact:
Beth Auster DeFares, Director of Education,
bodefaires@stevens.edu Tel: 201.216.5352

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*Figure 1: Brochure for the October, 2010 Course*

This course, and the courses expected to be developed during the rest of Project Year 3, will be self-supported via student tuition. It is anticipated that the contacts made, and
lessons learned via these interactions with maritime security professionals from industry and government will further enhance the impact of the CSR activities.

Research Overview

Research Area 1: Maritime Domain Awareness

There are three separate but integrated research activities under this Research Area. 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?” This issue of resolution – driven by the concern for threats associated with small surface vessels, UUVs, and divers – will be addressed during Year 3, along with issues related to the real-time delivery of actionable information. 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 are being 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 are being 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 is 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 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 along 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 and 2 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. In Year 3, these measurements will be used for the development of vessel classification algorithms and ship traffic pattern analyses.

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 to 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, and this will be the focus of the Year 3 effort in the decision-making area. Monmouth University’s (MU) contributions to this area of inquiry stem from work that leverages existing software engineering, modeling, and simulation talent and research capabilities to support rapid decision-making and assess activities to prevent, protect, respond and recover in the event of a homeland security or all-hazard disaster.

The integration and evaluation of the multi-layer, multiple technology system outlined here will take place in a series of field experiments conducted in NY Harbor, the Florida Keys, and along the west coast of Puerto Rico.
Research Area 2: 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. They are also identifying opportunities to make security and maritime resiliency investments leverage improvements in marine transportation business and economic performance.

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

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 will be defined and using a network model along with a System Dynamics model, the effect of port collaboration on the above mentioned resiliency metrics will be measured. An Enterprise Architecture approach will be used to develop an architecture for a Cognitive Port System.

The Enterprise Resiliency Modeling – Architecting Strategic Intent project will use 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 will then be actualized in an agent based modeling and simulation environment in order to capture the temporal and special dimensions of port enterprise resilience.

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 will take daily variations into consideration; this will require accessing a database with daily volumes for each US port which is not currently available in the public domain. The effort will also develop 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.