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Center for Secure and Resilient Maritime Commerce
(CSR)

YEAR ONE REPORT

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U.S. Department of Homeland Security  
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Center for Secure and Resilient Maritime Commerce (CSR)  

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YEAR ONE 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, Lockheed Martin Maritime Systems, the Pacific Basin Development Council, and Nansen Environmental Remote Sensing Center.

The CSR’s Vision is to function as a key national resource to DHS in all areas of maritime security and coastal safety through research and education. The Center aggressively strives to reach this vision through the application of the strength of its partnerships, its combined assets and resources, and its professional capabilities to three goals. The Goals are: 1. improving port security and the security of coastal and offshore operations and leveraging security investments to also improve economic performance; 2. improving emergency response to events in the maritime domain; and 3. improving the resiliency of the Maritime Transportation System (MTS), offshore operations, and our nation's coastal environments. To address each of these goals, CSR’s research efforts have been divided into two basic areas: Maritime Domain Awareness (MDA), and Topics in Global Policies influencing MTS Security and Coastal Safety.

Maritime Domain Awareness. 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 multi-sensor and multi-tiered surveillance systems. Integration of these systems is aimed at achieving vessel detection, classification, identification, and tracking. 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 Bight test-bed are being transferred to the University of Puerto Rico for testing in Caribbean waters. The University of Puerto Rico Mayagüez (UPRM) first year’s effort 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. A system was installed and is now operational at Club Deportivo del Oeste on the west coast of Puerto Rico. Also AIS for validation of the HF Radar ship tracking effort was installed at the UPRM’s Department of Marine Sciences field station.

Stevens Institute of Technology leads the nearshore and harbor multi-sensor and multi-tiered surveillance system portion of the MDA project. Much of the Stevens effort in Year 1 was devoted to the development of a passive acoustic array that can provide low-cost, highly portable acoustic surveillance capability. The first version of the passive acoustic system and the software for signal processing was developed during Year 1. 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 the Hudson River. These measurements will be used for the development of vessel classification algorithms and ship traffic pattern analyses. Stevens researchers also conducted investigations of emergency response decision-making and emergency management. With respect to decision-making, the researchers 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. Monmouth University’s (MU) 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 extant 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. Together in the first year, UCI and RRI supported CSR-relevant
initiatives including summer research programs, workshops, outreach, and training by developing emergency strategies, policies and educational outreach programs.

**Topics in Global Policies influencing MTS Security and Coastal Safety.** This element of the CSR research took 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.

Stevens Institute of Technology researchers are examining resiliency as the ability of a system (or enterprise) to absorb external shocks in a manner that its value delivery is not significantly undermined as a result of the shock. As part of this effort, they are investigating the concept of resiliency with regards to port infrastructure systems and other critical infrastructure and are developing the frameworks and methodologies that can assist decision-makers to make these systems more resilient in the face of natural and man-made disasters. Researchers are also examining resiliency modeling. Their research argues that systemic diagrams, i.e. Systemigrams, can capture strategic intent in a unique fashion. Moreover this approach can prevent enterprises from interfering with one another, safeguarding against unwanted crashes, and keeping the collective good very much on track. The effort to-date has demonstrated how to build a culture of systems thinking within an enterprise.

The Massachusetts Institute of Technology (MIT) and the Mattingley Group (MG) have been investigating supply chain resiliency. MIT’s prior research, which has helped guide corporate response to supply chain disruptions, is helping guide CSR resiliency research. MIT and MG researchers are investigating supply chain resiliency principles because although these principals have had a meaningful impact on industry and corporate practice, they have yet to be holistically applied to the MTS.

In addition to its research mission, the CSR has an Education mission. The first year’s activities focused primarily on planning, although there were several notable outcomes. Educational activities included the conduct of two CSR educational programs planning sessions, the development of new maritime security courses at Stevens Institute of Technology, and a “trial run” for the forthcoming Summer Institute. The Faculty Graduate Curriculum Committee at Stevens approved a new four-course graduate certificate program entitled “Maritime Security”. The program is composed of four security courses that were specifically developed for the certificate: Maritime Safety and Security; Fundamentals of Remote Sensing; Technologies for Maritime Security; and Advanced Maritime Security. During the summer of 2009, Rutgers University, the University of Puerto Rico, and Stevens Institute of Technology ran a pilot for the future CSR Maritime Security Summer Institute, leveraging support from DHS, NSF, NOAA, ONR and the Vetlesen Foundation. This Summer Institute pilot session focused on 10-
weeks of undergraduate instruction structured to provide an introduction to ocean sensing and modeling technologies. The students were divided into three groups involved with: shipboard technologies for use in an estuary; HF Radars for use in the coastal ocean; and autonomous underwater gliders for use in the global ocean. In Year Two, CSR will create a uniquely collaborative, multi-disciplinary, academic-industry-government enterprise that will plan and implement the CSR Summer Institute. The Institute will consist 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.
I. INTRODUCTION

This is the first annual report for CSR (Center for Secure and Resilient Maritime Commerce); accordingly, some background information is provided to help the reader put the Center’s purpose, goals, and objectives into perspective. This is followed by a short description of the organization of the report.

a. Heightened Maritime Concerns

In the years prior to September 11, 2001, the Marine Transportation System (MTS) and the logistic business community that it supports focused almost exclusively on speed, reliability, and the cost of operations. Security, when addressed, dealt primarily with protecting cargo from theft. Since that horrific day, the MTS stakeholders recognize that there is a myriad of threats, system vulnerabilities, and potential negative consequences that have emerged along the international supply chain and the world of international oceanborne shipping.

The United States is the world’s leading maritime nation, as measured by both the volume and the economic value of its maritime commerce. U.S. ports and waterways handle more than 2 billion tons of domestic and import/export cargo annually. By 2025, the total volume of cargo shipped by water is expected to be double that of 2000 volumes. There are approximately 360 deep-water ports in the nation. Many of these ports are along the East Coast and the Gulf of Mexico, while Southern California and the Pacific Northwest ports are the primary centers along the West Coast. For the cruise industry, the U.S. Maritime Administration’s figures showed that North American cruise passenger traffic had increased by 3.5 percent in 2005, with more than 9.7 million passengers carried on 4,463 cruises by the 17 largest cruise lines. In short, the MTS is big business for the U.S. economy, while it also provides new risks.

The 9/11 Commission Report noted that although there is a continuing threat against our aviation system, “…opportunities to do harm are as great, or greater, in maritime or surface transportation.” From smuggling to piracy, suicide attacks, to the threat of weapons of mass destruction being delivered to the United States in one of the 11 million containers that arrive here annually, the threats are many and varied. Maritime security analysts have discussed numerous potential tactics for terrorist attacks on U.S. maritime targets.

NSPD-41 / HSPD-13, National Maritime Security Strategy (21 December, 2004) established a Maritime Security Policy Coordinating Committee to oversee the development of a National Strategy for Maritime Security and eight supporting implementation plans to achieve:

• **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.

• **Maritime Operational Threat Response** aims for coordinated U.S. Government response to threats against the US and its interests in the Maritime Domain by establishing roles and responsibilities.

• **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."*

The following passage from the “National Strategy for Maritime Security” summarizes many of the tactics most commonly mentioned in maritime security discussions. “Terrorists can also develop effective attack capabilities relatively quickly using... explosives-laden suicide boats and light aircraft; merchant and cruise ships as kinetic weapons to ram another vessel, warship, port facility, or offshore platform; commercial vessels as launch platforms for missile attacks; underwater swimmers to infiltrate ports; and unmanned underwater explosive delivery vehicles. Mines are also an effective weapon.... Terrorists can also take advantage of a vessel’s legitimate cargo, such as chemicals, petroleum, or liquefied natural gas, as the explosive component of an attack. Vessels can be used to transport powerful conventional explosives or WMD for detonation in a port or alongside an offshore facility.”

**Reference:** *National Strategy for Maritime Security: National Plan to Achieve Maritime Domain Awareness, October, 2005*

While the focus of this introductory discussion has been on the terrorist threat to the maritime community, the continuing population growth of coastal communities, the forecasted increase in storm severity associated with global climate change, and the post-December 26, 2005 awareness of the potential Tsunami threat have emphasized the need to include consideration of the potential disruptions inflicted by natural disasters. In the
post-Katrina era, the MTS stakeholders have adopted an approach that addresses all threats (that is, both man-made and natural) to the global supply chain and coastal/island communities and resources.

The all-hazards approach to natural and man-made disruptions must include disaster prevention, emergency response and recovery in plans to reduce the risks and improve the security and resiliency of coastal communities. This new paradigm for maritime and coastal community security requires a layered approach and a strong and united effort with local, federal, and international partners in order to address the complexity and ambiguity of today’s global maritime environment in order to protect our nation’s ports and associated commerce as well as make them resilient to various types of disruptions.

b. **DHS S&T Response**

In early 2007, the U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate issued a Broad Agency Announcement (BAA) number DHS-07-ST-061-003 soliciting proposals from academia for establishing a Center of Excellence for Maritime, Island and Extreme/Remote Environment Security. S&T also solicited proposals for establishing other Centers of Excellence for Border Security and Immigration; Explosives Detection, Mitigation and Response; Natural Disasters, Coast Infrastructure and Emergency Management; Transportation Security, and later on for Command, Control, and Interoperability.

The Centers of Excellence program is managed by the Office of University Programs at DHS S&T. The purpose of these centers was summarized by the DHS award press release that stated: “…this program takes advantage of the unsurpassed research capabilities and intellectual capital of U.S. colleges and universities to fill knowledge and technology gaps for the department. By Congressional authorization, each Center will be responsible for conducting multidisciplinary research and developing education initiatives in areas important for homeland security.”

Stevens Institute of Technology assembled a team consisting of academic, industry, and public sector partners to submit a white paper and then was invited by DHS to submit a proposal for the Center of Excellence for Maritime, Island and Extreme/Remote Environment Security. DHS selected Stevens Institute and University of Hawaii from a competing pool of universities to co-lead the new center that: “...will be responsible for conducting research and developing new ways to strengthen maritime domain awareness and safeguard populations and properties unique to U.S. islands, and remote and extreme environments. The University of Hawaii leads research and education for maritime and island security, and Stevens Institute of Technology leads research and education for port security.”

The leadership and researchers at both the National Center for Islands, Maritime, and Extreme Environments Security (CIMES) and Center for Secure and Resilient Maritime Commerce (CSR) believe that collaboration between the two centers is essential to meet
DHS’s objectives. The two centers have parallel objectives and complementary expertise, and close coordination between the two centers will enhance the capabilities of each.

c. **Report Organization**

The purpose of this document (Year One Report) is to report on the first year’s activities at the CSR. The next section introduces the CSR partners and the Center’s goals and objectives. The Center’s goals and the research tasks completed in the first year to support those goals are presented in Section III. Section IV discusses the CSR educational principles and first-year activities. Accomplishments are summarized in Section V.
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 and coastal safety within the CSR Team and cooperating programs. CSR’s Director is Dr. Michael Bruno, Dean of the School of Engineering and Science at Stevens Institute of Technology. The Center is physically located on the Stevens Institute of Technology campus in Hoboken, New Jersey, which is adjacent to the Hudson River and the surrounding New York Harbor.

a. CSR Team Members

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

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

The non-academic partners include:

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

The Global Maritime and Transportation School at the U.S. Merchant Marine Academy, is an affiliated institution, which is funded by the federal government through other appropriation mechanisms outside of the CSR grant. The current CSR point of contact is Captain (ret) Fred Evans.
As stated above, the CSR team was assembled to take advantage of the strengths of each partner to address all aspects of Port Security that DHS envisions and expects from the Center of Excellence. 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 like the Naval Postgraduate School and the US Coast Guard Academy to advance its research agenda. This also allows CSR to leverage a bigger pool of all available resources and resident expertise.

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 – the region of most interest to the emergency management community – along the entire New Jersey shoreline. A newly-added storm surge and wave forecasting system provides early warning to State and Federal officials of possible flooding and/or severe erosion conditions along the shoreline. These warnings are provided via cell phone text messages to selected officials, and via email messages to the general public.

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. Advice was provided on sensor technology, beam mode specifications and data analysis. The analysis consisted of selection of maritime targets, testing procedures, image quality and usefulness for operational applications. 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/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 six 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;
- Surface traffic video tracking;
- CFD modeling and validation measurements of Small vessel wakes and SCUBA divers.
• IR monitoring of submerged objects, divers, and wakes produced by small vessels
• High resolution computer forecast model of the estuarine environment; including coupling of the model with estuarine SCUBA diver detection experiments;
• 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. **Vision, Goals and Objectives**

The CSR’s *Vision* is to function as a key national resource to DHS in all areas of maritime security and coastal safety through research and education. The Center aggressively strives to reach this vision through the application of the strength of its partnerships, its combined assets and resources, and its professional capabilities to three goals. The *Goals* are:

1. improving port security and the security of coastal and offshore operations and leveraging security investments to also improve economic performance;
2. improving emergency response to events in the maritime domain; and
3. improving the resiliency of the Maritime Transportation System (MTS), offshore operations, and our nation's coastal environments.

Within the framework of its Vision and Goals, CSR has established the following six *Objectives* to more fully respond to potential DHS needs within the MTS and coastal environment domains as the Department acts to meet its legislative mandate to protect the homeland. Specifically, CSR will:

- Be flexible and agile in dealing with new and emerging port security threats;
- Ensure close coordination and collaboration among the diverse professionals, industries, and institutions involved;
- Guarantee the very highest standards of excellence in the Center’s research, product development, and education/training activities, and deliver results on schedule and within budget;
- Facilitate partnering and outreach across the academic-government-industry communities;
- Engage Minority Serving Institutions to ensure meaningful contributions to the Center and its evolution; and
- Ensure effective communication to all stakeholders, including – as appropriate – the general public.
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. For CSR’s Port Security’s mission, this translates into supporting DHS efforts to secure the nation’s maritime borders, promoting safe navigation and commerce, protecting ocean resources and maritime infrastructure, and providing for the safe and secure use of our coastal and offshore areas.

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 and Coastal Safety
   - Task 2.1 Resilient Port Infrastructures
     - Task 2.2 Collaborative design of resilient extended enterprises
     - Task 2.3 MTS Recovery and Continuity of Operations

In the following, we provide a summary of the research efforts and results associated with each of these projects. As appropriate, websites for additional information and publications are provided.
1. Maritime Domain Awareness

Task 1.1 Space-Based Wide Area Surveillance
University of Miami (Dr. Hans Grabber, PI)

Project Abstract
CSTARS is continuing to explore the use of space assets such as high resolution synthetic aperture radar (SAR) to detecting and classifying small boats to large vessels. Recent studies with DoD agencies have shown that small, fast moving boats can reliably be detected, and large vessels can be tracked across ocean basins. Refinements are being made to the detection algorithms to validate with the Automatic Identification System (AIS). CSTARS is developing with NGA a SAR Architecture Center which will incorporate the new, high resolution SAR sensors such as Cosmo-SkyMed, TerraSAR-X and RadarSat2 to support global and near real-time acquisition of image data. While satellite based monitoring of vessel traffic has been demonstrated, a comprehensive end-to-end surveillance of the global maritime domain does not exist and must be tied to direct access of a diverse set of satellite sensors to maintain persistence. Only such an end-to-end system would allow the determination of anomalous behavior and mitigating the impact of potential terrorist threats. CSTARS will continue to participate in port security exercises to provide access to near real-time satellite data for situational awareness from port to longer ranges.

Project Objectives

Explore the use of polarimetry in vessel and wake detection.

Explore change detection of vessel movement using different satellite sensors within a GoogleEarth Enterprise solution.

Research Milestones Met
Satellite Reception
i. Supported acquisition with different satellite sensors for NY Harbor tests.
On 19 November 2008 we provided a variety of satellite sensor support for a Port of New York ship detection and monitoring exercise. The goal of this exercise was to test whether a multi-tiered port monitoring system using different surveillance systems such as satellites, HF radar, acoustic sensors and visible and infra-red cameras would provide the essential integrated, layered coverage envisioned as a primary CSR goal. Figure 1 shows a zoomed section of a panchromatic FormoSat-2 image (2m resolution). The passenger ferry “Seastreak New Jersey” is clearly visible, showing a long, persistent wake back to its docking place. Identification of the vessel has been verified with AIS data.
Figure 1: FormoSat-2 optical image on 19 November 2008 at 15:37:09 UTC.

About 10 minutes later a second optical satellite sensor, SPOT-4 with 10 m resolution but a 120 km field of view imaged the entire New York harbor area, including its approaches. Figure 2 shows the wide area situation awareness of vessel traffic in this location. AIS data was used to validate those vessels carrying the transponder while many unidentified vessels were moving in and out of the harbor area.
Figure 2: SPOT4; Collected: 11/19/2008; Scene Center time: 15:49:06 UTC; AIS contacts are indicated by colored dots.

Figure 3 shows an ENVISAT SAR image about one hour earlier over the region. Numerous vessels were identified which were later covered by clouds in the optical images. The combination of optical and microwave imagery was here shown to allow for persistent coverage day and night and provide unprecedented situational awareness.
Figure 3: ENVISAT ASAR image on 19 November 2008 at 14:48:53 UTC showing a cluster of vessels. Not all were identified by AIS although they appear large enough to broadcast AIS signals.

ii. Provided maritime domain analyses of satellite imagery
CSTARS participated in the assessment of RadrSat-2 on behalf of the USAF Space Missile System Center. With local support of DHS’ ICE Miami Maritime Unit, CSTARS arranged a testbed environment using two go-fast boats to evaluate the feasibility of detecting and classifying fast moving vessels offshore of Miami. A similar test was arranged with JIATFS offshore of Key West. Dr. Hans Graber participated in the go-fast test off Miami.

Figure 4 shows the wake signature of a 30 ft Eduardoño go-fast boat “Gotcha”
previously confiscated by JIATFS. The inset shows a photo of the wake generated while traveling at 33 knots. Figure 5 shows the difference between two RadarSat SAR images but with different resolution. “Gotcha” was used in several other exercises on small boat detection. In 2006, higher resolution radar sensors like RadarSat-2, TerraSAR-X and COSMO-SkyMed were not yet available and the current technology using 8 m fine beam mode barely detected small, low emitting targets. In contrast the higher resolution SpotLight modes with up to 1 m resolution easily detect small, fast moving targets.

Figure 4: RadarSat-2 SAR image on 21 May 2008 @ 23:22:30 UTC delineating a strong wake signature from a low emitting moving target. The inset shows a photo of the generated wake at this instance.
This is further confirmed in Figure 6 where a USCG Auxiliary Patrol boat and two Midnight Express go-fast vessels were imaged. The latter two go-fast boats could run at 60 mph! Figure 7 presents the induced Doppler shift caused by moving targets in SAR images. The ICE go-fast boat was moving at a speed of approximately 61 mph, giving rise to a 1.45 km displacement of the hard body target from the wake.
Figure 6: RadarSat-2 SpotLight SAR image on 21 June 2008 @ 23:18:36 UTC of two ICE Midnight Express go-fast boats moving at 60 mph. Note the long wake (dark streak) and very bright area caused by accelerating water particles from the bow wakes. A USCG Auxiliary Patrol boat was running parallel to Mike-77 (see inset).

Figure 7: Details of RadarSat-2 SpotLight SAR image on 21 June 2008 @ 23:18:36 UTC showing the large Doppler shift of a fast moving target. The Midnight Express go-fast boat was moving at 61 mph according to GPS and 63 mph from estimate derived from the Doppler shift.
iii. Developing new algorithms for wake detection (work in progress)

We are exploring new algorithms to better detect ship wakes in a variety of sea states or noisy environments in SAR images. In particular, we are exploring the use of a Radon Transform which is an ideal candidate for the extraction of linear features from noisy backgrounds such as SAR image data. The technique seems to be very suitable to both dark and bright wake features. Figure 8 shows an example of a short wake which may not be automatically detected with various image analysis techniques. However, the Radon Transform of this subset clearly elucidates the linear wake feature and makes automated detection of such feature more feasible in the Radon Transform space.

Figure 8: Subset of SAR image with weak, but visible wake (left). The subset in Radon Transform space clearly shows the presence of the wake and can also be used to derive heading and course direction.

iv. Attended DHS University Summit in Washington, DC on March 17 & 18, 2009

Participated in the DHS University Summit and interacted with various participants including the Science Advisor from the German Embassy. Also generated the CSR poster to highlight the CSR project (Figure 9).
Figure 9: CSR poster presenting the multi-tiered approach to port monitoring and surveillance.

Hosted CSR researcher meeting in Miami, Florida on January 29 & 30, 2009

Attended and participated as panel member and speaker at the 2008 Asia-Pacific Homeland Security Summit in Honolulu, Hawaii, on November 7-9, 2008

v. Participated in Southeast Florida Urban Area Security Initiative Regional Full Scale Exercise OPERATION CASSANDRA 2009 with the Port of Miami

Through the Port of Miami’s Director of Security, we were invited to participate in a regional urban area and port security exercise. CSTARS provided for three days overhead satellite imagery to the control center of the exercise. The day of the exercise, 29 July 2009 was extremely cloudy and limited results were expected with optical sensors. A COSMO-SkyMed 3 SAR image in Spotlight mode on July 29, 2009 @ 7:35 am local time was used to provide situational awareness. The 1 m resolution SpotLight image (Figure 10) showed several vessels docked and seven of them identified by AIS. Figure 11 shows an example of the resolution power of the COSMO SAR. A day earlier, on 28 July 2009, weather permitting, EROS-B, a very high resolution (70 cm) optical satellite imaged the port and was able to detect numerous vessels. Figure 12 shows the very high detail of the cargo ship “Maersk Dhaka” visible in this image.
Figure 10: COSMO-SkyMed 3 SAR image in Spotlight mode on 29 July 2009 @ 11:35 UTC showing numerous vessels docked including the University of Miami’s R/V F.G. Walton Smith at Virginia Key.

Figure 11: Details of the “Seaboard Costa Rica” seen by COSMO-SkyMed 3 SpotLight Image docked at the Port of Miami. Additional strong scatterers pier-side are caused by cranes, containers and vehicles.
Figure 12: A very high resolution panchromatic image from EROS-B collected on 28 July 2009 @ 19:24 UTC. The ship visible is the “Maersk Dhaka”, a cargo ship.

Extensive participation in the Foreign SAR Evaluation Project for the National Geospatial-Intelligence Agency (NGA). CSTARS provided analysis and intercomparison of targets and AOIs collected with all three sensors. All results are presented in the report: An Evaluation of New Foreign Commercial Radar Satellites: COSMO-SkyMed, RADARSAT-2, TerraSAR-X. Final Report. Dissemination of this report is restricted.

vii. Participated in Tandem Project in support of USAF Space Missile System Center
Acted as an advisor to the USAF in evaluating the usefulness of a tandem mission RadarSat-2 project. Advice was provided on sensor technology, beam mode specifications and data analysis. The analysis consisted of the selection of maritime targets, testing procedures, image quality and usefulness for operational applications.

viii. Key stakeholder in DIA Foreign Comparative Test for COSMO-SkyMed
As 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 groundstation with full tasking and reception capabilities for global and local near-real time acquisitions.
Collaborations

Worked with Stevens Institute of Technology to coordinate FlyOver Test in New York Harbor on November 19, 2008.

Supported DHS as panelist and speaker in the 2008 DHS Asia-Pacific Homeland Security Summit on November 7-9, 2008 in Honolulu, Hawaii.

Working partnership with DIA, NGA, USSOUTHCOM, ICE and USCG on various aspects of vessel detection.

Working with DIA, NGA and Navy TenCap to develop an end-to-end vessel detection and classification program.

Future Plans

a. Complete literature review on the detection and tracking of small surface vessels and Self-Propelled Semi-Submersibles (SPSS) via space-based systems

b. National SAR Architecture Center

i. Provide access in near real time to a broad selection of commercial satellite sensors

ii. Develop a collection plan to provide persistent imaging with overhead assets

c. European Collaborations

i. MARISS – GEMES MARitime Security Services

ii. NATO La Spezia – remote ground station operation

d. Data analysis

i. Wake detection

   o Radon transform approach

   o Examining quad polarization data

   o Pattern analysis of elementary shapes

   o Speckle noise reduction
ii. Innovative antenna configuration

- Explore squinting algorithm for moving targets
- Develop new methodologies using phase history data to better detect targets in background noise

**Documentation**


Numerous presentations to NGA senior staff of CSTARS capabilities including CSR project goals.

Presentation to Admiral J. Stavridis, former USSOUTHCOM Commander, of CSTARS current and future projects and how goals of DHS CSR goals fit within MDA mission (April 17, 2009).

Presentation to CIA staff on CSTARS efforts in ship and wake detection and relationship to the DHS CSR program (December 1, 2008).

Presentation to Senator Nelson’s Chief of Staff, Pete Mitchell, on CSTARS research programs and DHS CSR project (March 20, 2009).

USAF EagleVision brief on MDA activities with multiple satellite sensors (May 26, 2009).

**Other Resources Leveraged**

- DIA’s Foreign Comparative Test for COSMO-SkyMed
- NGA’s CSTARS SAR Architecture Pilot Project
- USAF SMC’s Tandem Mission
- USSOUTHCOM Innovation Cell Quick-Look Project
- Cooperative maritime support from ICE and USCG
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
• Improve ship detections with SeaSonde type HF radar
• Improve Maritime Domain Awareness

Before describing the year-to-date progress, we first provide an introduction to CODAR.

CODAR stands for Coastal Ocean Dynamics Applications Radar, or in short, Coastal RADAR. It is a High Frequency (HF) radar system that remotely measures ocean surface currents. The system allows one to obtain a synoptic map of ocean currents (see below). Each map has a range of about 50 kilometers (about 30 miles) from the coast with a measurement every 1.5 kilometers (0.9 miles). The Rutgers University CODAR system, deployed along the New Jersey coast, is the only operational HF-Radar system of its kind in the entire eastern United States. It consists of two remote sites, located in Brant Beach and Brigantine New Jersey, and a central site in Tuckerton, New Jersey.

Each remote site contains two antennas and a small 6' x 8' shed. One antenna transmits a radio wave out across the ocean surface. The power of this transmitted signal is only 40 watts. Unlike radio stations that only transmit a signal, CODAR uses the second antenna to listen for and measure the transmitted signal. The part of the transmitted signal that is reflected back toward the site by the ocean waves can be recorded and processed. It is this returned signal that is used to measure the moving ocean surface. CODAR uses the Doppler Shift to determine the surface current from the backscattered radio wave. By measuring the return signal, the CODAR system can determine the speed of the ocean waves that scattered the signal. From this wave speed a surface current can be calculated.
Milestones

Year 1 focused on improving the New York Harbor Testbed and the ship detection algorithm. The SeaSonde 13 MHz radar was installed at Sandy Hook National Park in December 2004. The hourly coverage from July 25, 2008 to August 1, 2008 for this radar is given in Figure 1. This coverage was deemed poor when compared to other SeaSondes operated in the US. The site was moved 8 km to the south in September 2008 to Sea Bright, NJ. The coverage improved dramatically after the site move, as shown in Figure 2. There are several factors that we are still examining in order to determine what caused the increased coverage. One possible cause is the fact that the cable run for the transmit antenna was reduced from 500 ft to 150 ft. This reduction in cable length increased the radiated power from the antenna. Another possible cause is the fact that the hardware was replaced with a newer generation hardware.

The equipment from Sandy Hook was shipped to the University of Puerto Rico at Mayaguez to establish the tropical test bed. The equipment at Puerto Rico has been functioning well so we will rule out the hardware as being the cause of the low coverage. The last factor to consider is the distance from the antennas to the water. The distance had been 110 m for the receive antenna and 90 m for the transmit antenna. With the site move to Sea Bright this distance was reduced to 50 m for both the receiver and transmit antenna. Codar recommends the maximum distance from the antennas to the water be 150 m. Our initial conclusion is that the reduced cable length and reduced distance to water increased the coverage.
Figure 1: Coverage map for 13 MHz SeaSonde located at Sandy Hook, NJ. This represents one week of data every hour. The black represents coverage more than 75% of the time, red represents coverage more than 50% of the time and the light red represent coverage more than 25% of the time.
Rutgers operated a single Automatic Identification System (AIS) receiver at its field station in Tuckerton, NJ at the start of the CSR project. The AIS transmissions are used as ground truth for the HF radar ship detections. Rutgers installed two additional AIS receivers at Sandy Hook, NJ and Loveladies, NJ. Figure 3 shows the location of the three AIS receivers operated by Rutgers University. Figure 4 shows the position of ships reported over the AIS signal for June 15, 2009. The range of the AIS signal is typically 30 nautical miles but under certain atmospheric conditions range can be upwards of hundreds of nautical miles. Figure 5 shows the density of AIS reports for the week of June 15-21, 2009. The figure indicates heavy traffic areas in the Ambrose Channel as well as the coast of New Jersey. We are currently examining these data more closely, because the speed of the vessel dictates how often an AIS signal is transmitted and this could bias the data to areas where ship velocity is high.
Figure 3: Location of the three AIS receivers operated by Rutgers University shown as green circles. A picture of an AIS receiver is shown in the inset.
Figure 4: Map showing data coverage of the Rutgers AIS network for June 15, 2009
Rutgers conducted two field experiments in Year 1. The first was the coordinated experiment between Rutgers, Stevens and the University of Miami on November 19, 2008. This focused on collecting simultaneous sensor data on common targets in the vicinity of NY Harbor, Rutgers focused on ship detections with the HF radar. All three technologies (HF radar, acoustic and satellite) detected the approach of the cargo ship Antwerpen Express. Figure 6 shows the detections made by the SeaSonde 25 MHz Radar located at Staten Island, NY. The vessel was approaching NY Harbor and the GPS track is shown as the aqua line in the figure. The detections are shown as the dots in the figure. The most consistent detections occur in the 15:50 to 16:00 time frame. We learned that the cruising speed for many of the vessels entering or leaving the harbor is above the aliasing speed for the 25 MHz radar at its normal operational settings. The sampling rate of the radar can be doubled which would double the aliasing speed from 12 knots to 23 knots. The penalty that is paid for this is that the velocity resolution for surface ocean current mapping is reduced from 2 cm/s to 5 cm/s. However, this can be overcome by increasing the averaging time. We will explore this trade off between current mapping and ship detection at 25 MHz in Year 2.

The second field experiment Rutgers conducted took place February 26, 2009. This experiment focused on the ship traffic outside NY Harbor and utilized the 13 MHz SeaSonde located at Sea Bright, NJ. The aliasing speed for the 13 MHz system is 22
knots so a majority of vessels are capable of being detected without modifying the normal settings of the SeaSonde. Detections were made on two vessels transiting along the coast. This is a shift from our previous research that focused on detection of ships moving radially towards or away from the coast. The two vessels were the Maas Trader, a 139 m cargo ship IMO Number: 9308625 MMSI Number: 244178000, and the Dolphin, a 41 m tug boat IMO Number: 7319010 MMSI Number: 366920980. Figure 7 shows the detections of the two vessels relative to the radar location. The detections made of the Maas Trader used the Infinite Impulse Response background, an FFT of 256 points and a threshold of 10 dB. The detections made of the Dolphin used the Median background, an FFT of 256 points and a threshold of 10 dB. The arrows indicate the direction of the vessels.

Figure 6: Plot of detections by 25 MHz SeaSonde HF Radar located on Staten Island, NY. The subplots from the top are range(km), range rate (m/s) and bearing (degrees CWN) all versus time.
Figure 7: Map showing the detections made by the 13 MHz SeaSonde at Sea Bright, NJ.

Collaborations
USCG, in particular via SAROPS support (A. Allen, POC)

University of Puerto Rico at Mayaguez (UPRM)
- Established tropical HF Radar test bed
- Assistance in CODAR site evaluation, installation and operation
- Hosted 2 students from UPRM for DHS Summer Institute

Stevens Institute of Technology
- Collaborated with Stevens on November 19, 2008 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 19, 2008 field experiment
Documentation
Here is a summary of presentations, papers and related grants.

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Location</th>
<th>Date</th>
<th>Title of Presentation</th>
</tr>
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<tbody>
<tr>
<td>Homeland Security Workshop</td>
<td>New Brunswick, NJ</td>
<td>November 16, 2008</td>
<td>Phased Deployment and Operation of the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS)</td>
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<td>Homeland Security Meeting Maritime Domain Awareness</td>
<td>Honolulu, HI</td>
<td>October 06, 2008</td>
<td>National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)</td>
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<td>CSR Researcher Meeting</td>
<td>Miami, FL</td>
<td>January 29, 2009</td>
<td>National Center for Secure and Resilient Maritime Commerce and Coastal Environments (CSR)</td>
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<tr>
<td>2009 DHS University Programs Summit</td>
<td>Washington, DC</td>
<td>March 16-19, 2009</td>
<td>The National Center for Secure and Resilient Maritime Commerce and Coastal Environments: Results from the First NY Harbor Testbed Exercise</td>
</tr>
<tr>
<td>Norway and United States Ship Detection Collaboration</td>
<td>Oslo, Norway</td>
<td>May 29, 2009</td>
<td>The National Center for Secure and Resilient Maritime Commerce and Coastal Environments: Results from the NY Harbor Testbed Exercise</td>
</tr>
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</table>

Papers
Roarty, Barrick, Kohut, Glenn (2009) “Dual-Use of Compact HF Radars for the Detection of Mid and Large Size Vessels” Submitted Turkish Journal of Electrical Engineering and Computer Sciences

Related Grants
“Establishing a Department of Energy Center of Excellence for Offshore and Coastal Wind Energy”, Department of Energy, $8,000,000

“An Advanced Atmospheric / Ocean Assessment Program Designed to Reduce the Risks Associated with Offshore Wind Energy Development Defined by the NJ Energy Master Plan”, NJ Board of Public Utilities, $1,900,000
“Littoral Expeditionary Autonomous Power (LEAP) Buoy Vessel Detection System”
United States Navy, $2,500,000

“Over the Horizon Vessel Tracking “ Naval Surface Warfare Center, Dahlgren Division, $785,000

Future Plans
In year 2 we will be examining instances when the radar/algorithim was not able to make a detection of a vessel offshore. The radar was a Codar SeaSonde located at Sea Bright, NJ. The sampling window spanned from 08:57 GMT to 51:13 GMT on February 26, 2009. The radar operated at 13 MHz with a bandwidth of 50 kHz. The following two figures give the range (km) range rate (m/s) and bearing (degrees CWN) of the detections (blue diamonds), ground truth data of ship location from GPS (aqua line) transmitted via the Automatic Identification System (AIS). The range rate is defined as positive towards the radar and negative away from the radar. Each detection is represented by a square (error box) with half the height as the uncertainty and the width as the length of the FFT. Figure 8 gives the output of the ship detection algorithm using the IIR background. Figure 9 gives the output of the ship detection algorithm using the Median background.
Figure 8: Detection of the Maas Trader from Sea Bright 13 MHz SeaSonde system using the IIR background.
Figure 9: Detection of the Maas Trader from Sea Bright 13 MHz SeaSonde system using the Median background.

At time 00:28 the radar does not detect the vessel. Again at 00:40 the radar loses the vessel again. A first explanation for non detection at 00:40 is that the vessel crossed through the zero-Doppler region. The thresholding is excluded for regions around the zero-Doppler position and sea-echo Bragg peaks. Both regions produce strong signal returns that would make detecting a ship nearby very difficult. The non detection at 00:28 is still being investigated.

We will operate the radar at multiple frequencies to find ones that are optimal for this location.
Table 1: FCC approved frequencies for Rutgers University at Sea Bright, NJ

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>Bandwidth (kHz)</th>
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<tbody>
<tr>
<td>12140</td>
<td>100</td>
</tr>
<tr>
<td>13430</td>
<td>100</td>
</tr>
<tr>
<td>13450</td>
<td>100</td>
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<tr>
<td>13530</td>
<td>100</td>
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</table>

We are currently only using 50 kHz of bandwidth which amounts to 3 km spatial resolution. If we increase the bandwidth to 100 kHz, the spatial resolution can be increased to 1.5 km.

The enhanced blanking option will be tested to see if this illuminates targets close to shore. Figure 10 depicts the pulsing or blanking that the SeaSonde utilizes for its processing.

Figure 10: Figure depicting the pulsing used by the SeaSonde HF radar. Top: Red curve, normal pulsing and Bottom: Blue curve, enhanced pulsing mode for increasing power on targets close to the radar
Other Resources Leveraged

- IOOS/MARCOOS HF Radar Network
- IOOS/MARCOOS Autonomous Underwater Vehicle Fleet
Task 1.2, Project 2
University of Puerto Rico Mayagüez (Dr. Jorge E. Corredor, PI)

Milestones:
A 13 MHz CODAR system was installed at Club Deportivo del Oeste -CDDO (West coast of Puerto Rico in the Municipality of Cabo Rojo, see Figures 1 and 2)

Figure 1: The Mona Passage, west of the island of Puerto Rico
In parallel with this effort, and in order to complement/validate the CODAR detections, an AIS system was installed at the UPRM Department of Marine Sciences field station in La Parguera (Southwest coast of PR in the municipality of Lajas). AIS visualization software was developed and is operational at [www.caricoos.org](http://www.caricoos.org)

Authorization was received for a second CODAR emplacement procured with FURA (Police rapid action force) at the Añasco police station, identified in Figure 2.

As a preliminary step towards the inaugural 2010 CSR Summer Institute, two students from UPRM traveled to New Jersey to be trained in CODAR operation at the Rutgers Internship in Oceanographic Research – RIOS (June – August 2009), leveraging funds available through the Rutgers Institute of Marine and Coastal Sciences.

**Collaborations:**
- Rutgers University
  - Assistance in CODAR site evaluation, installation and operation
  - RIOS summer traineeships for two UPRM students
b. CariCOOS (NOAA funded Caribbean Coastal Ocean Observing system)
   iii. AIS page development (see above)
   iv. Troubleshooting of data transmission and power supply at CDDO
   v. Procured authorization for CODAR emplacement at CDDO

Future Plans (2009-2010)

a. Recruitment of undergraduate students to assist in equipment installation and data analysis
b. Installation of second CODAR emplacement at FURA Añasco site
c. Co-installation of second AIS at same site
d. Antenna calibration/antenna pattern documentation for CDDO and FURA sites
e. Development of real-time surface current maps for Mona Passage
b. In situ validation of current data using ADCP to be supplied by CariCOOS
c. Proof of concept for ship detection and tracking capability in Mona Passage

Documentation:
“Shiptracker” software at http://www.caricoos.org/drupal/node/98

Resources Leveraged:

a. Collaboration with the NOAA-IOOS funded project entitled “Caribbean Integrated Coastal Ocean Observing System (CariCOOS)” has been extensive. CariCOOS has provided administrative assistance in travel coordination, equipment procurement, permit procurements and shipping, technical assistance in CODAR operation and software development. CariCOOS will also be providing an ADCP unit for CODAR current validation. Dr. Jorge Capella of CariCOOS will assist in data processing.

b. CSR has in turn provided CariCOOS with real-time AIS data for its “shiptracker” page and will be providing realtime surface current data for visualization through CariCOOS web page.
Task 1.3 Nearshore and Harbor Maritime Domain Awareness Via Layered Technologies
Stevens Institute of Technology (Dr. Alexander Sutin, PI)

Project Objectives and Significance to Stakeholders

Most coastal monitoring systems are based on the use of coastal surveillance radar, Automatic Identification System (AIS) receivers and local Vessel Tracking Monitoring Systems. These systems provide significant levels of information for ship detection, classification, and tracking, but they can be tampered with and/or switched off. Many small boats are not equipped with AIS and so cannot be identified remotely. Passive acoustic methods show promise of providing independent and reliable ship detection, classification, and tracking. These methods are based on the recording and analysis of the ship’s acoustic signatures. Similar passive acoustic methods are widely applied for submarine detection. Passive acoustic systems can detect small fast moving boats and provide boat identification. They are especially useful in conditions of low visibility and at night. The acoustic portion of the Stevens project is aimed at the development of a passive acoustic array that can provide low-cost, highly portable acoustic surveillance capability. Our efforts involve the tuning of the passive acoustic sensors to the power and frequency ranges associated with vessels of interest. The Stevens effort includes the building of a database of acoustic signatures of vessels, as well as the background, ambient noise in an urban harbor, NY Harbor.

In 2003, Stevens Institute of Technology established a research laboratory in support of the U.S. Navy’s efforts in the area of Anti-Terrorism and Force Protection (AT/FP). The Maritime Security Laboratory, or MSL, provides the capabilities of experimental verification of AT/FP research in the realistic environment of the Hudson River Estuary. The goals of MSL are:

- To continuously advance the state-of-the-art in technologies key to maritime security in an estuarine environment
- To develop transportable intruder detection prototypes embodying results of new maritime security research, deployable to harbors around the world for military and commercial applications
- To become a resource for the US Navy and also for the domestic maritime industry, and natural hazards mitigation communities.

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. The initial infrastructure has since been extended to include computer optic and infrared vision capabilities, and to enhance acoustic experiments by combining them with these capabilities.

These integrated capabilities have enabled experiments in support of the CSR effort to develop technologies capable of determining the position and trajectory of surface traffic.
This knowledge can be used for measurements of the acoustic noise of various types of vessels and their classification, determination of sound attenuation in a wide frequency band, and the development and testing of methods of passive acoustic triangulation and location of sources of sounds.

Part of the uniqueness of Stevens’ Maritime Security Laboratory is its location on the Hudson River tidal estuary, which is a key waterway that defines the Port of New York/New Jersey, one of the busiest harbors in the U.S. From a scientific perspective, this harbor embodies a high degree of complexity due to variability of the current, salinity, temperature, winds, turbidity, as well as man-made factors including ambient noise due to surface and air traffic, construction noise, and various forms of electromagnetic radiation. All of these enter into the analysis of surface and underwater threats.

Hence the estuary itself is an integral part of the laboratory. Via the MSL and various Federal and State projects, Stevens has deployed instrumentation throughout the estuary to collect weather and environmental data, and through computer modeling, to predict their characteristics. For the actual MSL execution of experiments, the test site has been chosen based on its scientific characteristics and its accessibility both by radio communications and by safety considerations. The MSL research vessels and other MSL assets are shown in Figure 1. The larger boat is the RV Savitsky. It is specially constructed and fitted out for maritime research purposes. Towards the stern is an A-frame for loading large and heavy items onto and off of the boat. Radio antennas are affixed to the mast to transmit real-time data to the MSL Visualization and Analysis Center (VAC). The smaller boat, the Phoenix, is a support boat. It is used to deploy sensors while they are cabled to the Savitsky. It is also used to deploy remote instrumentation, divers, and provide for safety. In addition, it is used as the point of acoustic radiation in experiments involving acoustic propagation between two points and measurements of the temporal variability of the acoustic field.
The complex acoustic conditions of an urban estuarine environment in combination with the numerous sound sources in the proximity of a large city require a sophisticated approach to the problems associated with the generation and propagation of sound by small vessels. Prior investigation of the physics of acoustic signal generation and propagation conducted by Stevens is being used for the development of a portable passive acoustic system optimally tuned to the power and frequency ranges associated with underwater threats (divers and UUVs) as well as vessels of interest (see Figures 2 and 3).
Figure 2: Typical vessel traffic in NY Harbor, at mid-town Manhattan

Figure 3: Measurement of acoustic background in NY Harbor, 10/22/2008
Research Milestones Met

i. The development of a novel cross-correlation method of water traffic monitoring

The classification of ships using acoustic signatures is usually conducted on the basis of the spectral analysis of ship noise and its modulation spectra. The low frequency ship noise usually is measured using omnidirectional hydrophones that do not allow separation of signals from several ships. Detection, tracking and classification of small boats in busy urban environments require methods of ship localization and separation of the ship’s individual signatures. Application of acoustic arrays for these purposes requires systems with a large aperture that are expensive and difficult to operate. Much less expensive and simpler are methods based on acoustic signal recording by several hydrophones and application of generalized correlation of broad band signals. These methods were initially developed for passive submarine detection and localization, and we have here developed under CSR funding the application of cross-correlation methods for the separation of acoustic signals from several boats, measurements of their acoustic signatures and modulation spectra.

Let us consider how the measurements of cross-correlation can be used for estimation of the spectral density of the acoustic signal recorded by two hydrophones. Consider the signals received by two hydrophones separated by a distance \( L \). They record the noise radiated by a ship whose direction makes an angle, \( \alpha \) with the normal to the line between the hydrophones. The distance between the ship and the hydrophones is much larger than \( L \). An example of such a configuration is illustrated in Figure 4. The noise radiated from the ship reaches the two hydrophones with a delay \( \Delta T \):

\[
\Delta T = \frac{L \sin \alpha}{c}
\]  

(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 and scaled versions of the same signal:

\[
h_2(t) = \beta h_1(t - \Delta T)
\]  

(2)
where $\beta$ is a scaling factor (accounting for different hydrophone sensitivity and attenuation) and $\Delta T$ is the delay introduced in (1). The cross-correlation is defined as:

$$R_{12}(\tau) = \int_{-\infty}^{\infty} h_1(t')h_2(\tau - t')dt'$$  

(3)

For two delayed signals of the form (2),

$$R_{12}(\tau) = \beta R_{11}(\tau - \Delta T)$$  

(4)

The cross-correlation $R_{12}(\tau)$ of the signals from the two hydrophones has the same shape as the autocorrelation $R_{11}(\tau)$ of the signal from the hydrophone 1, scaled by factor $\beta$ and translated by $\tau = \Delta T$. Because the autocorrelation of a signal is maximum at $\tau = 0$, 

Figure 4: Snapshot of the test site in the Hudson River. A moving ship radiates noise (yellow) that propagates and reaches the sensors (red circles) with a delay that depends on the direction
the cross-correlation $R_{12}(\tau)$ is maximum at $\tau = \Delta T$. The location of the maximum of the cross-correlation can be used to estimate the direction to the ship (using (1)). The spectrum of the cross-correlation can be used to extract the spectrum of the ship generated noise.

The power spectral density $S_1(f)$ of a signal $h_i(t)$ is defined as the Fourier transform ($TF$) of its autocorrelation:

$$S_1(f) = TF[R_{11}(\tau)] \quad (5)$$

The Fourier transform of the cross-correlation is called cross-spectral density:

$$S_{12}(f) = TF[R_{12}(\tau)] = \beta \exp(2j\pi f \Delta T)S_1(f) \quad (6)$$

Consequently, the signature of the ship (frequency dependence of the radiated noise) can be estimated independently from the signal of a single hydrophone using the autocorrelation from the signals of two hydrophones using the cross-correlation.

Let us now consider the signals recorded on the hydrophones as the superposition of the noise $z_i(t)$ radiated from $N$ ships plus uncorrelated ambient noise $n_1(t)$ and $n_2(t)$:

$$h_1(t) = n_1(t) + \sum_{i=1}^{N} \beta_{1i}z_i(t-t_{1i})$$
$$h_2(t) = n_2(t) + \sum_{i=1}^{N} \beta_{2i}z_i(t-t_{2i}) \quad (7)$$

where $\beta_{1i}$ and $t_{1i}$ ($\beta_{2i}$ and $t_{2i}$) accounts for the attenuation and propagation time from the ship $i$ to the hydrophone 1 (2). In such a case, the power spectral density of either hydrophone signal includes contributions from each individual ship and from the ambient noise. Since these ship sounds overlap in time, their contributions cannot be separated directly in the power spectral density recorded by a single hydrophone. Under certain assumptions, the cross-correlation offers an opportunity for separation of the individual ship signals.

The cross-correlation of the signals (7) consists of many components. Assuming the ambient noise recorded by a given hydrophone is correlated neither to the background noise recorded by another hydrophone nor to the sounds radiated by the vessels, contributions to the cross-correlation involving ambient noise vanish. Furthermore, assuming the sounds from the various ships are also uncorrelated, the only contributions that remain are the auto-correlations of the sound of the ships:
\[ R_{12}(\tau) = \sum_{i=1}^{N} \beta_i R_{i}(\tau - \Delta T_i) \]  

(8)

where \( \beta_i = \beta_{i1} \beta_{i2} \), \( \Delta T_i = t_{zi} - t_{iu} \) and \( R_{zi}(\tau) \) is the autocorrelation of signal \( z_i(t) \). In (8), each ship provides a contribution whose maximum is at \( \tau = \Delta T_i \). If these contributions are separated by more than the width of the autocorrelation function \( (\Delta \tau) \), they can be separated. From (1), this condition can be written as:

\[ |\Delta T_i - \Delta T_j| = \frac{L}{c} |\sin \alpha_i - \sin \alpha_j| \geq \Delta \tau \quad \text{for all } i \neq j \]  

(9)

This expression shows that if the directions of the various ships with respect to the hydrophone system are such that their contributions to cross-correlation do not overlap, they can be separated. In such a case, an individual ship signature can be estimated by taking the Fourier transform of the associated contributions in the cross-correlation in the time window around the peak of the cross-correlation function.

Experimental data were collected on August 21, 2008 in the Hudson River near Manhattan. ITC 6050 hydrophones produced by International Transducer Corporation were used due to their high sensitivity and low noise level in the frequency band up to 100 kHz. They were placed on the river bottom on stands of 60 cm height. The distance between hydrophones was about 15 m and the depth in the place of the hydrophones deployment was about 3 m.

All deployed hydrophones were connected by cable to the on-board computer for data processing and storage. The signals from the hydrophones were amplified and filtered in the frequency band 5-95 kHz. This filtering was applied for suppression of the high acoustic noise level in the low frequency band, which limits the dynamic range of measurements and for elimination of spurious aliasing signals produced by electromagnetic noise at frequencies above 100 kHz. The amplified and filtered signals were digitized at a sampling frequency of 200 kHz. The boat computer was wirelessly connected with MSL Visualization and Analysis Center (VAC) for real-time display, thus allowing scientists in the VAC to control the experiments.

In addition to real-time data feeds into the VAC, six video cameras were deployed to provide real-time visual observation of experiments, as well to provide video data and to analyze water traffic. The video recording allowed for the connection of the recoded acoustic signals with a defined vessel. Figure 5 is a snapshot of a portion of video. The lower part is 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. The curved line
is the track of the passing ferry that is seen in the top right. Another track is visible on the cross-correlation chart that corresponds to another ship that is not yet in the field of view of the cameras.

Figure 5: Snapshot of the video from two video cameras and floating chart of cross-correlation

In order to validate and illustrate the potential of the proposed cross-correlation method for the estimation of ship signatures, two examples are considered. The first example demonstrates that in the case of a single ship, the cross-correlation method yields the same result as the conventional method. The second example considers a case with two ships in order to demonstrate the ability to separate the contributions from each ship.

Figure 6a shows the cross-correlation of the acoustic signal generated by the ferry shown in the inset (the same as in Figure 5). The cross-correlation was calculated for acoustic signals of 0.66s duration. The contribution from a single ship is shown in red. That contribution has been used to determine the power spectral density that is shown in red in Figure 6b. The power spectral density estimated using the direct signal from one hydrophone is shown in blue and matches very well with the dependence obtained using the cross-correlation that is shown by red.
In the second example shown in Figure 7, the cross-correlation clearly exhibits contributions associated with two different ships. The spectra of these two contributions are shown along with the power spectral density computed from the signal from a single hydrophone. It is seen that the latter can be decomposed into the contributions from each ship as obtained using the cross-correlation method.
The other widely used method of ship classification is based on measurements of the high frequency ship noise modulation. Indeed, the noise radiated by a ship is modulated at a rate dictated by some parameters of the propeller (number of blades, rotational speed). Evaluation of that modulation provides information on the ship that can be used for classification. The method for estimation of the envelop modulation is known as DEMON (Detection of Envelope MOdulation on Noise), and a block diagram of this method is shown in the Figure 8a.

![Figure 7: (a) Cross-correlation showing contributions from two ships. (b) Power spectral density estimated from the signal from a hydrophone (blue) and from part of the cross-correlation (red and green)](image)

![Figure 8: Block diagram for the evaluation of the modulation spectrum using DEMON (a) and cross-correlation (b)](image)
Since the peak of cross-correlation is proportional to the intensity of the acoustical signal, the modulation of acoustic signal intensity can be recovered from the cross-correlation. For measurements of this modulation the cross-correlation has to be computed at a sufficient rate (at least twice more than the maximal modulation frequency), which also requires a short enough time window. The block diagram for that method is shown in Figure 8b.

Figure 9 was obtained by computing the cross-correlation using 20 ms windows at a rate of 400 Hz. For each cross-correlation, the ship contribution is extracted and its energy computed (RMS), leading to one point on the envelope of the cross-correlation. The spectrum of that envelope gives the modulation spectrum. An example is shown in Figure 9a, along with the results obtained using the conventional DEMON method. In both cases, the digitized signals were filtered in the 20 to 90 kHz range, in order to remove the low frequency noise that is strong in the Hudson River. The match between the two methods is very good.

![Figure 9: Modulation spectrum of the ship computed in the same time frame using cross-correlation (a) and DEMON (b).](image)

Figure 10 further illustrates the potential of the method by demonstrating the ability of the method to decompose the spectrum obtained using the DEMON method into individual contributions from two ships.
ii. Multilayer approach for detection, tracking and identification of vessels

As part of the CSR Project, Stevens Institute of Technology, Rutgers University, and the University of Miami conducted a coordinated field test on November 19, 2008 in the NY Harbor aimed at the detection, identification, and tracking of vessels using layered sensing. All three universities detected and tracked the same vessels that were traveling in the Harbor. The first global scale sensing layer was provided by the University of Miami’s satellite optical imaging capability and detected the ships using a hi-res electro-optical system FormoSat 2 m Panchromatic Close Up. The second layer was HF Radar sensing performed by Rutgers University and detected and tracked the ships using a 25MHz HF Radar, located at Great Kills Park, Staten Island NY. The third local scale layer was Stevens’ passive acoustic array that allowed recording of vessel acoustic signatures. The hydrophone array was suspended from one of the Stevens research vessels, the R/V Savitsky. In addition, the AIS data was consulted to compare the vessels type and location with the result of measurements. The three layers were coordinated and geo-referenced so that the output of the various sensors could be easily and intelligently fused to provide detection, tracking and identification of the vessels. See Figure 11.

Figure 10: Modulation spectra computed by using cross-correlation method for two ships, a) ferry, b) fast boat, c) DEMON calculation of the recorded signal where the modulation of the two boats are mixed.
iii. Assessment of the feasibility of acoustic and non-acoustic means for detecting and tracking small surface vessels and self-propelled semi-submersibles (SPSS)

At the request of the Division of Borders and Maritime, Stevens Institute of Technology researchers conducted a literature review and assessment of various surveillance technologies and methodologies with the aim of identifying those that show promise for assistance in the detection and tracking of small surface vessels and self-propelled semi-submersibles (SPSS). A draft report was delivered in the Fall of 2009. That report is attached here as Appendix E.

The technology assessment identified the capabilities of several existing sensor technologies, including contemporary infrared techniques, in detecting the surface temperature variability associated with surface and underwater dynamic activities in upper layer water bodies, as well as a self-propelled body (diver, surface boat, underwater vehicle) and its wake. Realistic image interpretation and real-time image analysis require better understanding of Kelvin waves, turbulent wake dynamics, bubble wakes and their interaction with ambient fields.
Synthetic Aperture Radar (SAR) imaging shows great promise in this application, with an output that includes ship position, length, heading and speed. AIS has emerged as an important recent development in SAR ship detection since it permits the opportunity to explicitly identify ship signatures detected in SAR imagery. Inconsistencies in the two data sources would serve to indicate ships of interest for additional surveillance. Space-borne SAR and High Resolution Visual systems which are in operational use, show promise in the detection of SPSS vessels having lengths less than 30 meters. Another approach might be the detection of vessel wakes. Ship wakes are a very visible feature on SAR images or high resolution optical images, since they stretch over kilometers. As such, they are a tell-tale signature of a ship. The wake is generally categorized into two phenomena. First, there is the turbulent ship wake, which appears as a long, dark streak behind the ship. The second phenomenon is the Kelvin wake, consisting of a system of waves in a 39° cone (if the sea is of “nearly infinite” depth). An analysis of the Kelvin wake can yield an estimation of the ship's speed and heading, which can be merged later with other observations in a fusion scheme so as to increase the robustness of the overall estimation of these parameters.

Self-propelled semi-submersibles are vessels, and as with any vessel they radiate sound during movement. The main sources of radiated ship noise can typically be categorized as one of three classes: 1) mechanical engine noise, 2) propeller noise and 3) hydrodynamic noise. The radiated sound has been widely used for ship and submarine detection over the years, and it is believed that passive acoustic methods can be applied for SPSS detection, classification and localization. However, this approach is very likely to be limited to applications covering relatively small regions of interest.

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.

Future Plans

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

b. Consider various methods of optimization of vessel acoustic detection systems based on collected vessel signatures, ambient noise, and acoustic transmission loss.
c. Conduct measurements and analysis of background ambient noise in NY Harbor for various points and environmental conditions.

d. Expand the ship detection, classification and tracking capability to underwater threats, building on the pre-existing work sponsored by ONR.

e. Continue the assessment of acoustic and non-acoustic means of detecting and tracking Self-Propelled Semi-Submersibles (SPSS).

Documentation
a. These abstracts were (or soon will be) presented to International and national conferences:


Patent Activity:
A provisional patent application, “Passive underwater acoustic system for detection, localization and classification of acoustic sources “, has been prepared and was approved by the Stevens Patent committee on October 8, 2009. The application describes the Stevens system and algorithms that were recently successfully tested at the Naval Undersea Warfare Center (Newport, RI). The Stevens system detected both open and closed-circuit scuba divers, a diver riding a Diver Propulsion Vehicle, a surface swimmer, and a UUV. The detection distance for open circuit scuba reached 700 meters.
**Resources Leveraged**
The passive acoustic system and acoustics buoy were developed in close collaboration with the Stevens Maritime Security Laboratory supported by the Office of Naval Research.

The NY Harbor Observation and Prediction System receives partial support from the NOAA IOOS program and the NJ Dept of Transportation.
Project Objectives and Significance to Stakeholders

a. Objective: enhance and support emergency decision-making
   - Assess the strengths and weaknesses of human decision-making
   - Assess cultural/institutional practices that support decision-making
   - Develop & test new decision technologies that fill the critical gaps in human cognition and cultural/institutional practices

b. Significance: Inform improvements in emergency decision-making
   - Increase awareness of both the common strengths and common weaknesses of security personnel
   - Inform the development of training materials and exercises
   - Inform the development and deployment of institutional practices
   - Inform the development and deployment of decision technologies

Research Milestones Met

We examined decision-making dynamics using a variety of visualization tools and video game environments. Single and multiple decision-makers were evaluated under a number of different scenarios, including the Harbor Scenario illustrated in Figure 1.
Stevens Institute of Technology researchers (PI: Dr. Nickerson) found that emergencies can bring out the best and, more often, the worst in human decision-making. When pushed to their cognitive limits, decision makers often fall back on overly simple reasoning strategies. 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. Where gaps remain, decision technologies—ranging from belief networks to paper and pencil—fill needs for greater computational power and extended memory. Nevertheless, cultural practices and technology use are poorly understood, especially when and why they fail to yield sound decisions.

The researchers took an experimental approach to understanding how cultural practices and decision technologies extend or constrain human cognition. Over the past year, they ran a number of online studies using a seemingly simple task: speeded discrimination of friend and foe—to assess the biases people bring to novel problems and to compare the effects of various cultural practices. In one experiment, learning from one’s predecessor yielded richer decision heuristics and overrode fixation on prior knowledge.

The decision-making researchers also participated in a Joint Situational Awareness exercise that was conducted with the participation of many players, including the Naval Postgraduate School, US Coast Guard Sector New York, the US Army, NYPD, the NJ State Police, and the Port Authority of NY and NJ. The role of the research team was to analyze the communications and behavior of the participants during a simulated threat of a nuclear weapon onboard a ship. This exercise proved useful and showed the weaknesses and areas that need improvement during an emergency, when multiple agencies need to communicate with each other during response to a threat.

Taken together, these studies yielded a number of conclusions, including:

a. Study 1: Demonstrated human reliance on prior knowledge and bias for overly simple heuristics in time-constrained decision-making
b. Study 2: Demonstrated that observing the decisions of predecessors yields richer decision heuristics and overrode fixation on prior knowledge
c. Study 3: Demonstrated that evocative descriptions of a target yields better threat detection than technical descriptions
d. Study 4: Demonstrated that having an implied other, rather than one’s self, point out non-threatening targets (deictic training) yields better anomaly detection
e. Study 5: Assess how deictic training together with variable base rates of anomalous targets affect the detection of anomalies (in process)

1. **Future Plans**
   a. Experiments with multi-dimensional problems with multiple solutions
      • e.g. disaster response problems
CSR Year One Report
1 October 2009

i. Managing evacuations
ii. Maintaining trade
iii. Minimizing loss of life

b. Experiments with ship-tracking and port security problems
   - Detecting anomalous targets from “real time” (simulated) tracking data
   - Detecting threatening anomalies from tracking data
   - Handoffs: communicating threats between humans and machines. Those working on tracking have discussed the problem of handing off the tracking of a target from one technology to another. The handoffs between humans and machines are perhaps more problematic.

c. Decision Technologies
   - Explore when and how people use or avoid decision technologies
   - Assess how changes in the timing and intrusiveness of technological interventions affect the use and acceptance of decision aids

d. Memory Technologies: adaptive responses to disasters and other complex problems require that people remember similar problems from the past, how they or others responded to those problems, and the outcomes of those responses
   - Investigate technology-aided memory (e.g., chat logs & video)
   - Investigate community memory (e.g., how institutional structure maintains and propagates knowledge)

Documentation
c. Creatures (desktop). A “video game” for assessing collaborative, adversarial, and individual decision making in a laboratory setting.
e. Mutants (light). An online “video game” for assessing rapid detection of anomalies.
Monmouth University (Dr. Barbara T. Reagor, PI and Mr. Anthony Macdonald, Esq.)

Monmouth University Program Elements:
The Rapid Response Institute (RRI) 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 or all hazard disaster. The Urban Coast Institute 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 are supporting CSR research initiatives including summer research programs, workshops, outreach, and training in order to:

- Develop Emergency Strategies, Policies and Educational Outreach in support of Ports and Harbor Security;
- Assist local communities adaptation strategies to address the climate change and sea level rise issues that impact our National Security;
- Assist to develop hazard resilient coastal community indicators and a framework to enhance stewardship, storm readiness and vulnerability reduction;
- Work with CSR to identify user needs, societal benefits and improved links between coastal monitoring and ocean observations networks;
- MU Students and Faculty to Participate in CSR Summer Research Institute;
- Conduct supported (CSR, RRI, UCI, MU) STEM Summer Research programs for High School Students and High School Teachers;

Leveraging Existing Programs:
Together the RRI and UCI are working with the CSR to develop and coordinate the delivery of workshops and training “On-Site” to Coastal Communities utilizing the RRI Joint Mobile Command and Training Center. The JMCTC Truck was developed under US Army Contract W911SR-06-C-0007.
Figure 1: Joint Mobile Command and Training Center

The full description of the Joint Mobile Command and Training Center is provided in Appendix C.

Year One Participation:
MU’s RRI & UCI participation for the year includes a presentation at the Mid-Year Conference: January 28, 2009 in Hawaii, attendance at the DHS University Summit: March 28, 2009 in Washington, DC, assistance with the CSR – EOC Workshop – June 10, 2009 at Stevens, and the conduct of a STEM Summer Research Program at MU funded by CSR, US Army and MU. June 29 through August 27, 2009

The Emergency Operations Centers Workshop – June 10, 2009:
As a member of the organizing committee and facilitators for two afternoon workshops, MU supported the EOC Workshop from the planning stage through delivery. Dr. Reagor facilitated the workshop breakout session on EOC Process. Mr. James Hammill – RRI SB Contractor under US Army Contract W911SR-08-C-0083 conducted the workshop breakout session on EOC Process.

EOC Workshop – Breakout Session - June 10, 2009:
A small subgroup of the attendees (6) participated in the EOC Breakout Session on the afternoon of June 10, 2009. We discussed the presentations made in the morning. As facilitator we presented them with the following questions for consideration.

- What existing processes are common to your EOC that other EOCs are using successfully?
- What gaps in existing processes are common to your EOC that other EOCs are suffering from?
• What do you need the private sector to do (e.g., Wal-Mart and Home Depot) to make the processes for your EOC more efficient and better for sending and receiving information?
• Are the processes in your EOC set up correctly to deal with Port Security and Resiliency issues

All agreed that the EOC’s discussed have many similarities but several key differences or gaps that affect how they operate individually or together. Key areas that need improvement include:
• Information management within or between EOC’s
• How to effectively share resources especially for the local or business environments
• Clarity of position – Who is in charge
• Consistency of information – same message whether it goes up or down or across levels
• Need to develop message discipline and timeliness of delivery

Key actionable areas to address:
• Need to develop better planning upfront
• Need to create regional views to insure interoperability is working
• Need to increase training and discipline
• Need to understand vulnerabilities at all levels

All Participants agreed that technology is necessary in the EOC but alternative ways are needed as well. It was pointed out that issues with the interoperability of radios were a major problem between EOC’s and within EOC’s.

**STEM Summer Research Program:**
MU- RRI conducted a Pilot High School Student/Teacher program outside of CSR in the summer of 2008. In 2009, we integrated that program to be supported by CSR, MU School of Science and US Army contract W011-SR-09-C-0083 and UCI. Below are the details of the program.

**Dynamic Information Visualization**
RRI’s interest in displaying dynamically changing objects on maps and similar geo-location spaces, suggests a number of possible areas for development of software modules to be used in this research. The basic model is to define sensor objects of various kinds and maps and other geo-location spaces. The research would explore methods for placing sensor results onto these geo-location spaces. To provide the most powerful basis for prototype-based research, we would create a set of software module utilities to interact with a family of sensors families and geo-location objects.

The students have already developed some of these modules with one team focusing on sensors and the other on the geo-location objects. Their project overview and
accomplishments to date were presented as a poster during the MU School Of Science Summer Research Program on August 12, 2009 and a formal presentation with slides and real-time demonstrations to family and school officials on August 27, 2009.

The objective of the student project was the dynamic display of changing objects on maps and geo-location spaces. The students used the real-time ocean sensor data from the Stevens New York Harbor Observation and Prediction System (NYHOPS). Figures 1 and 2 illustrate the results of this summer project.

The simple architecture below depicts some of these modules with some sensor families shown and Google Earth as a geo-location object though another space like FloorView could be a display target.
Stevens Sensor Maps

Figure 1: Web Portal created by High School students
Figure 2: Data display developed by High School students
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<tr>
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2. Topics in Global Policies influencing MTS Security and Coastal Safety

Task 2.1 Resilient Port Infrastructures
Stevens Institute of Technology (Dr. Roshanak Nilchiani, PI)

Project Objectives and Significance to Stakeholders
The essential first step in this task was to define resiliency in the context of the complex, intermodal Marine Transportation System. Once this was accomplished, we would then seek to identify the major elements of systems-level resilience for the MTS. A framework for resiliency assessment for infrastructure systems supporting the MTS could then be developed, and the major threats to port infrastructure systems could be identified. This effort will eventually provide decision-makers with the ability to identify vulnerabilities in the system under their management, and provide them with a framework to measure the resiliency of the system and allow them to work cross-organizationally on improving the resilience of the entire port system of systems.

Research and Education Milestones Met
The approach adopted included the development of a conceptual model for maritime and port infrastructure systems resiliency. A Network Systems Analysis was then performed for ports and other infrastructure resiliency. Finally, a risk management approach for port and other infrastructure resiliency was attempted.

i. Defining resiliency in the context of the MTS
The research group collaborated with decision-makers from various DHS agencies in a DHS-sponsored workshop on defining resilience needs and concepts for port infrastructure systems. This research was conducted in collaboration with other CSR researchers (i.e. Jim Rice, Mo Mansouri, Ali Mostashari, Matt Mattingly, Beth Rooney). The workshop, entitled, “Port Systems Resiliency”, was hosted by DHS S&T on May 27-29, 2009, in Charlottesville, Virginia. The workshop’s primary objectives were the identification of the critical challenges to designing and building a resilient port system (and other systems that interrelate); and the identification of the knowledge gaps in order to inform future DHS S&T-sponsored research. While there was difficulty in achieving a single definition of resiliency, the participants did agree that resiliency is quite different from recovery in that resiliency is a characteristic of a system (in this case, the MTS) that enables it to continue operating at some level of functionality in the face of a challenge or an event. Within the context of two port closure event scenarios, participants were asked to consider the economic, transportation, and security challenges faced by the MTS industry. Much of the discussion centered on the need to develop modeling tools (and basic understanding) sufficient to enable the accurate modeling of the intermodal MTS, as well as the need for more effective information sharing and information integration.
ii. A framework for resiliency assessment for infrastructure systems supporting the MTS
The Systems Analysis Framework for Port and other infrastructure resiliency is depicted
in Figure 1.

Figure 1: Systems Analysis Framework for Port and other infrastructure resiliency
The risk management-based resiliency framework is depicted in Figure 2.

Figure 2: risk management-based resiliency framework

Future Plans

a. Application of risk-based and network-based resiliency assessment methodologies to port infrastructure in southeastern and northeastern United States
b. Collective threat assessment for the U.S. Eastern shore ports
c. Development of resiliency strategies for port infrastructure systems
d. Exploration of network-based options for increasing resiliency in maritime transportation and port infrastructure systems
e. Development of agent-based models for port infrastructure systems resiliency
f. Development of Cognitive Port Enterprise models for learning port infrastructure with adaptation and recovery capabilities
Task 2.2 Collaborative design of resilient extended enterprises
Stevens Institute of Technology (Dr. Brian Sauser, PI)

Project Objectives and Significance to Stakeholders
The primary objective of this task was defining the problem space with Systemigrams (Systemic Diagrams) - a graphical technique for understanding and identifying the significant elements and their inter-relationships captured in multiple and diverse expressions of stakeholder concerns and needs. Once developed, the MTS Systemigram would be used to:

- Raise awareness of systems thinking generally and the systemigram technique through education and training;
- Solicit feedback from a wide audience on the value proposition for systems thinking and the systemigram technique;
- Perform a series of demonstrations of systemigrams;
- Using master class graduates, conduct specific applications of the systemigram technique on identified port systems;
- Encapsulate lessons learned on the role of systemigrams with a goal to produce an industrial strength toolkit for designing resilient enterprises (still in progress);
- Create a road map showing the impact of complexity on enterprise architecting, the role of systems thinking in dealing with this complexity, and the relationship of the systemigram technique to other systems thinking tools (still in progress)

As in Task 2.1, this effort will eventually provide decision-makers with the ability to identify vulnerabilities in the system under their management, and provide them with a framework to measure the resiliency of the system and allow them to work cross-organizationally on improving the resilience of the entire port system of systems.

Research and Education Milestones Met
The word “Systemigram” derives from systemic diagram. Its value lies in the transformation of “rich text” into a structured diagram in which the principal concepts are identifiable and the sentence structures recoverable. It is here regarded as a valuable tool in capturing complexity in extended enterprises and complex systems. The design rules governing the development of a Systemigram include the following:

- A primary sentence (mainstay) which supports the purpose of the system will read from top left to bottom right
- Ideally there should be 15-25 nodes (less can make for a trivial system description, more can create clutter and illegibility)
- Nodes must contain noun phrases
- Links should contain verb phrases (to reduce trivial links)
- No repetition of nodes
- No cross-over of links
- Beautification (e.g. shading and dashing of links and nodes) should help the
reader read the sentences in the diagram

- Exploit topology to depict why, how, what (who when and where is built into system description)

The Systemigram depicted in Figure 1 was created in a Wiki environment via an online class (ES 684: Systems Thinking). Students were distributed around the world, and made individual contribution through a class collaboration based on a defined system, i.e. Singapore Port Transportation.

**Figure 1: Singapore Port Transportation System**

Figure 2 is Version 3.0 of the “What is Resiliency?” Systemigram. This was created based on a workshop entitled, “Port Systems Resiliency” hosted by DHS S&T in May, 2009, mentioned earlier. At this workshop, 40 participants were asked to comment and make recommendations for revisions to Version 2.0. Version 2.0 was created based on a workshop entitled, “Resilience for Maritime Transportation Systems: Dispelling the Myths; Exploring the Truths” conducted at the 2009 DHS Maritime Homeland Security Summit. At this workshop, 20 participants were asked to comment and make recommendations for revisions to Version 1.0. Version 1.0 was created by Brian Sauser based on a literature review of Resiliency conducted by Ozgur Erol (research assistant), Roshanak Nilchiani (Assistant Professor), and Mayada Omer (Research Assistant). It was Dr. Sauser’s interpretation of the literature independent of Erol, Nilchiani, and Omer.
Collaborations

The research group collaborated with decision-makers from various DHS agencies in two DHS-sponsored workshops on defining resilience needs and concepts for port infrastructure systems. This research was conducted in collaboration with other CSR researchers (i.e. Jim Rice, Mo Mansouri, Ali Mostashari, Matt Mattingly, Beth Rooney).

Future Plans

a. Raise awareness of systems thinking generally and the systemigram technique specifically by means of a series of basic (1-day), advanced (2-day) and master classes (3-day), with the goal of establishing a community of expert systemigram practitioners;

b. Complex Problem Resolution via “Wisdom of the Crowds”

c. Conduct a series of experiments where the Systemigram modelers are not experts in the subject but masters only of the Systemigram technique. Using a
collaborative learning environment where individual contributions are made to a collaborative whole.

d. The SystemiGame

e. Creation of a virtual gaming environment where the participants have to assemble a Systemigram based on a perception of the truth.

f. Dynamic Systemigrams

g. Add quantitative analysis to SystemiTool that will allow Systemigrams to become dynamic; e.g. Systems Dynamics; Casual Loops

h. Systemigram Libraries - Creation of class libraries of Systemigrams to aid in the building of Systemigram models, e.g. Library on Resiliency

Documentation (for Tasks 2.1 and 2.2, since many were joint)

- Publications


- Presentations and Workshops


Other Resources Leveraged

The research group leveraged students who worked on resiliency research and modeling funded by other sources to synergistically support research for this project. In particular two graduate students funded by other sources were leveraged for parts of the project.
Task 2.3 MTS Recovery and Continuity of Operations
Massachusetts Institute of Technology (James Rice, PI)

Project Objectives
This project seeks to employ lessons learned via the MIT Center for Transportation and Logistics’ work on supply chain security and resilience in order to assist the CSR efforts towards enabling MTS resilience. Among the most important issues being addressed are the identification of the critical processes and systems of the MTS that need to be resilient; and the development and/or identification of methods for making critical MTS processes and systems resilient. Resiliency provides the ability to reduce the consequences of a challenge or event. In the course of this effort, we must first understand completely the failure modes for each component of the MTS, including:

- Navigable waterways
- Ports
- Vessels
- Intermodal connections
- Users

Research Milestones Met

i. Port resiliency survey
Developed an initial survey instrument, for distribution to shippers, carriers, terminal operators, port authorities, and key third parties, and aimed at gaining their views on the following:

- port processes and capacity that need to be resilient
- their experience with disruptions in port operations
- their recommendations for making ports resilient

The survey was developed with critical input and guidance from key parties including Matt Mattingly (The Mattingly Group) and Beth Rooney (PA-NYNJ). The survey findings will direct subsequent steps for further study and preliminary model and framework development.

Two rounds of informal user testing were performed in Year 1. We also completed the proper COUHES training (Committee on the Use of Humans as Experimental Subjects) and subsequently received COUHES approval of initial instrument. The survey is included at the end of this report as Appendix D.

The survey has been widely disseminated to the MTS community throughout the nation, with the support and participation of organizations such as the American Association of Port Authorities and the Transportation Research Board of the National Research Council.

ii. Developed initial failure mode analysis for the Maritime Transportation System.
This activity is continuing in Year 2, and borrows from lessons in our work in supply chain resiliency. Disruptions to the system result in a loss of:
- Capacity to acquire materials (supply)
- Capacity to ship/transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Demand (market, customer failure)
- Human resources (personnel)

Lessons learned from MIT’s work in supply chain security and resiliency include the notion that Vulnerability = f(probability & consequence). Our approach therefore must be to reduce probability via security, e.g., in the form of early warning systems, and reduce consequences via resilience, in the form of a revamped national MTS. Recall that in a prior section, under task 2.1, we described “resiliency” as being quite different from “recovery” in that resiliency is a characteristic of a system (in this case, the MTS) that enables it to continue operating at some level of functionality in the face of a challenge or an event. In other words, Resilience defines the ability to regain (or recreate) prior capability of the system, and is therefore not simply a short-term response to a disruption. Achieving system-wide resiliency therefore requires advance planning, additional capabilities/capacity, in essence a “design for resilience”.

Such systems-level designs could achieve resilience via flexibility and/or redundancy. However, an obvious question is “how much of each?” One might define “flexibility” as meaning, for example a crosstrained workforce, multi-product production systems, and a system designed with late customization (postponement). Redundancy might be defined as carrying inventory, maintaining capacity above average demand requirements, and ensuring the availability of back-up suppliers. Clearly, there are challenges to both of these elements of resiliency, since flexibility will require potentially significant investment in infrastructure and capabilities; and redundancy will require investments in capability and capacity that may never be used.

Again borrowing from supply chain resiliency concepts, there are many pathways toward flexibility, including:

- Flexibility through interchangeability
  - Standard facilities (Intel, GM)
  - Standard parts (Dell, Lucent SCN, Southwest Airlines)
  - Standard processes (Helix, UPS)
- Flexibility through postponement (Benetton, H-P)
- Flexibility through supply (Jabil, Lucent, Toyota)
- Flexibility through distribution (Caterpillar, Dell)
- Flexible culture
  - Awareness of risks, tradeoffs
  - Early warning systems (Nokia)
  - Education for awareness
  - Training for response (Intel)
  - Distributed decision-making (P&G, UPS)
  - Open and unconstrained communication (Dell)
Figure 1 illustrates the concept of resiliency in the context of the supply chain, including the competitive advantage afforded to a resilient enterprise. We will continue to examine these issues in the unique context of the national MTS.

The MTS-centric effort will need to consider the unique, and complex failure modes for each component of the MTS, mentioned earlier:

- Navigable waterways
- Ports
- Vessels
- Intermodal connections
- Users

iii. Built port resilience team
We leveraged funds from non-DHS sources in order to hire a dedicated researcher to work on this CSR project. We also hired two visiting scholars to assist in the research.

iv. Completion of Related Project – “100% Container Scanning Project”
v. **Preliminary Literature Review on funding of port infrastructure**

**Collaborations**

1. Worked with Stevens Institute of Technology (Tom Wakeman, Brian Sauser, Hady Salloum) in the planning and preparation for DHS S&T workshop on “Improving Resiliency for the National Interest” in Charlottesville, VA
2. Participated in the workshop in Charlottesville, VA
3. Supported DHS as panelist in the 2009 DHS S&T University Network Summit on March 17-19, 2009 in Washington, DC
4. Working partnership with Matt Mattingly on various aspects of the research plan.
   - Input on draft survey instrument to identify concerns, actions, trends, challenges for terminal operators, shippers, carriers, freight forwarders, port authorities, other key parties, etc.
   - Input on failure mode analysis
   - Input on and planning for field visits to ports in U.S.
   - Weekly conference call/meeting between MIT Port Resilience Project Team and Matt Mattingly

**Future Plans**

1. Complete literature review on port resilience
2. Quantitative data collection and analysis via port resilience survey
   - Identify key port systems to make resilient
   - Identify history of disruptions to MTS components in ports
3. Field visits
   - Five US ports
   - Semi-structured interviews with port authorities, terminal operators, carriers
   - Semi-structured interviews with select shippers
4. Data analysis
   - Capacity data table
     - US port capacity
     - Dispersion of capacity and impact on resilience
     - Potential modeling for resilience based on preliminary data analysis
     - Analyze existing capacity versus needed capacity by type, location and needed infrastructure and superstructure
   - Survey data
     - Identify critical areas for resilience, by region, by role in port operations (e.g., port authority, terminal operator, carrier, shipper, freight forwarder, other)
     - Identify historical disruption patterns and critical systems based on history

**Documentation**

"100% Container Scanning: Security Policy Implications for Global Supply Chains", June 2008, Allison Bennett, Yo Zhuan Chin, MIT MLOG Thesis
Requests for assistance from DHS
  - Conversations with Auto-ID expert Prof. Sanjay Sarma
Congressional Testimonies
  - Prof. Yossi Sheffi, “Resilience: What it is and how to achieve it” May 6, 2008
Mattingley Group (Matt Mattingley, PI)

Milestones Met:

i. Definition of MTS resiliency
   Worked closely with researchers from Stevens and MIT, and members of the MTS community, in particular Beth Rooney from the Port Authority of NY & NJ, to develop a working definition of port resiliency. This working definition was employed at the early stages of the workshop “Port Systems Resiliency”, on May 27-29, 2009, in Charlottesville, Virginia, mentioned earlier in this report.

We also conducted a review of the resiliency work of the DHS National Center for Food Protection and Defense, led by the University of Minnesota. We believe that there are valuable lessons to be learned from the food safety community in this regard, and we plan to continue this inquiry in Year 2.

ii. Literature survey of prior port disruptions
   This effort involved the study of several notable port disruptions. The disruption that was selected for the most detailed study was the Port of Kobe disruption following the 1995 earthquake. This analysis enabled us to facilitate the practical application of resiliency principles in the early stages of the CSR project. In particular, we identified lessons learned from Kobe experience, as well as notable mitigation measures that may serve as examples of strategies for designing for resilience at the single port level.

iii. Assistance with development of the port resiliency survey
   In this activity, we worked closely with the MIT researchers to develop a draft survey instrument, with a focus on identifying the concerns, actions, trends, and challenges faced by port operators, shippers, carriers, importers, trade associations, port authorities, local government, etc.

iv. Assistance with the development of the initial failure mode analysis for the Maritime Transportation System
   We identified standardized nodes for supply chains to facilitate focus on failure node analysis.

Collaborations:

a. Port Authority of New York & New Jersey
   i. Identify port resiliency issues and challenges
   ii. Practical application of mitigation measures
   iii. Input on security technologies
   iv. Input on port resiliency survey direction and content

b. Massachusetts Institute of Technology
   i. Analyze failure node concept
   ii. Develop draft survey instrument for industry and government input
c. University of Minnesota
   i. Draw upon lessons learned by National Center for Food Protection and Defense

**Future Plans (2009-2010):**
   a. Literature review and analysis for lessons learned from real-world port disruptions
   b. Statutory and regulatory review of laws and regulations impacting port resiliency capabilities and effectiveness.
   c. Refine and conduct initial survey of port resiliency issues
   d. Accomplish a number of port visits for representative sampling of port resiliency issues

**Documentation:**
   a. NCFPD Presentation, “Food Defense: Threats, Risks, and Countermeasures,” 9 Oct 08
   b. Final Report, “DHS Workshop on Future Directions in Critical Infrastructure Modeling and Simulation,” 23 Dec 08
   c. After action report, CSR Resiliency Workshop Organizing Session, 6 Jan 09
   d. MG Group Presentation, “The Need for Practical Application of Resiliency Principles,” CSR Miami Meeting, 29-30 Jan 09
   f. MG Group Presentation, “Supply Chain Standardized Nodes,” 29 Jul 09.

**Resources Leveraged:**
   a. DHS Science & Technology Directorate Workshop on Future Directions in Critical Infrastructure Modeling and Simulation. Focused on the use of modeling and simulation to effectively deal with the consequences of catastrophic events on critical infrastructure in order to formulate sound investment decisions, as well as research strategy, plans, and objectives for critical infrastructure and key resources.
   b. Port Authority of New York & New Jersey has provided practical experience and examples of port disruption scenarios, first response capabilities, resiliency plans and mitigation efforts, and identifying potential respondents and participants in resiliency survey effort.
   c. National Center for Food Protection and Defense provided lessons learned on resiliency in the nation’s food supply system after sustaining disruptions. While circumstances and details differ, responses and principles have applicability to port resiliency operations.
d. MIT brings substantial background and expertise in supply chain efficiency and security studies and data analysis and modeling capabilities. The development of a comprehensive and accurate survey instrument, its execution and subsequent analysis, have the potential to focus effort on priority issues and bring resources to bear for their resolution.
3. Collaboration with CIMES

Starting with the premise that in research the old adage “the whole is greater than the sum of the parts” is true, 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 set up a meeting at the University of Hawaii in November 2008 to share information about the research and education activities at the partner universities from both centers. This meeting was very productive in that there was an open discussion among the participants regarding various activities, and the key researchers for each activity were identified for follow up discussions. This led to another meeting in January 2009 that was hosted by the University of Miami and was used to discuss research collaboration among participants.

The collaboration is ongoing between the two Centers. The following areas are examples of collaboration during our first year:

- Passive acoustics: Researchers from Stevens and the University of Hawaii shared data and results of the work they have been performing in passive acoustics and discussed ways for improving passive acoustic methods of port protection, including detection, classification and localization of surface ships, divers and UUVs. Several meetings have been held between the two universities’ acoustic research teams, with the notable result that the Stevens team has provided the Hawaii team with the detailed technical specifications and design guidance for a passive acoustic system, and the Hawaii team has provided algorithms and signal processing guidance to the Stevens team in order to improve the performance of the existing Stevens systems. **We are confident that this joint effort will prove remarkably successful in the coming years in terms of providing the community with a passive acoustic surveillance capability that does not presently exist.**

- Non-Linear Acoustics: Researchers from the University of Hawaii and Stevens discussed their research in Time Reversal Acoustics and its application to port security (e.g., the use of the technology for non-lethal deterrence).

- HF Radar Surveillance: The HF Radar teams at Rutgers University and the University of Hawaii have met and are discussing collaboration in terms of comparing the vessel detection and tracking capabilities using their two different RADAR systems and supporting algorithms. It is anticipated that future collaborative activities will include comparative tests in field experiments under different environmental conditions.

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

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

During Year 2, there are many meetings planned between the two Centers’ Directors as well as visits by researchers between the two centers. It is also planned to continue the ongoing collaboration in the areas mentioned above as well as new areas with activities that include university partners from both centers.
IV. EDUCATIONAL ACTIVITIES

With respect to its education mission, the CSR focused primarily on planning during the first year, although there were several notable outcomes. Educational activities included two planning sessions, the development of new maritime security courses at Stevens Institute of Technology, and a trial run for the forthcoming Summer Institute. Before reporting on these activities, a short description of the CSR educational vision is presented in the following section.

a. Educational Objectives

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.

b. Planning Meetings

Two CSR planning meetings were held during the reporting period: November 12, 2008 and January 30, 2009.

The first meeting of the CSR Education Committee was led by Dr. Scott Glenn, the CSR Director of Education. The meeting was held at Rutgers University, Institute of Marine and Coastal Sciences, New Brunswick, New Jersey. The chief topic of discussion was the ETO objectives for CSR. The Bergen Model was described. In that model, the University staff works with industry and government to find opportunities for students to work on projects of interest to the participants. For example, starting with industry input, the faculty members design a research project that is applicable to some industry problem. Once a project is defined, a student or students are assigned to the project and work begins. There is an effort to have the student’s work supported by the industry stakeholder. At the end of the process, the student graduates (MS or certificate) with a link to a cooperating firm/industry.

A second meeting was held during the Spring CSR-CIMES Principle Investigator meeting held in January 2009 at the University of Miami, Florida. The entire meeting focused on the requirements for DHS for their objectives to support an HS-STEM program. As a result, CSR developed recommendations, concerns and/or questions for
DHS consideration. The list of recommendations was developed by members of the Education Committee and shared with DHS.

c. New Maritime Security Courses at Stevens

The Faculty Graduate Curriculum Committee at Stevens Institute of Technology has approved a new four-course graduate certificate program entitled Maritime Security. The four new security courses have been developed and have also been approved by the Committee:

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

The first Maritime Security certificate was awarded in December, 2009.

d. CSR Maritime Security Course in Washington DC

In a unique and significant initiative, the CSR partner universities have teamed to develop and implement a 1-week, intensive course in maritime security surveillance technologies. This course is intended for delivery to the maritime security technology workforce, including designers, operators, and acquisition personnel. The course, outlined in the brochure provided in Figure 1, will provide 3 graduate credits for application to certificate or graduate degree programs. 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.
### DHS Maritime Security Summer Institute Pilot

Rutgers University, the University of Puerto Rico, and Stevens Institute of Technology ran a pilot for the DHS Summer Institute in the summer of 2009, leveraging support from DHS, NSF, NOAA, ONR and the Vetlesen Foundation. This Summer Institute pilot session focused on 10-weeks of undergraduate instruction structured to provide an introduction to ocean sensing and modeling technologies. The students were divided into three groups involved with:

- shipboard technologies for use in an estuary;
- HF Radars for use in the coastal ocean; and
- autonomous underwater gliders for use in the global ocean.

The student and faculty participants are pictured in Figure 2. A total of 19 students participated in the program, including students from Rutgers University, the University of Puerto Rico Mayaguez (UPRM), Stevens, and Hampton University.
The Coastal Ocean Observing Laboratory of Rutgers University provided significant assistance in CODAR and AIS site evaluation, installation and operation during the program. Two interns from UPRM were trained in CODAR operation during the summer Rutgers Internship in Oceanographic Research – RIOS (June – August 2009) at the Rutgers New Brunswick campus in New Jersey. These two students have returned to Puerto Rico and will now be involved with the DHS tropical HF Radar test bed that Rutgers is constructing with UPRM.

Figure 2 - Students and Faculty during a Field Trip in New York Harbor

All of the students participated in several research cruises regardless of their focus. For the estuary component, students participated in research cruises on the Raritan River and the Mullica River Estuary on the two Rutgers research vessels, and in New York Harbor on the Stevens Institute of Technology Research Vessel.

For the CODAR component, students set up a CODAR system on campus as a training exercise, then went in the field to work on several beach locations. For the glider component, the students participated in both a glider deployment cruise as well as a glider recovery cruise. The featured guest speaker for the Summer Institute was Dr. Don
Barrick, President of CODAR Ocean Sensors and the world’s leading expert on HF Radar. While working in a team atmosphere, each student also conducted their own research experiment, summarizing their results in a poster presentation at the end of the summer.

In 2010, CSR will create a uniquely collaborative, multi-disciplinary, academic-industry-government enterprise that will plan and implement the **CSR Maritime Security Summer Institute**. The Institute will consist 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 faculty will be drawn from the following universities:

- Stevens Institute of Technology
- The University of Miami
- Rutgers University
- MIT
- The University of Puerto Rico
- Monmouth University

A novel concept will be formally initiated in the 2010 Maritime Security Summer Institute. The concept is “the cognitive port”, and describes a system of sensors, data fusion algorithms, decision-making systems, and “smart” port infrastructure. This cognition-centric port system would - by virtue of its self-awareness, its learned (or trained) behavior, and its real-time knowledge of the environment in which it functions - become a resilient system, capable of reacting to challenges and events as they occur while retaining a minimum level of functionality. We recognize that the requisite knowledge and technologies to achieve this goal do not exist today, but this is the essence of visionary long-term research. We believe that by making it the umbrella under which the research and lectures conducted by the students and faculty during the 2010 Summer Institute, we will chart the course for significant progress in the years ahead.

The student and faculty/industry participant selection process will be highly competitive. Stipends and material and logistic support will be commensurate with an international-class activity, as will the research and education facilities. The site of the 2010 Institute will be the Stevens Institute campus in Hoboken, NJ. It is our intention to create in the
CSR Summer Institute an activity that is world renowned as being of superior quality and impact in the broad maritime community by virtue of its multi-disciplinary and collaborative nature. The information and application materials for the 2010 Summer Institute can be found at www.stevens.edu/CSR/SummerInstitute. The brochure for the 2010 Summer Institute is re-produced here in Figures 3 and 4.

Figure 3: 2010 Summer Institute brochure, page 1
The CSR Summer Research Institute provides undergraduate and graduate students with a unique opportunity to participate in marine research. The institute is designed to enhance student's understanding of marine science and technology, and promote the development of new knowledge and skills in these fields. The institute offers a variety of courses and workshops aimed at providing students with a comprehensive understanding of marine science and technology.

The institute is located on the campus of the University of California, Santa Barbara. The institute is co-sponsored by the University of California, Santa Barbara, and the National Oceanic and Atmospheric Administration (NOAA). The institute is led by Dr. Jane Smith, a professor of marine science at the University of California, Santa Barbara.

The institute offers a variety of courses and workshops aimed at providing students with a comprehensive understanding of marine science and technology. The courses cover a wide range of topics, including marine biology, marine chemistry, marine geology, and marine physics. The workshops provide hands-on experience with marine equipment, including boats, trawlers, and ROVs (remotely operated vehicles).

The institute is open to undergraduate and graduate students from all over the world. Students can apply for summer positions, and the institute provides a stipend to cover their living expenses. The institute also offers a variety of scholarships to students who show exceptional promise in marine science and technology.

The institute is a unique opportunity for students to gain valuable experience in marine science and technology. The institute is well-equipped with state-of-the-art equipment, and the institute faculty is dedicated to providing students with a high-quality education. The institute is an excellent opportunity for students who are interested in pursuing careers in marine science and technology.
V. SUMMARY OF ACCOMPLISHMENTS IN YEAR 1

a. Table 1: List of Accomplishments

<table>
<thead>
<tr>
<th>Categories of Accomplishments</th>
<th>Number/Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students matriculated</td>
<td>6</td>
</tr>
<tr>
<td>Papers</td>
<td>23</td>
</tr>
<tr>
<td>Software Products Developed</td>
<td>2</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>3</td>
</tr>
<tr>
<td>Requests for assistance or advice from Federal, State, Local Government</td>
<td>4</td>
</tr>
<tr>
<td>Presentations</td>
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<tr>
<td>Congressional Presentations</td>
<td>7</td>
</tr>
<tr>
<td>Projects Completed</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: There were no patentable inventions resulting from year 1 work.

b. Active Assistance to First Responder Community

- **US Airway Accident**
  
  In the late afternoon on January 15, 2009, Stevens learned that US Airways Flight 1549 with 155 people on board had landed in the Hudson River. CSR personnel at Stevens immediately contacted the US Coast Guard Sector New York and the New York City Office of Emergency Management (OEM) to offer assistance in the rescue. The Stevens NYHOPS – New York Harbor Observing and Prediction System website (www.stevens.edu/maritimeforecast/) was employed in the preparation of a detailed summary of the present water conditions in the Hudson River surrounding the landing site, and a forecast of conditions for the next 48 hours. Within minutes of the landing, this water conditions analysis summary and forecast were transmitted to the Director of Watch Command for the NYC OEM and the EMS Command Center, Fire Department of New York.
- **Helicopter Accident**

On Saturday August 8th, 2009, a small plane collided with a sightseeing helicopter carrying Italian tourists above the Hudson River, scattering debris into the water. The plane was carrying a pilot and two passengers, while the helicopter was part of ‘Liberty Helicopter Sightseeing Tours’ and carried the pilot, and 5 passengers. Within an hour of the accident, CSR personnel from Stevens were called to the scene for analysis of currents and the proposed search area. The CSR forecast model indicated that the currents were incoming for the first hour after impact and then strongly outgoing. This helped the NYPD, NJ State Police, FBI Dive teams and the USCG aerial search teams to plan the search. Over the next 3 days, the ocean forecasts proved invaluable to the search and recovery.

**Deborah A. P. Hersman**, the Chairman of the NTSB had this to say regarding the assistance provided by Stevens:

"I am writing on behalf of the NTSB investigative team to express our gratitude for the assistance offered to us by the Stevens Institute of Technology during the on-scene portion of the investigation of the mid-air collision over the Hudson River that occurred on August 8. The contribution and professionalism of the men and women of the Stevens Institute that assisted our team during the initial hours and days after the accident was crucial to our ability to conduct a thorough and timely accident investigation."
Three days after the collision, the search continued for the plane wings, the helicopter rotor assembly and other critically-important pieces of the wreckage. This search was aided by the Stevens ocean forecasting system. Special drogue simulations were run based on two scenarios: A surface drift showed a wide search and recovery area extending from Monmouth County, NJ to Orange County, NY, while a sink-and-drift pointed to a much smaller area a few miles radius around the impact location. The National Transportation Safety Board enlisted the Stevens research vessel, the ‘R/V Savitsky’, as a staging platform for dive operations to locate, identify and recover wreckage. The Stevens team successfully recovered a windshield frame, a portion of the fuselage and inspected various location targets as advised by the NJ State Police.

- **HF RADAR incorporation into USCG SAROPS**

The primary objectives of the USCG search and rescue (SAR) program are fourfold:

1. Minimize loss of life, injury, and property loss and damage in the maritime environment;
2. Minimize crew risk during SAR missions;
3. Optimize use of resources in conducting SAR; and
4. Maintain a world leadership position in maritime SAR

The USCG has also set quantifiable SAR goals for itself, including, after USCG notification and in waters over which the USCG has SAR responsibility, saving at least 93% of all people whose lives are in distress. Additionally, the USCG aims to prevent the loss of 80% of the property at risk of destruction. In pursuit of these goals, the USCG has established several self-regulating standards that they strive to achieve and even surpass, including a maximum of a two-hour response time from notification to arrival on scene.

The USCG has recently begun using a Search and Rescue Optimal Planning System (SAROPS). Using the Environmental Data Server (EDS) at the USCG’s Operational System Center in West Virginia, oceanographic conditions (e.g., wind and currents) are collected, converted into a compatible format, and uploaded to SAROPS, either by request or four times daily. Having access to real-time ocean current information is
critical for numerous maritime-based activities, but the USCG’s SAR operations can especially benefit.

Rutgers University’s Coastal Ocean Observation Lab (COOL) maintains the only operational high-frequency (HF) radar network in the eastern United States. Coastal Ocean Dynamics Application Radar (CODAR) consists of several pairs of antenna sites on the New Jersey coast. For each pair of sites, one remote site broadcasts radio waves across the ocean surface; the second remote site picks up the signal after it has been bounced back by the ocean waves. The measurements gathered from these two sites are used to determine the net movement of the water’s surface, and, therefore, the surface current speed in real-time. Presently, this CODAR system covers virtually the entire offshore New Jersey region, out to 100 nautical miles (nm); the most high-resolution results (detected by shorter range radar), however, are detected out to 20 nm.

In addition to this existing Rutgers system, the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) has formed a coalition of HF radar operators from southern New England to North Carolina as a pilot project for a future nationwide system. By combining and collating efforts, eleven long-range HF radar sites and three short-range (but higher resolution) sites in the Mid-Atlantic Bight (MAB) area will form a regional network that will measure real-time ocean currents for the majority of the MAB shelf. HF radar networks like the existing CODAR system and the planned MACOORA consortium provide high-resolution information about the state of the ocean, down to detailed accuracy of characteristics like coastal eddies, wave height, and other meso-scale features.

As demonstrated by Rutgers COOL, sea surface temperatures and other relevant remotely sensed ocean data can be combined with the real-time current information to provide critical decision-making tools to the USCG such as survival likelihood, search area planning and transect plotting, and the identification of the most likely location of the target, given the ocean and climate conditions. Users will be able to customize their data requests and use IOOS-based modeling tools to determine, for example, search radii based on currents, winds, wave information, and potential conditions that may compromise an effective search (e.g., fog). IOOS will allow formerly disparate sources of critical information to be collated and manipulated, augmenting the base of data currently utilized by the USCG and potentially improving SAR effectiveness. In conditions where the environmental conditions are highly uncertain (e.g., where currents and other oceanographic conditions are not known), the USCG experiences a 22% success rate. Using HF radar, the USCG has the potential to increase this success rate to 48-67%, thereby saving 26-45 additional people every year.
c. List of Publications

Twenty three papers were prepared and many were presented to disseminate the results of the first year’s work. A list of these papers follows:


• “Usable Information Delivery for Emergency Decisions” Allen Milewski; Robert Kelly; Chemical and Biological Defense Physical Science and Technology (CBD PS&T) Conference New Orleans, Louisiana USA November 17 – 21, 2008 Publication in Conference Proceeding.

• “Communicating Decisions When There Is No One To Talk To” Barbara T Reagor; James M Hammill; Poster Presentation; Chemical and Biological Defense Physical Science and Technology (CBD PS&T) Conference New Orleans, Louisiana USA November 17 – 21, 2008 Publication in Conference Proceeding.


• "100% Container Scanning: Security Policy Implications for Global Supply Chains", June 2008, Allison Bennett, Yo Zhuan Chin, MIT MLOG Thesis
VI. APPENDICES
APPENDIX A: Outline of Year 2 Plans

Introduction
As a result of the progress in various areas of inquiry during Year 1, the Year 2 plan has been refined to include four separate (but integrated) activities:

a) Maritime Domain Awareness
b) Emergency Response
c) MTS resiliency
d) Education

The following section contains short summaries of the Year 2 plans; more detailed descriptions can be found at the end of each project report in Section III. We begin by describing the overarching aim of the integrated Year 2 effort.

Integrated Activities in Year 2
The Year 1 effort facilitated the rapid creation of a close-knit team of researchers, each with their own expertise, capabilities, and facilities, but all contributing to a set of common goals under the broad categories of Maritime Domain Awareness and MTS resiliency. The Year 1 effort included major events in which the various teams joined together to produce integrated actions and results, most notably the NY Harbor experiment in November, 2008 (the MDA team) and the May, 2009 Port Resiliency Workshop (the MTS resiliency team). The Year 2 effort will seek to capitalize on these initial joint successes, and will build on them to move the CSR research to the next level, in which technology products and methodologies in support of the Department’s maritime security mission can be developed, tested, and brought to the field.

The Year 2 effort in Maritime Domain Awareness will include the specific activities described later in this section and in Section III. In addition, the effort will include at least two major field experiments in NY Harbor with the aim of answering the essential question – “how small is too small”? In other words, the research teams will systematically assess the feasibility of detecting, classifying, and tracking surface vessels (and to the extent possible, semi-submersible and submerged threats) using each available technology and at various scales of resolution. We will assess the potential of a multi-layered sensor system to provide near real-time surveillance for vessels/objects ranging in size from the largest cargo vessels to small (10 meter and less) vessels.

The Year 2 effort in MTS resiliency will be tightly integrated, with the MIT/Mattingley port resiliency survey used to inform the SIT teams’ efforts in developing a framework for the design-for-resiliency and in developing tools and models to support better understanding and accurate simulation of the national MTS. The formerly parallel tracks of information gathering and modeling & simulation will therefore be joined in Year 2 to create a much more tightly integrated effort, and one which enlists the maritime community in a very strong fashion.
These two joint activities will be combined with the emergency management research activities (focused on decision-making), and the education activities via a novel concept that will be formally initiated in the 2010 Maritime Security Summer Institute. The concept is “the cognitive port”, and describes a system of sensors, data fusion algorithms, decision-making systems, and “smart” port infrastructure. This cognition-centric port system would - by virtue of its self-awareness, its learned (or trained) behavior, and its real-time knowledge of the environment in which it functions - become a resilient system, capable of reacting to challenges and events as they occur while retaining a minimum level of functionality. We recognize that the requisite knowledge and technologies to achieve this goal do not exist today, but this is the essence of visionary long-term research. We believe that by making it the umbrella under which the research and lectures conducted by the students and faculty during the 2010 Summer Institute, we will chart the course for significant progress in the years ahead.

a. **Maritime Domain Awareness**

- *Satellite-Based ship detection, classification, identification and tracking*

In Year Two, the University of Miami’s CSTARS is planning to perform several activities including:

1. Complete literature review on small vessels and Self-Propelled Semi-Submersibles (SPSS); initiate further work as requested
2. National SAR Architecture Center
   a. Provide access in near real-time to a broad selection of commercial satellite sensors
   b. Develop a collection plan to provide persistent imaging with overhead assets
3. European Collaborations
   a. MARISS – GEMES MARitime Security Services
   b. NATO La Spezia – remote ground station operation
4. Data analysis
   a. Wake detection
      - Radon transform approach
      - Examining quad polarization data
      - Pattern analysis of elementary shapes
      - Speckle noise reduction
   b. Innovative antenna configuration
      - Explore squinting algorithm for moving targets
      - Develop new methodologies using phase history data to better detect targets in background noise
• *HF Radar coastal over-the-horizon ship detection and tracking using advanced dual-use RADAR technologies*

In Year Two, Rutgers University will be examining instances when the radar/algorithm was not able to make a detection of a vessel offshore. The radar was a Codar SeaSonde located at Sea Bright, NJ. The radar operated at 13 MHz and the researchers were only using 50 kHz of bandwidth, which amounts to 3 km spatial resolution. The researchers will operate the radar at multiple frequencies to find the frequencies that are optimal for this location (see Table 2). The assumption is that if the bandwidth is increased to 100 kHz, the spatial resolution can be increased to 1.5 km.

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>Bandwidth (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12140</td>
<td>100</td>
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<tr>
<td>13430</td>
<td>100</td>
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<tr>
<td>13450</td>
<td>100</td>
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<tr>
<td>13530</td>
<td>100</td>
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</tbody>
</table>

• *Nearshore and Harbor multi-sensor and multi-tiered surveillance*

In Year Two, Stevens Institute of Technology will focus on five tasks:
1. Development of ship classification methods using a library of acoustic signatures collected in New York Harbor;
2. Consideration of various methods of optimization of vessel acoustic detection systems based on the collected vessel signatures, ambient noise, and acoustic transmission loss; and
3. Measurement and analysis of background ambient noise in NY Harbor for various points and environmental conditions.
4. The integrated use of vision-based and IR camera systems for the detection and classification of both surface and underwater vessels and objects.
5. The detection and tracking of Self-Propelled Semi-Submersibles (SPSS)
b. **Emergency Response**

- **Decision-making**

In Year Two, Dr. Nickerson at Stevens Institute of Technology will focus on performing experiments with multi-dimensional problems with multiple solutions (e.g., disaster response problems, managing evacuations, maintaining trade, and minimizing loss of life). Other experiments are being considered, including detecting anomalous targets from “real time” (simulated) tracking data; detecting threatening anomalies from tracking data; and handoffs: communicating threats between humans and machines. Those working on tracking have discussed the problem of handing off the tracking of a target from one technology to another. The handoffs between humans and machines are perhaps more problematic.

With respect to decision technologies, work will be performed to explore when and how people use or avoid decision technologies; and assess how changes in the timing and intrusiveness of technological interventions affect the use and acceptance of decision aids. The last area being considered is Memory Technologies: adaptive responses to disasters and other complex problems require that people remember similar problems from the past, how they or others responded to those problems, and the outcomes of those responses. Investigations are planned into technology-aided memory (e.g., chat logs & video) and community memory (e.g., how institutional structure maintains and propagates knowledge).

c. **MTS Resiliency**

- **Port Infrastructure Resiliency**

In Year Two, Dr. Nilchiani of Stevens Institute of Technology will continue her work to examine the application of risk-based and network-based resiliency assessment methodologies to port infrastructure in the southeastern and northeastern United States; to perform a collective threat assessment for the U.S. Eastern shore ports; to develop resiliency strategies for port infrastructure systems; explore network-based options for increasing resiliency in marine transportation and port infrastructure systems; to develop agent-based models for port infrastructure systems resiliency; and to develop Cognitive Port Enterprise models for learning port infrastructure with adaptation and recovery capabilities.

- **Resiliency Modeling**

In Year Two, Dr. Sauser of Stevens Institute of Technology plans to undertake the following work:
1. Systemigram Workshops: Raise awareness of systems thinking generally and the systemigram technique specifically by means of a series of basic (1-day), advanced (2-day) and master classes (3-day), with the goal of establishing a community of expert systemigram practitioners;
2. Complex Problem Resolution via “Wisdom of the Crowds”: Conduct a series of experiments where the Systemigram modelers are not experts in the subject but masters only of the Systemigram technique. This will employ a collaborative learning environment where individual contributions are made to a collaborative whole;
3. The SystemiGame: Creation of a virtual gaming environment where the participants have to assemble a Systemigram based on a perception of the truth;
4. Dynamic Systemigrams: Add quantitative analysis to SystemiTool that will allow Systemigrams to become dynamic; e.g. Systems Dynamics; Casual Loops: and
5. Systemigram Libraries: Creation of class libraries of Systemigrams to aid in the building of Systemigram models, e.g. a Library on Resiliency.

- Ports & Supply Chain Resiliency

i. In Year-Two, MIT will conduct a study to identify the processes and systems that are critical to creating MTS resilience with the intent of identifying methods to create resilience in those critical systems.

ii. In Year Two, MG Group will assist in the preparation and development of such policies through direct and indirect interaction with port and supply chain stakeholders.

d. Education – the DHS Maritime Security Summer Institute

CSR will create a uniquely collaborative, multi-disciplinary, academic-industry-government enterprise that will plan and implement the CSR Summer Institute. The Institute will consist 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 faculty will be drawn from the following universities:
As mentioned earlier, a novel concept will be formally initiated in the 2010 Maritime Security Summer Institute. The concept is “the cognitive port”, and describes a system of sensors, data fusion algorithms, decision-making systems, and “smart” port infrastructure. This cognition-centric port system would - by virtue of its self-awareness, its learned (or trained) behavior, and its real-time knowledge of the environment in which it functions - become a resilient system, capable of reacting to challenges and events as they occur while retaining a minimum level of functionality. We recognize that the requisite knowledge and technologies to achieve this goal do not exist today, but this is the essence of visionary long-term research. We believe that by making it the umbrella under which the research and lectures conducted by the students and faculty during the 2010 Summer Institute, we will chart the course for significant progress in the years ahead.

The student and faculty/industry participant selection process will be highly competitive. Stipends and material and logistic support will be commensurate with an international-class activity, as will the research and education facilities. The site of the 2010 Institute will be the Stevens Institute campus in Hoboken, NJ. It is our intention to create in the CSR Summer Institute an activity that is world renown as being of superior quality and impact in the broad maritime community by virtue of its multi-disciplinary and collaborative nature. The information and application materials for the 2010 Summer Institute can be found at www.stevens.edu/csr/SummerInstitute.

The brochure for the 2010 Summer Institute is re-produced here in Figures 1 and 2.
Figure 1: 2010 Summer Institute brochure, page 1
Appendix C: Description of the MU Joint Mobile Command and Training Center (JMCTC)

Network
- Thin Client Environment
  - HP Thin Client
  - Using two HP Servers running VM Ware and Windows Server 2003 with Citrix Server Software
  - External Network Access

Broadband Satellite Communications:
- 1.2 Meter Satellite Dish
- Tracstar Modem
- Clear Channel Broadband Service
- Up 384 Kbps/down 1500 Kbps

On the Move Satellite with DirecTV Service

IP Phone Access:
- Voice Over IP Communications
- Soft Phones—virtual phone able to display on each desktop to be used with a headset on the thin client for each user
- Up to 20 voice lines available

Multi-Screen Video Wall:
- In rear of vehicle
- 4-Screen Video Wall
- Veemux Video switches
- KVM Video switch

Security Cameras:
- Connected through a DVR
- On display at all times to give a 360 degree view of the truck from inside, as there are no windows in the vehicle
RF Interoperability:

- Motorola XTL 2500
- Kenwood Radio
  - Low Band (35—43 MHz)
  - VHF Band (148—174)

2 LCD TV Displays:

- In front of vehicle
- One for cable TV
- Other uses such as streaming video feed from helicopter

Video Tele-Conferencing:

- Tandberg VTC Unit
- IP Address for contacting the RRI JMCTC Truck: 216.117.240.23

Overhead Projector:

- Projects to full-size pull-down screen

MapSketch and Strategy Table:

- RRI Patented MapSketch Emergency Management Software Tool
- 360° Strategy Screen
Appendix D: The MIT Port Resiliency Survey

1. Please note your headquarters location (if you are a shipper, carrier, third party or freight forwarder) and/or your terminal locations (if you are also a terminal operator or port authority):

<table>
<thead>
<tr>
<th>Headquarters Location</th>
<th>Primary Operations Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td></td>
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<tr>
<td>Central America</td>
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<tr>
<td>South America</td>
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<tr>
<td>North Europe</td>
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<tr>
<td>Eastern Europe</td>
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<tr>
<td>South Europe</td>
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<tr>
<td>North Africa</td>
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<tr>
<td>Africa</td>
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<tr>
<td>China</td>
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<tr>
<td>Other Asia Pacific</td>
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<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>
2. Please note your role in the maritime transportation system:
- Terminal operator
- Terminal operator and carrier
- Port authority
- Port authority and terminal operator
- Carrier
- Carrier and freight forwarder
- Shipper
- Shipper and terminal operator
- Freight forwarder
- Other third party
1. How frequently have you experienced or observed disruptions in WATERWAY OPERATION in the past 5 years? Please note the source of the disruption.

<table>
<thead>
<tr>
<th>Source of Disruption</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Quarterly</th>
<th>Annually</th>
<th>Less frequently than annually</th>
<th>N/A</th>
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<tbody>
<tr>
<td>Labor agreements/availability</td>
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<tr>
<td>Equipment availability (e.g. tugs, other vessels used to coordinate and locally move vessels)</td>
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<tr>
<td>Channel clearing systems and equipment</td>
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<td>Waterway monitoring systems (e.g. level, flow, water condition, weather condition)</td>
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<td>Waterway access coordination</td>
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<td>Electric utilities</td>
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<td>Water/waste water systems</td>
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<tr>
<td>Communication/Information Systems</td>
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<tr>
<td>Other (e.g. lock availability; please add comments in text box)</td>
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</table>
2. How long were the delays in WATERWAY OPERATIONS? (Please note the average and the longest delay for those disruptions experienced to the best of your memory).

<table>
<thead>
<tr>
<th>Average delays (in days)</th>
<th>Longest delay (in days)</th>
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<td>Labor agreements/availability</td>
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<td>Waterway access coordination</td>
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<td>Water/waste water systems</td>
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<td>Communication/Information Systems</td>
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<td>Other (e.g. lock availability; please add comments in text box)</td>
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3. If you are a carrier only, please click below:

1. How frequently have you experienced or observed disruptions in TERMINAL OPERATIONS in the past 5 years? Please note the source of the disruption.

<table>
<thead>
<tr>
<th>Source of Disruption</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Quarterly</th>
<th>Annually</th>
<th>Less frequently than annually</th>
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<td>Labor agreements/availability</td>
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<td>Equipment availability (e.g. cranes, material handling equipment)</td>
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<td>Storage availability</td>
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<td>Yard/storage operations</td>
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<td>Screening/inspection operations</td>
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<td>Gate operations</td>
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<td>Electric utilities</td>
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<td>Other (e.g. ship delays; please comment in text box below)</td>
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2. How long were the delays in TERMINAL OPERATIONS? (Please note the average and the longest delay for those disruptions experienced to the best of your memory).

<table>
<thead>
<tr>
<th>Category</th>
<th>Average delays (in days)</th>
<th>Longest delay (in days)</th>
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<tbody>
<tr>
<td>Labor agreements/availability</td>
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<td>Equipment availability (e.g. cranes, material handling equipment)</td>
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<td>Storage availability</td>
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<td>Yard/storage operations</td>
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<td>Screening/inspection operations</td>
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<td>Water/waste water systems</td>
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<td>Communication/Information Systems</td>
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<td>Other (e.g. ship delays; please comment in text box)</td>
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</table>
1. How frequently have you experienced or observed disruptions in INTERMODAL CONNECTIONS in the past 5 years? Please note the source of the disruption.

<table>
<thead>
<tr>
<th>Source of Disruption</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Quarterly</th>
<th>Annually</th>
<th>Less frequently than annually</th>
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<td>Labor agreements/availability</td>
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<tr>
<td>Equipment availability (e.g. trucks, gate operations, inspection processes)</td>
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<td>Truck loading and unloading operations</td>
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<td>Rail loading and unloading operations</td>
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<td>Roadway capacity</td>
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<td>Gate operation/port entry operations</td>
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<td>Other (comments in text box)</td>
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</tbody>
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2. How long were the delays in INTERMODAL CONNECTIONS? (Please note the average and the longest delay for those disruptions experienced to the best of your memory).

<table>
<thead>
<tr>
<th></th>
<th>Average delays (in days)</th>
<th>Longest delay (in days)</th>
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<tbody>
<tr>
<td>Labor agreements/availability</td>
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<td>Truck loading and unloading operations</td>
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<td>Rail loading and unloading operations</td>
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<td>Roadway capacity</td>
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<td>Rail capacity</td>
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<td>Water/waste water systems</td>
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<tr>
<td>Communication/Information Systems</td>
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<tr>
<td>Other (comments in text box)</td>
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</tr>
</tbody>
</table>
1. To what extent do government agencies' (at all levels) policies and enforcement impact the delays in ports?

<table>
<thead>
<tr>
<th></th>
<th>No impact</th>
<th>Slight impact</th>
<th>Moderate impact</th>
<th>Significant impact</th>
<th>Not applicable/not familiar with this regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones Act</td>
<td></td>
<td></td>
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<td></td>
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<td>96 Hour Advanced Notice of Arrival</td>
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<td>Hours of Service Rules</td>
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<td>Vessel Inspections</td>
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<td>Visa requirements for crew members</td>
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<td>10+2 Importer Security Filing requirements</td>
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<td>Cargo inspections (CBP, FDA, USDA, ATF, FW, etc.)</td>
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<td>Petro-chemical</td>
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No impact  Slight impact  Moderate impact  Significant impact  Not applicable/not familiar with this regulation

shipping requirements

2. In your opinion, what regulations make ports - the terminals, intermodal connections, and waterways - more resilient?

3. In your opinion, what regulations make ports - the terminals, intermodal connections, and waterways - less resilient?